A CANADIAN RESEARCH HERITAGE

75 years of federal government research in minerals, metals and fuels

A. IGNATIEFF

Canada

A CANADIAN RESEARCH HERITAGE

An Historical Account of 75 Years of Federal Government Research and Development in Minerals, Metals and Fuels at the Mines Branch

A. Ignatieff
Mines Branch (1947 – 1972)

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Pouring molten steel at 1600°C from a bottom-pour ladle into a sand mould at the Foundry Section of the Physical Metallurgy Research Laboratories. These facilities are unique in Canada and are essential to an organization performing research into the development of new alloys as well as processes for the manufacture of metal parts.

No man is an island, entire of itself, every man is a piece of the continent, a part of the main.

DEVOTIONS, Upon Emergent Occasions (1624) by John Donne (1573 - 1631)

This volume is dedicated to past, present and future generations of employees of the federal government organization known successively as Mines Branch - Bureau of Mines - Mines Branch - CANMET

Many of the staff served Canada, not only in this institution, but also in its defence forces. There was a particularly large intake in the Mines Branch of World War II veterans and their service is mentioned when known. However, records are incomplete. This note pays tribute to all generations who gave of themselves in the hour of their country's need.

INTRODUCTORY NOTE

Alex Ignatieff was associated with John Convey during most of the latter's tenure as director of the Mines Branch. Dr. Convey suggested that Alex Ignatieff prepare a history of events in the Mines Branch, and this suggestion was supported and encouraged by Don Coates who succeeded Dr. Convey. At my request, Dr. Convey agreed to add a foreword with information on the picture of the evolution of mineral research that has emerged.

Following his retirement in 1972, Alex Ignatieff received an honorary doctorate from the University of Alberta; an award which was well deserved.

For Alexis Ignatieff, this history has been purely a labour of love without remuneration in his retirement years; the branch and the department will forever be indebted to him.

W.G. Jeffery,
Director-General,
CANMET

FOREWORD

When I first approached Alexis Ignatieff with respect to the writing of a history of the Mines Branch, I expected the usual chronological presentation of the important highlights of the branch's development. Knowing Alex as I do, I should have known that he would prepare and present a thorough, searching, itemized, chronological, technical appraisal. He has always been a true believer in the fact that with adequate information one can improve one's life, one's health and in fact improve the world.

For many years Alex occupied the main office in the Booth Street building known as the Fuels Division. There in his large room he sat at an expansive old-fashioned desk, which was usually completely covered with reports, memos and daily nuisance letters, in the midst of which one could find Alex. Unfortunately his desk proved to be too small to cater to his paper assembly, so he had a large rectangular conference table placed in his office...supposedly for staff meetings. This second table soon became paper buried as in the fashion of his desk. However, submerged as he was in paper, whenever a subject was under discussion he could retrieve immediately the needed reference from his forest of papers. With this talent for the ready recovery of needed information from reams of written material, one can see why this volume of the Mines Branch history reflects Alex's uncanny ability to sift through, research and present the valid technical achievements of the Mines Branch.

Alex is by choice and training a mining engineer, a product of the Royal School of Mines of Great Britain (1927). His early professional years spent in the gold, lead, zinc and coal mining industries provided him with international experience in West Africa, Central America, Eastern Europe and Great Britain. He eventually came to Canada in 1947, and became a member of the Mines Branch, Ottawa. I believe it is true to say that his real career preference was coal mining, or as he would say - a love for lost causes. His interest in coal, with time, expanded to other energy resources, and his horizon broadened into the whole energy field. Ahead of his colleagues, he unwittingly became one of the pioneering activists of what is now referred to as "Materials Science". As an example he introduced physicists to underground coal mining, as members of his rock mechanics study team. To him, all mines whether in coal or hardrock, open pit or underground were all laboratories, providing studies into safety, economic retrieval and the conservation of mineral resources. Mines Branch study teams became located in mining areas across Canada. As a scientist, he believed that the conservation of resources was of prime interest, and in the early 1950's he recognized Canada's lack of information with respect to coal and oil reserves, particularly in Western Canada.

Knowing Alex Ignatieff, one recognizes immediately a scholar, always a gentleman who is both witty and unassuming and who devotes his time to the helping of others to help themselves. He forever appears to be in full control of himself. Throughout his career at the Mines Branch he supported the human values he admired most: hard work, thrift and a calm courage through difficult times. Add to this his talent of being a good listener and very human in his relationship with other people, then one can assess that his success as a team leader was easily achieved.

Occasionaly he would refer to himself as a very verbose person, but I always found his supposed verbosity to be carefully thought-out, and logically presented. If he was as verbose as he thought himself to be, then I am sure that he found great difficulty in restraining himself from embellishing his technical history of the Mines Branch with numerous personal experiences. Perhaps some day these extraordinary personal experiences of the Mines Branch team can be recorded.

From the early recognition that the Mines Branch must examine the possibility of developing Canadian processing techniques for minerals to replace those which were imported into Canada, the initial phase of the branch's existence emphasized mineral resource assessment and possible production. Mineral processing was in its early infancy, and Canadian expertise grew within the Ottawa laboratories, especially during World War I.

With World War II came a very urgent need for accelerated minerals and metals production. New techniques and production controls became essential, so much so that the pragmatic production operations of past years were drastically improved and in many cases replaced by more scientifically based methods. Exotic metals such as uranium, titanium and magnesium were in demand, for which extraction and refining production techniques had to be created. Add to this the recognition that energy supplies were not as abundant as expected. This overall challenging situation was met by the Mines Branch team, in what may be referred to as Phase II of the branch's history.

Interest in the development of Canada's fuel resources stimulated the rapid growth of the Fuels Division of Mines Branch. Since coal mining has always been technically difficult, the branch initiated a mining research group. This effort was primarily the brain child of Alex Ignatieff.

The need for increased metals production with improved metallurgical properties resulted in the birth of the Physical Metallurgy Division. Atomic reactors needed uranium metal, almost impurity free, creating an introduction into the metallurgical study of pure metals.

With the increased awareness of environmental matters and the need to conserve energy, greater attention was focused on methods of extracting metals from mineral concentrates. Progress was made in the use of hydrometallurgy to overcome the SO_2 effluent problems associated with pyrometallurgy. The scientific approach to the treatment of ores and extraction processes was increasingly used in the Mineral Sciences and Extraction Metallurgy divisions.

Phase III of the Mines Branch history is related to the Canadian minerals industry with reference to the conservation of energy and mineral resources, pollution abatement and economic production. The Mines Branch team now recognized that each so-called technical division was a component of an overall scientific approach towards the development of the Canadian minerals industry. Atomic science provided the key, when a micro interest in minerals and metals properties replaced the old macro approach. Metallic and non-metallic minerals, ferrous and non-ferrous metals, conductors and insulators all possessed recognized interrelated atomic basic structures. Modern materials science had arrived and the Mines Branch development reflected these changes. The staff became multi-disciplinary in essence.

Throughout the pages of this historical account of the technical development of the Mines Branch, we receive an extraordinary visual statement of the work and achievement of those who preceded us as members of the Mines Branch team. From those of us who have survived we say, thank you Alex for providing us with many relived, memorable experiences, with a deeper appreciation of our many colleagues who helped through team action and at times sheer hard work to make Canada more self-sufficient. To those readers who were not members of the Mines Branch team, I can assure that as you read through this volume you will find a rich storehouse of ready reference technical material which reflects the growth of Canada's mineral industry.

John Convey
Director (1951-1973)

PREFACE

Maggie Ralph (1919 - 1956) attempted for several months in 1948 to publish a Mines Branch monthly newsletter in which she presented, as a serial feature, a section dealing with the history of the branch. This effort lasted only for a short time due to lack of contributions from the staff. A pamphlet with historical notes was published on the occasion of the official opening of the building at 555 Booth Street/300 Lebreton Street in 1957, which coincided with the fiftieth anniversary of the Department of Mines Act of 1907; similar historical notes were published in the first issues of the Mines Memo, the annual report of the Mines Branch. An historical booklet was published on the history of the Fuels Division, the first laboratory division of the Mines Branch, titled "Fifty years of fuel testing" by A.A. Swinnerton. In the late sixties, Betty Hutchings (née Macfarlane) collected considerable material on the past directors such as Eugene Haanel, John McLeish, W.B. Timm, and C.S. Parsons. She transcribed some original reports. The author of this volume acknowledges the information derived from the documents referred to.

Except for Chapters 1 and 2 dealing with the origin and legislation pertaining to the Mines Branch, this historical account is organized into periods approximately coincident with the tenures of office of the six directors and the legislative changes which occurred. The total period covered is from 1901 to the end of 1975. However, for clarity in the description of lesser projects, these are completed without interruption outside the time frame indicated by the chapter title. This approach is particularly evident in Chapter 6, the longest, where descriptions are carried into the seventies.

To accommodate a time span of some seventy-five years within the confines of a single volume, a substantially condensed synthesis was required; hence the account cannot represent a truly comprehensive history. It is hoped, however, that a reasonably detailed résumé is presented of the activities of a scientific and technical federal institution through the ups and downs of a period in Canadian history which included two world wars and a serious depression.

In place of a subject index, the table of contents includes all main and subsidiary headings to assist the reader in finding a particular subject. Two different systems of headings are used throughout the volume - one relates to organization and the other to R & D by commodity or discipline. Two different systems of references or bibliographic citations are also used, one being noted in the text in abbreviated form and the second generally refers to more extensive research projects or investigations and is given in a bibliography at the end.

Efforts have been made to humanize the technical narrative by mentioning as many members of the Mines Branch family as possible but this could not include all contributors to specific projects because of incomplete records of personnel and limitations of space. Names mentioned for the first time in the text carry the pertinent dates of service in brackets; where only the initial date is given it signifies that the individual was still in service as of December 31, 1975. An appendix contains separate lists of women and men with 10 or more years of service; the women who formed a small but respected constituency would be difficult to identify if included with the men.

Ottawa, July 1981

A. Ignatieff
(1947-1972)

Carolyn Beaton

Don Coates

Nola Ferguson

Joan Stewart

Graham Taylor

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John Walsh

Tom Cochrane

Art Darling

Joan Scott

Chris Mamen

Al Gilmore

Doug Montgomery

Jim Kanasy

Ron Kelso

John Perry

John Ingles

Les Job

Basil Whalley

Bob Cunningham

Gloria Peckham

Irene Wilkes

Elaine Atkinson

Cyril Dixon

Ray MacDonald

Nita Metz

Marilyn Fraser

Krisztina Nagy

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CHAPTER 1

GEOLOGICAL SURVEY OF CANADA (GSC) - THE PARENT

The exploitation of mineral resources requires three distinct steps - geological exploration and mapping, mining development and extraction from the ground of ores and minerals, and the processing and refining of these materials of geological origin. Their association with the geological environment and materials is retained until the degree of purification is reached where man-made products can be manufactured and used. Science and technology that parallel the three steps are used for the complete evaluation of a nation's mineral resources and aids their rational exploitation.

The primary role of geology is reflected by the historical evolution of formal mineral resource studies in Canada. These commenced with the passing of a resolution of the Parliament of the United Province of Canada (Upper and Lower Canada lost their identity in 1840 and the terms Canada West and Canada East were in use in 1841) on September 10, 1841, "causing a Geological Survey of the Province to be made" for which the sum of 1500 pounds was to be provided. William Edmond Logan, later to be knighted, was chosen to be the head of this survey in 1842, the accepted date for its founding - in reality, a term project at that time. It required the 1845 Act to grant some continuity for the Geological Survey of Canada (1).

For a period of thirty-five years, from 1842 to 1877, the GSC operated in an early style of a Crown agency with its mandate renewed by Parliament from time to time and reporting at first to the Provincial Secretary and later to the Secretary of State. During this period the staff did not enjoy civil service status. The Department of the Interior was created in 1873, largely to open up the West for settlement and for resource development. In 1877, the Geological Survey, located in Montreal, became an "outside" branch of the Department of the Interior and the staff was brought under the Civil Service Act. The Survey moved to Ottawa in 1881. By the Act of May 16, 1890 (53 Victoria, Chapter 11) the Survey was granted special departmental status responsible to the Minister of the Interior through its own director or deputy minister. In this Act, as in the 1845 Act, emphasis on mining and mining resources is again evident from the three subsections of Section 5 dealing with duties, objects and purposes of the department. Subsection 5 (a) states that duties are "to make a full and scientific examination and survey of the geological structure, mineralogy, MINES and MINING RESOURCES, and of the fauna and flora". The first part of section 5 (b), reads "to maintain a museum of geological and natural history and to collect, classify and arrange for exhibition in a museum of the Department such specimens as are necessary to afford a complete and exact knowledge of the geology, mineralogy, and MINING RESOURCES of Canada"; subsection 5 (c) deals with the preparation and publication of maps, etc. to illustrate and elucidate the reports of surveys and investigations; and subsection 5 (d) "to collect and to publish, as soon as may be after the close of the calendar year, full statistics of the MINERAL PRODUCTION and of the MINING and METALLURGICAL INDUSTRY of Canada; to study the facts relating toward the supply, both for irrigation and domestic purposes, and to collect and preserve all available records of artesian or other wells, and of MINES and MINING WORKS in Canada."

In the ex post facto knowledge of the tremendous effort that went into producing a primary geological map of Canada, the implication of the change in the word "mineral" in the 1845 Act to "mining" resources in the 1890 Act appears surprising as "mining" may be interpreted as "mineable". Perhaps the anticipated rapid conclusion of the survey and the expectation that the Geological Survey could assess the "mineral" or "mining" resources of the Dominion of Canada from "sea to sea" were not comprehended by the legislators of the day as the gigantic tasks they were to be for the limited staff available.

The accelerated tempo of surveying was made possible in the post World War II era by modern surveying and air transportation methods, and today Canada is mapped geologically almost completely to a scale of one inch to eight miles from reconnaissance surveys with large areas of one inch to four miles standard scale and one inch to one mile and even larger scale maps. The latter are used in areas of complex geology and more particularly where mineralization is considered to have economic possibilities. Reports accompanying the maps interpret these possibilities. Throughout the history of the Geological

4 & 5 *Vic.* 10° *Septembris.* 1841

81st Resolution: £1,500, st'g, Geological Survey.

81. *Resolved*—That a sum not exceeding one thousand five hundred pounds, sterling, be granted to Her Majesty to defray the probable expense in causing a Geological Survey of the Province to be made.

ANNO OCTAVO

VICTORIÆ REGINÆ.

CAP. XVI.

An Act to make provision for a Geological Survey of this Province.

[17*th March*, 1845.]

Preamble.

WHEREAS a Geological Survey of this Province of Canada has been instituted for ascertaining the Mineral Resources thereof; And whereas the sum of fifteen hundred pounds, already granted to Her Majesty to defray the probable expenses of the same, has been found inadequate for the effectual investigation of so extensive a Territory as is comprised within the limits of the Province; And whereas it is expedient that the said Survey should be continued to a completion: Be it therefore enacted by the Queen's Most Excellent Majesty, by and with the advice and consent of the Legislative Council and of the Legislative Assembly of the Province of Canada, constituted and assembled by virtue of and under the authority of an Act passed in the Parliament of the United Kingdom of Great Britain and Ireland, and intituled, *An Act to Re-unite the Provinces of Upper and Lower Canada, and for the Government of Canada*, and it is hereby enacted by the authority of the same, That it shall and may be lawful for the Governor of this Province, in Council, to employ a suitable number of competent persons, whose duty it shall be, under the direction of the Governor in Council, to make an accurate and complete Geological Survey of this Province, and furnish a full and scientific description of its Rocks, Soils and Minerals, which shall be accompanied with proper Maps, Diagrams, and Drawings, together with a collection of Specimens to illustrate the same; which Maps, Diagrams, Drawings and Specimens shall be deposited in some suitable place which the Governor in Council shall appoint, and shall serve as a Provincial collection, and duplicates of the same, after they have served the purposes of the Survey, shall be deposited in such of the Literary and Educational Institutions of the Eastern and Western divisions of the Province, as by the same authority shall be deemed most advantageous.

The Governor in Council may appoint proper persons to make a Geological Survey of this Province.

A sum appropriated annually during five years for the said purpose.

II. And be it enacted, That from the unappropriated public monies of the Province, a sum not exceeding two thousand pounds, shall be annually applied, for a term of years not exceeding five years from the passing of this Act, to defray the expenses of the said Survey, or any arrears of expenditure already incurred, which sum shall be paid at such times and in such manner as the Governor in Council may direct.

Reports to be made to the Governor.

III. And be it enacted, That the person or persons employed by the Governor in Council for the purposes mentioned in the first section of this Act, shall make a report to the Governor of this Province on or before the first day of May in each year, setting forth generally the progress made in the Survey hereby authorized.

Interpretation clause.

IV. And be it enacted, That the words " Governor in Council," wheresoever they occur in this Act, shall be understood to mean the Governor, Lieutenant-Governor, or person administering the Government of this Province, acting by and with the advice of the Executive Council thereof.

Accounting clause.

V. And be it enacted, That the due application of the monies hereby appropriated shall be accounted for to Her Majesty, Her Heirs and Successors, through the Lords Commissioners of Her Majesty's Treasury, in such manner and form as Her Majesty, Her Heirs and Successors shall direct; and an account thereof shall be laid before the Provincial Legislature at the then next Session thereof.

MONTREAL :—Printed by STEWART DERBISHIRE and GEORGE DESBARATS,
Law Printer to the Queen's Most Excellent Majesty.

The Act of 1845 making provision for a Geological Survey, (Courtesy of Dr. P. Harker, GSC and J.H. Perry, Mines Branch)

Survey in making reconnaissance surveys, field officers recorded mineral occurrences, and in fact important discoveries were made whose development was postponed to more economically propitious times.

Inquiries on mining and processing matters were dealt with from the early years of the GSC under its first director, Sir William E. Logan, largely by T.S. Hunt, a chemist and mineralogist who was hired in 1847 to become Logan's principal assistant.

The second director of the GSC, Dr. A.R.C. Selwyn, was appointed in 1869, two years after Confederation, when Canada started its march to full nationhood. He considered his first priority to be the geological exploration and mapping of the vast land mass. He himself was engaged in this work for several years.

The attention given by the GSC to the more populated and mineral promising areas was considered inadequate by the burgeoning Canadian mining industry and by some of the politicians and the public. This attitude resulted in a parliamentary enquiry in 1884 when the GSC had been for seven years a branch of the Department of the Interior. The committee was composed of M.P.'s mainly from mining constituencies and, as one would expect, their view was that the primary role of the GSC was "to obtain and disseminate, as speedily and as extensively as possible, 'practical' information as to the economic mineral resources of the country, and that scientific investigations should be treated as of secondary importance except where necessary in procuring 'practical' results" (2). This mood in a section of the Canadian constituency concerned with mining persisted for some twenty years, for example, in the 1902 resolution of the Canadian Mining Institute (later the Canadian Institute of Mining and Metallurgy) the phrase is used - "urges - - the establishment of a strong and 'practical' Department of Mines and of a Department which shall be devoted to the interest of mining and metallurgical industries and which shall include the Geological Survey and all other necessary branches" (3).

It should be noted that criticism of the GSC was not unanimous as many of the mining profession appreciated its work in continuously increasing the knowledge of Canada's geology.

Dr. Selwyn anticipated the Parliamentary Committee's report by hiring two mining engineers, E.D. Ingall and E. Coste in 1883 and appointed them in 1884 as mining geologists with H.P.H. Brumell as assistant who became responsible for the statistical work. Selwyn did not give the seniority of an assistant director to the senior mining engineer as recommended by the Committee. Many mining areas were examined in detail and reports issued by the GSC in the period 1886 to 1907. Ingall started a record of drilling logs in 1889 and this was the forerunner of the Borings Division of which he was chief from 1907 to 1928.

The first statistical report entitled "Production, value, exports and imports of minerals in Canada for 1886" was issued in 1887 by the GSC. With the formation of the Department of Mines in 1907, this task was taken over by the Mines Branch, to be transferred in 1921 to the Dominion Bureau of Statistics and remains to this day with the successor, Statistics Canada.

The elevation of the GSC to departmental status by the Act of 1890 did not provide it with the same autonomy it enjoyed prior to 1877. This was because it had to report to Cabinet and Parliament through the Minister of the Interior, Canada's principal minister responsible for renewable and nonrenewable resources and human settlement in the West and the North who had a strong managerial position in all the agencies under his control. Clifford Sifton was appointed Minister of the Interior in 1896 at a time when the Canadian mining industry was reaching an economic importance equivalent to that of agriculture and forestry. Mining associations were being formed and their voices were augmented by the "Canadian Mining Review", the forerunner of the present "Canadian Mining Journal", clamouring for the government to be attentive to the mining industry's needs, including specialist information and statistics. Apparently Sifton was sympathetic to this industry view.

One of Sifton's principal advisers at this time was his professor of science at Victoria University when it was located at Cobourg, Ontario - Eugene Haanel. Dr. Haanel left for Syracuse University in 1888 but kept in touch with Canada where his teaching and administrative abilities were recognized. His competence was fully proved later in his management of the Mines Branch for 19 years. Dr. Haanel was offered the position of "Superintendent of Mines" in the Department of the Interior, the appointment dating from June 5, 1901. Prior to this appointment he was already advising the minister on policy as well as on specifics such as the establishment of a Dominion Assay (bullion) Office and laboratory in Vancouver which opened its doors in July 1901. The 28th Annual Report (1901) of the Deputy Minister of the Department of Interior under section "Departmental Changes" reads in part as follows: "I desire also to record the appointment on 5th of June last of Professor Eugene Haanel, Ph.D. as Superintendent of Mines in lieu of Mr. William Pearce, who was transferred by Order in Council of 8th June to the Office of the Chief Inspector of Surveys."

"It may be explained in this relation that in view of the recent development of mining industries in the Yukon Territory and other sections of the country where the lands are under the control of the Dominion Government, it was felt that provision should be made for the appointment of a special technical officer whose scientific knowledge and practical experience in mining matters would fit him to take charge of this particular branch, such officer to advise the department upon the requirements in connection with this service and prepare reliable information for publication. Professor Haanel, who was latterly employed as Professor of Physics at the University of Syracuse, in the State of New York, had previously, for some fifteen years, held the Chair of Science at Victoria University, Cobourg, Ontario. He is a member of the Royal Society of Canada, an expert mineralogist, and otherwise specially qualified by scientific knowledge and attainments to take charge of the important position to which he has now been appointed. He has already rendered very valuable services in connection with the establishment of the new Dominion Assay Office at Vancouver, and as he will be specially charged with the compilation of accurate information and official statistics with regards to mines and mining industries generally throughout the Dominion, there is no doubt that he will thus be in a position to supply a long-felt want in this respect."(4)

Interpreting the early period of the GSC and the hesitant birth of one of its progenies - the Mines Branch - a reviewer cannot but conclude that much was achieved by a small group of well motivated persons in the face of considerable difficulties and human frustrations largely connected with the limitation of resources available for achieving the goals of their institutions. The cardinal difficulty for the GSC was to decide what proportion of their limited resources could be allocated to detailed geological work necessary to open up promising mining areas as against pursuing the goal of providing a geological base for the nation, the usual primary goal of most national geological surveys.

The coming of an organization like the Mines Branch quite naturally caused resentment but was inevitable because of the interdisciplinary requirements and emphasis on various technologies in the new organization. A good example of organizational evolution is provided by the United States. Notwithstanding their larger resources allowing the U.S. Geological Survey to provide considerable assistance to the U.S. mining industries, the Bureau of Mines was formed in 1910, both organizations remaining to this day in the same Interior Department.

As mentioned at the outset of this chapter, because of the geological origin of mineral resources, logic dictates that the two scientifically distinct groups should coexist, each respecting the other's achievements. This is the case of the Geological Survey of Canada and the Mines Branch which have been together in the same department for over 70 years. There has been considerable contact and cooperation between the two groups. They participated in four departmental reorganizations commencing with the formation of the two-branch Department of Mines in 1907.

CHAPTER 2

APPELLATIONS AND LEGISLATION

The founding date of the Mines Branch is usually accepted as April 27, 1907 when the Geology and Mines Act was promulgated, setting up the Department of Mines. However, there was already in existence for nearly six years in the Department of the Interior an organization with similar functions and objectives as those of the future Mines Branch. This was directed by Dr. Eugene Haanel who had been appointed superintendent of mines in June 1901.

DEPARTMENT OF THE INTERIOR, 1901-1907

The terms "Superintendent of Mines" and "Mines Branch" were inherited from the Department of the Interior where they described functions quite different from those of the new director and the branch, as can be seen from the interpretation that follows. The designations of "Superintendent" and "Commissioner" were applied to managerial positions concerned with one or another area of the Department of the Interior's responsibilities such as immigration, forestry, Dominion Lands, etc. The heads of these administrative centres were called superintendents as in Immigration, Forestry and Rocky Mountains Park, whereas in Dominion Lands, the head was a commissioner. Some reported to the minister, others to the deputy minister. In the Dominion Lands Administration there was at that time an office of superintendent of mines in Calgary. The 1900 annual report by William Pearce, the superintendent, reporting to the commissioner, refers mostly to livestock and only briefly to the Alberta coal and coke developments. A year later Eugene Haanel was installed in this position which had obviously been upgraded, as Dr. Haanel addressed his first report from June 16 to June 30, 1902 and subsequent annual reports up to 1907 inclusive to the Minister of the Interior.

There was no statutory basis for the existence of branches in the department. The name "Mines Branch" first appears in the annual report for 1903-4 by Dr. Haanel who referred to the "conduct of the Mines Branch" (5). He continued to be superintendent of mines until official formation of the Mines Branch in 1907.

A curious situation arose in the departmental annual report for 1906-7 which reported the change of the fiscal year from June 30 to March 31, covering only nine months. It contained two separate reports from two Mines Branches, one by E. Haanel to the Minister of the Interior and the other by H.H. Rowatt, chief clerk, who reported to the deputy minister on the creation of a Mines Branch in the Dominion Lands Administration on July 1, 1906. The latter was subsequently renamed Mining Lands and Yukon Branch. It is clear that the terms "Superintendent of Mines" and "Mines Branch" were assigned for the sake of convenience and were not precise designations. They were intended to be used for various aspects of administering federal crown lands and not to establish research and development in technologies based on the primary sciences of chemistry and physics. The term "Mines Branch" was legislated into an official designation by the 1907 Geology and Mines Act but this was changed to Bureau of Mines with the reorganization brought about by the 1936 Department of Mines and Resources Act. It was brought back into use after the third reorganization arising from the 1950 Mines and Technical Surveys Act and was retained in the fourth departmental reorganization under the 1966 Government Organization Act which gave the department the name of Energy, Mines and Resources.

The retention of the term "Mines" in the departmental title from 1907 to the present reflects the views of successive governments and of the general public as to the national importance of the Canadian mining industry. As to whether "Mines" was appropriate for the branch name in the first place, succeeding chapters will show that historically the branch was concerned with metallurgical and fuels processing and with physical metallurgy.

Mining research in terms of extraction of economic minerals from the ground started only in 1950. On the other hand, there was a major contribution by the Mines Branch in mineral economics, and in the early period, in the compilation of official statistics.

In January 1975, the Mines Branch was renamed the "Canada Centre for Mineral and Energy Technology", CANMET for short. Though there is at present a nostalgic affection for the term Mines Branch which had been in use for over 70 years, the new name reflects more accurately the functions of the organization.

6-7 EDWARD VII.

CHAP. 29.

An Act to create a Department of Mines.

[Assented to 27th April, 1907.]

HIS Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:—

Short title.

1. This Act may be cited as *The Geology and Mines Act.*

Definitions.

2. In this Act, unless the context otherwise requires,—
(*a*) "department" means the Department of Mines;
(*b*) "Minister" means the Minister of Mines.

Department constituted.

3. There shall be a department of the Civil Service to be called "The Department of Mines," which shall be under the control and management of the head of one of the present departments of the Government of Canada, who shall be named from time to time for that purpose by the Governor in Council, and who shall be called "The Minister of Mines."

Subjects of administration.

4. The department shall administer all laws enacted by the Parliament of Canada relating to mines and mining, and shall also have the management and direction of all subjects assigned to it by the Governor in Council.

Transfer of subjects from other departments.

2. Whenever, under the provisions of this section, the management and direction of any subject is transferred from any other department to the Department of Mines, the Minister of Mines and the Deputy Minister of Mines shall be substituted for, and have all the powers and perform all the duties of, the minister and deputy minister, respectively, of such other department, as defined and provided by the Acts and regulations relating to such subject.

Mines Branch and Geological Survey.

5. The department shall consist of two branches, one of which shall be called the Mines Branch, and the other of which shall be called the Geological Survey.

Functions of Mines Branch.

6. The functions of the Mines Branch shall be,—
(*a*) to collect and publish full statistics of the mineral production and of the mining and metallurgical industries of Canada, and such data regarding the economic minerals of Canada as relate to the processes and activities connected with their utilization, and to collect and preserve all available records of mines and mining works in Canada;
(*b*) to make detailed investigations of mining camps and areas containing economic minerals or deposits of other economic substances, for the purpose of determining the mode of occurrence and the extent and character of the ore-bodies and deposits of the economic minerals or other economic substances;
(*c*) to prepare and publish such maps, plans, sections, diagrams, drawings and illustrations as are necessary to elucidate the reports issued by the Mines Branch;
(*d*) to make such chemical, mechanical and metallurgical investigations as are found expedient to aid the mining and metallurgical industry of Canada;
(*e*) to collect and prepare for exhibition in the Museum specimens of the different ores and associated rocks and minerals of Canada and such other materials as are necessary to afford an accurate exhibit of the mining and metallurgical resources and industries of Canada.

Functions of Geological Survey.

7. The functions of the Geological Survey shall be,—
(*a*) to make a full and scientific examination and survey of the geological structure and mineralogy of Canada; to collect, classify, and arrange for exhibition in the Victoria Memorial Museum such specimens as are necessary to afford a complete and exact knowledge of the geology, mineralogy, palæontology, ethnology, and fauna and flora of Canada; and to make such chemical and other researches as will best tend to ensure the carrying into effect the objects and purposes of this Act;
(*b*) to study and report upon the facts relating to water supply for irrigation and for domestic purposes, and to collect and preserve all available records of artesian or other wells;
(*c*) to map the forest areas of Canada, and to make and report upon investigations useful to the preservation of the forest resources of Canada;
(*d*) to prepare and publish such maps, plans, sections, diagrams and drawings as are necessary to illustrate and elucidate the reports of surveys and investigations;
(*e*) to carry on ethnological and palæontological investigations.

Museum.

8. The department shall maintain a Museum of Geology and Natural History for the purpose of affording a complete and exact knowledge of the geology, mineralogy and mining resources of Canada.

Officers and employees.

9. The Governor in Council may appoint a Deputy Minister, a Director of the Mines Branch, a Director of the Geological Survey, and such other officers and clerks as are required for the proper conduct of the business of the department, who shall be appointed and classified under schedule A of *The Civil Service Act*, and in accordance with and under the terms of section 6 of the said Act.

Technical officers.

10. Such officers of the department as are continuously engaged in the prosecution of original scientific work or investigation shall be classified as technical officers, under paragraph (*b*) of schedule A of *The Civil Service Act;* and the Governor in Council may cause to be prepared a list of such officers of the department as are considered to be entitled to be thus classified, with any designations deemed expedient to indicate the scientific work in which they are engaged.

Qualifications of technical officers.

11. No person shall be appointed to the department under paragraph (*b*) of schedule A of *The Civil Service Act*, unless he is a science graduate of either a Canadian or a foreign university, or of the Mining School of London or the Ecole des Mines of Paris, or of some other recognized science school of standing equal to that of the said universities and schools, or a graduate of the Royal Military College.

Temporary assistants.

12. When the Deputy Minister reports, for reasons set forth in such report, that assistance of a technical or professional character is required in the department, the Governor in Council may, without reference to any examination, or to the age of the person, if the Minister concurs in such report, temporarily employ such person at such remuneration as is deemed expedient.

Appointments on probation.

13. Any person appointed to the department shall be appointed on probation and shall not receive a permanent appointment until he has served a probationary term of at least one year, during which probationary term he may be rejected upon the report of the Director of the branch in which the temporary appointment has been made; but if he is not rejected, the Deputy Minister may signify, in writing, to the Minister that he considers the person so appointed competent for the duties of the Department, and the appointment may thereupon be made permanent.

Duties of employees

14. Persons employed in one section of a branch may be directed by the Minister to perform any duty in or with respect to any other section in the same branch.

Present officials of Geological Survey.

15. The Governor in Council may, on the recommendation of the Minister, assign the present officials of the Geological Survey to the branch in which it is deemed desirable that their services shall be utilized; provided that the rate of pay or tenure of office as at present existing shall not be impaired or altered by such assignment.

Present assistant directors.

16. Nothing in this Act shall be construed to invalidate or interfere with the commissions, as assistant directors, heretofore issued under orders in council to certain members of the scientific staff of the Geological Survey.

Restrictions upon employees.

17. No person employed in or under the department shall, directly or indirectly,—

(*a*) purchase any Dominion or provincial lands other than for personal residential purposes, except under authority of the Governor in Council;

(*b*) locate military or bounty land warrants, or land scrip, or act as agent of any other person in that behalf;

(*c*) disclose to any person, except his superior officer, any discovery made by him or by any other officer of the department, or any other information in his possession in relation to matters under the control of the department or to Dominion or provincial lands, until such discovery or information has been reported to the Minister, and his permission for such disclosure has been obtained;

(*d*) make investigations or reports relating to the value of the property of individuals, or hold any pecuniary interest, in any mine, mineral lands, mining works or timber limits in Canada.

Reports.

18. The Directors of the branches shall, as soon as may be after the close of each calendar year, make summary reports of the proceedings and work of their respective branches for the year, and shall also furnish final and detailed reports, to be issued from time to time in such manner and form as the Minister directs; and the Minister shall cause the said reports to be laid before Parliament, with such remarks, explanations and recommendations as he thinks proper.

Books and apparatus.

19. The department shall be furnished with such books, instruments and apparatus as are necessary for scientific reference and for the prosecution of the work of the Mines Branch and of the Geological Survey.

Distribution of specimens and publications.

20. The Minister may cause distribution to be made of duplicate specimens to scientific, literary and educational institutions in Canada and other countries, and also authorize the distribution or sale of the publications, maps and other documents issued by the department.

Surveys.

21. The Minister may, for the purpose of obtaining a basis for the representation of the mineral, mining and forestry resources and of the geological features of any part of Canada, cause such measurements, observations, investigations and physiographic, exploratory and reconnaissance surveys to be made as are necessary for or in connection with the preparation of mining, geological and forestry maps, sketches, plans, sections or diagrams.

Repeal.

22. Chapter 65 of the Revised Statutes, 1906, is repealed.

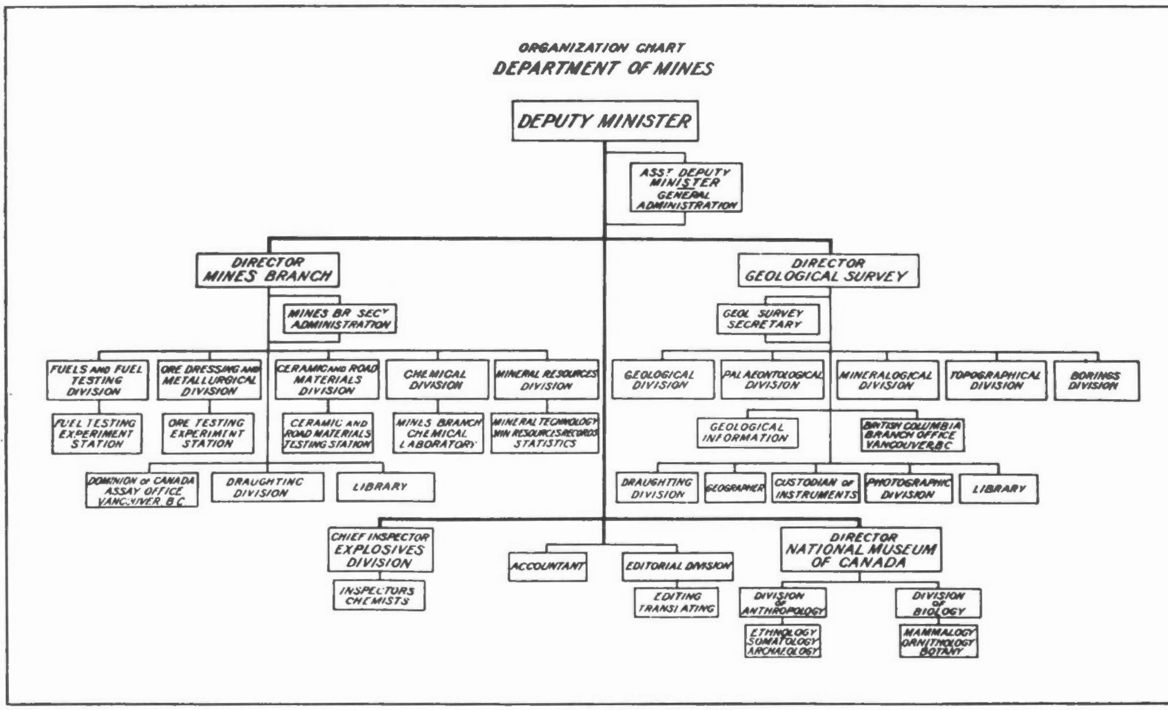
OTTAWA: Printed by Samuel Edward Dawson, Law Printer to the King's most Excellent Majesty.

The Act of 1907 creating a Department of Mines

DEPARTMENT OF MINES, 1907-1936

It seems appropriate for reference purposes to reproduce the 1907 Geology and Mines Act in full as this is the founding Act of the Mines Branch and some of the principal provisions are still in force.

It will be noted in Section 3 of the Act that the department was not entitled to a full-time minister. Thus, the first Minister of Mines, William Templeman (1907 to 1911) was also Minister of Inland Revenue. The first deputy minister was Dr. A.P. Low (1907 to 1913), who was the fifth director of the Geological Survey (1906-7). The Department of Mines with two small revisions of the 1907 Act in 1918 and 1927, not affecting the functions, existed for 29 years until 1936 when the second Mines Branch reorganization was made. During this period there were fourteen ministers and four deputy ministers, the latter all being former officers of the GSC: Dr. A.P. Low (1907 to 1913), Dr. W. Brock (1914), Dr. R.G. McConnell (1914 to 1920), and Dr. Charles Camsell (1920 to 1936, Department of Mines, and 1936 to 1946 Department of Mines and Resources, an aggregate of 26 years as deputy minister of departments which included the Mines Branch).



Organization chart of the Department of Mines, 1922

Explosives Act, 1920

Legislation related to the functions of the Mines Branch and similar scientific and technological institutions has usually been permissive whereas Explosives Acts are prescriptive. The administration of all Acts are proposed by government and decided by Parliament. In the case of explosives, the choice in Canada has been the department concerned federally with the mining industry. The Explosives Acts are brought together for the sake of continuity and are interposed in the narrative between the departmental Acts of 1907 and 1936.

The regulation of nonmilitary explosives in most countries requires its own Act. The initiative for a Canadian Explosives Act can be credited to the director of Mines Branch, Eugene Haanel, who "deplored" in the Mines Branch annual reports of 1909 and 1910, the high loss of life in factories and mines arising from the manufacture and use of explosives. Captain Desborough, Home Office (U.K.), H.M. Inspector of Explosives, acted as adviser to the department in drafting the Explosives Act which was introduced to the House of Commons by W. Templeman, the minister, on May 14, 1911. However, due to dissolution of Parliament and other delays the Act was assented to only on June 12, 1914. Largely because of the First World War, the proclamation of the Act was delayed and it came into force only on March 1, 1920.

A close association of the Explosives Division with the Mines Branch has existed to the present day, largely in the testing and chemistry of explosives. There was a Division of Explosives in the Mines Branch as reported in the annual reports of 1911-1916, with the solitary classified incumbent of J.G.S. Hudson. The situation remained in limbo until promulgation of the Explosives Act in 1920 when Hudson was transferred to the Explosives Division which was given departmental status as a division. The chemistry laboratory was part of the division. At the formation of the Department of Mines and Resources, the Explosives Division (with the laboratory) was integrated with the Bureau of Mines but it regained departmental status when the department name changed to Mines and Technical Surveys. The laboratory was transferred to the Mines Branch in 1959 where it presently remains with CANMET under the distinctive name acquired in 1967 of the Canadian Explosives Research Laboratory.

In the Mines and Resources Act of 1936, succeeding the Department of Mines Act of 1907, there is no specific reference to the minister's responsibility in explosives but there is an implication to that effect in Section 9(1) in the responsibility in the Department of Mines and Resources; the minister and the deputy minister being responsible for any prior Acts of predecessor departments, ministers and deputy heads.

Explosives Act, 1946

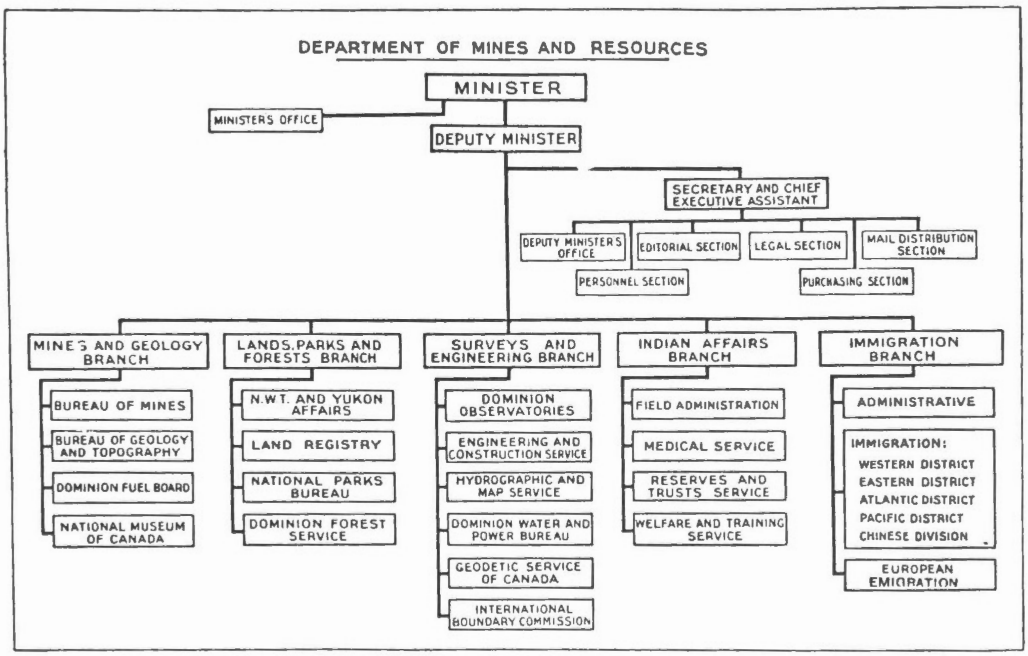
The Act was revised in 1946, the main changes relating to (a) the sale of explosives, (b) seizure of unauthorized explosives, or where an offence under the Act is believed to be committed and, (c) the destruction of abandoned or deteriorated explosives. There were two revisions in 1949 and 1952 of the 1946 Explosives Act, the first dealing with inclusion of Newfoundland and the second with naming of the Department of Mines and Technical Surveys and its minister as responsible for the Act.

The 1949 Department of Mines and Technical Surveys Act specifies the minister's responsibility for explosives. Section 5 states "The duties, powers and functions of the Minister extend to and include all matters over which the Parliament of Canada has jurisdiction relating to mines, minerals, EXPLOSIVES and technical surveys". Similarly, the Resources and Technical Surveys Act of 1966 Section 9 (2) states "Whenever in any contract, lease or other document and power, authority or function in relation to mines, minerals, EXPLOSIVES or technical surveys is vested in or exercisable by .... (previous ministers and departments) .... the power, authority or function shall be vested in and shall or may be exercised by the Minister of Energy, Mines and Resources and the Deputy Minister of Energy, Mines and Resources, respectively, or by such other minister or deputy minister as the Governor in Council may designate".

There were further amendments to the 1946 Explosives Act in 1953-4 (Chapter 14 of the Statutes of Canada). Some 14 changes of sections and subsections, one of which, 3 (1), extended the jurisdiction of the Act to the provinces. The important order under Section 8 of the Act (in explosives component parts) authorized, by Order in Council P.C. 1957-335 of March 14, 1957, the blending of ammonium nitrate and fuel oil in open pit mines and quarries for use therein. A further amendment was made in 1966-7 when the Minister and Department of Energy, Mines and Resources were designated, superseding the Mines and Technical Surveys. The consolidation of the Act and regulations were issued in 1956 and 1974. At this date (1975) the 1946 Act is still in force. In view of the increase of accidents in the use of fireworks and explosives, particularly the former, amendments were anticipated that would introduce for the first time in the federal Explosives Act a regulatory use concept. Another new concept that was anticipated was the prohibition of possession of an explosive by a private individual.

DEPARTMENT OF MINES AND RESOURCES, 1936-1950

The second reorganization in which the Mines Branch was involved, as mentioned earlier, was by Act 1 EDWARD VIII, Chapter 33, respecting the Department of Mines and Resources, assented to on June 23, 1936, and which came into force on December 1, 1936. This reorganization was brought about by the resources of Western Canada finally being transferred to the provinces, leaving only the Northwest Territories and the Yukon and a few areas in the National Parks and some scattered blocks like those adjoining the western regions of the CPR, under federal jurisdiction. The transfer coincided with the great depression of the 1930's. The creation toward the end of the depression of a large department embracing human and natural resource interests may have been done to demonstrate economy in government administration. The result of this reorganization in December 1936 was the dissolution of the departments of Interior, Mines, Indian Affairs, and Immigration and Colonization. The functions of the Mines Branch and those of the Geological Survey described in Sections 6 and 7 of the 1907 Department of Mines Act remained unrepealed. Section 4 (2) of the Act provided for branches or divisions as follows: "The Governor in Council may, with respect to the organization of the Department, divide the Department into not more than eight branches or divi-



Organization chart of the Department of Mines and Resources, March 1939. The Bureau of Mines comprised the following divisions: Economics, Explosives, Metallic Minerals, Industrial Minerals and Fuels sions, and he may in the first instance appoint a chief officer, who shall be called Director, for each such branch or division and who shall hold office during pleasure and shall have such powers and perform such duties under the Deputy Minister as may be assigned to him by the Governor in Council or the Minister."

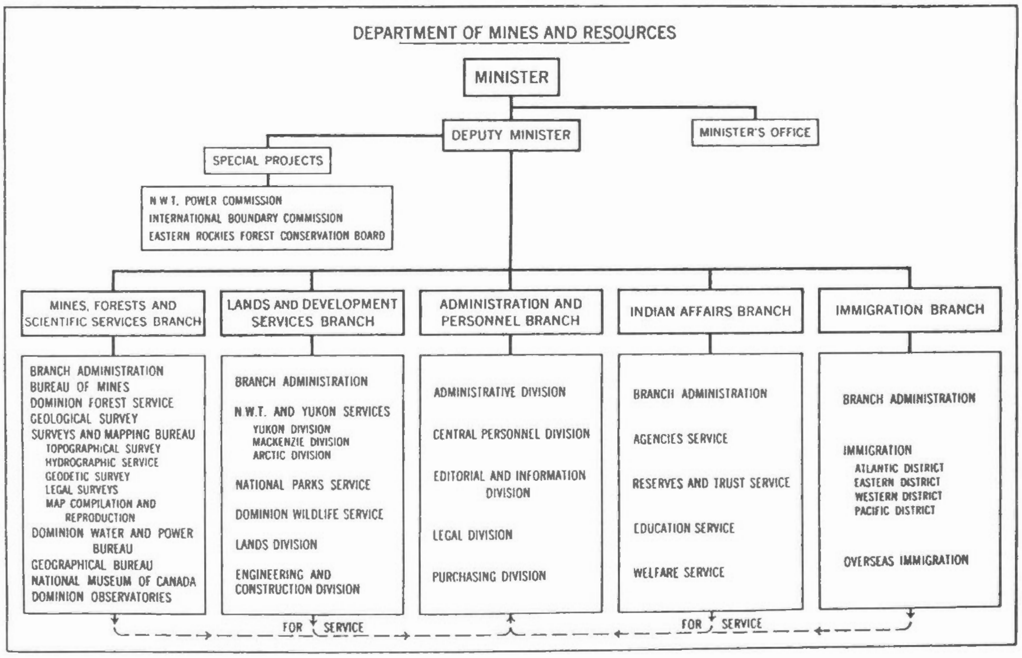
The Mines Branch and the Geological Survey were brought together in the Mines and Geology Branch. They were renamed the Bureau of Mines and the Bureau of Geology and Topography respectively. Their heads had titles of chiefs and to that extent they were relatively downgraded in the large department. The remaining four principal branches created were Lands, Parks and Forests; Surveys and Engineering (including water resources); Indian Affairs; and Immigration. There was a limited departmental reorganization under the authority of Order in Council P.C. 37 /4433 of November 1, 1947, which reflected the Government's desire to consolidate all renewable and nonrenewable resources in one scientific group other than agriculture and fisheries. The Mines, Forests and Scientific Services Branch was formed for this purpose embracing the following sub-units: Branch Administration; Bureau of Mines; Dominion Forest Service; Geological Survey; Surveys and Mapping Bureau including Topographical Survey, Hydrographic Service, Geodetic Survey, Legal Surveys, Map Compilation and Reproduction; Dominion Water and Power Bureau; Geographical Bureau; National Museum of Canada; and Dominion Observatories.

Indian Affairs and Immigration branches remained the same but the previous Lands, Parks and Forests Branch became Lands and Development Service Branch. The Surveys and Engineering Branch was abolished and a new Administration and Personnel Branch created. A special projects headquarters group comprising Northwest Power Commission, International Boundary Commission and Eastern Rockies Forest Conservation Board was formed. The effect of this reorganization could not be evaluated because in 1950 a number of departments were formed including Mines and Technical Surveys. During the 13 years of its existence the department had three ministers - T.A. Crerar was Minister of Mines from 1935 to 1936 and Minister of Mines and Resources from 1936 to 1945. He was the minister with the longest period of service in the departments that included the Mines Branch. Dr. Charles Camsell and Dr. Hugh L. Keenleyside were deputy ministers during this period. Camsell retired from the public service after completing a career of 46 years of which 21 years were with the Geological Survey of Canada and 26 years as deputy minister of the two departments that included the Mines Branch and GSC. Keenleyside served a three-year term from 1947 to 1950.

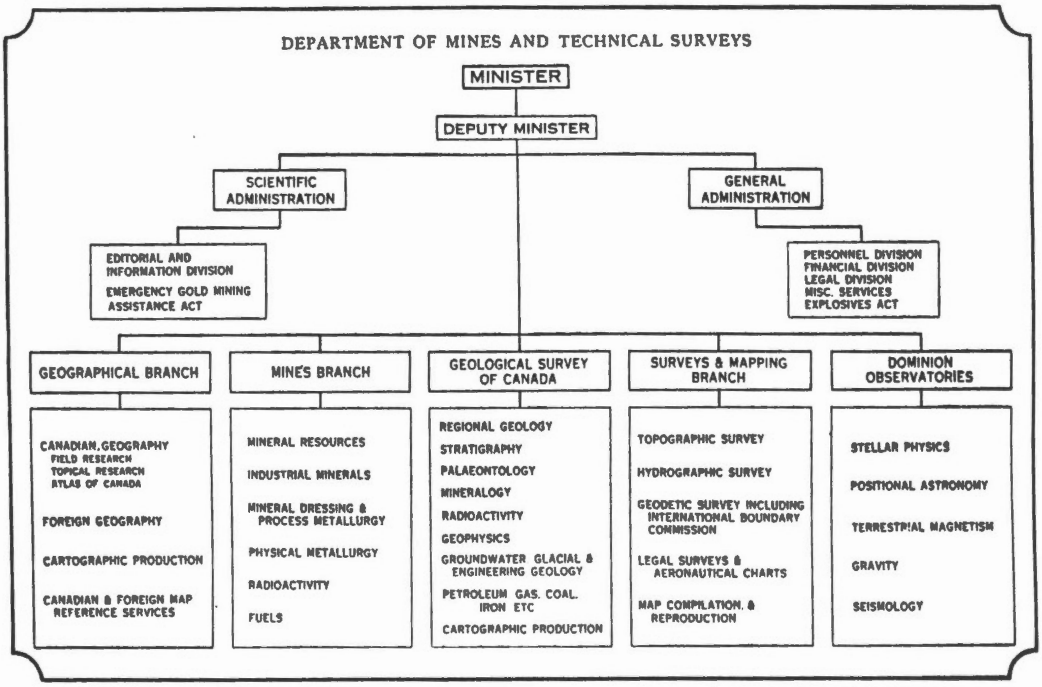
DEPARTMENT OF MINES AND TECHNICAL SURVEYS, 1950-1966

The omnibus Department of Mines and Resources served the government's purpose, not unlike the Department of the Interior, until the immediate postwar period when Canada started its two-decade march of rapid development.

The Department of Mines and Resources dissolved into three departments in December 1949 - Mines and Technical Surveys, Resources and Development, and Citizenship and Immigration. The Department of Mines and Technical Surveys Act was passed in 1949 and came into force on January 20, 1950. The Act did not indicate a specific infrastructure but a minister was to be solely responsible for the department. The initial internal organization consisted of five branches: Mines, Geological Survey of Canada, Surveys and Mapping, Geographical, and Dominion Observatories.



Organization chart of the Department of Mines and Resources, March 1948



Organization chart of the Department of Mines and Technical Surveys, 1950

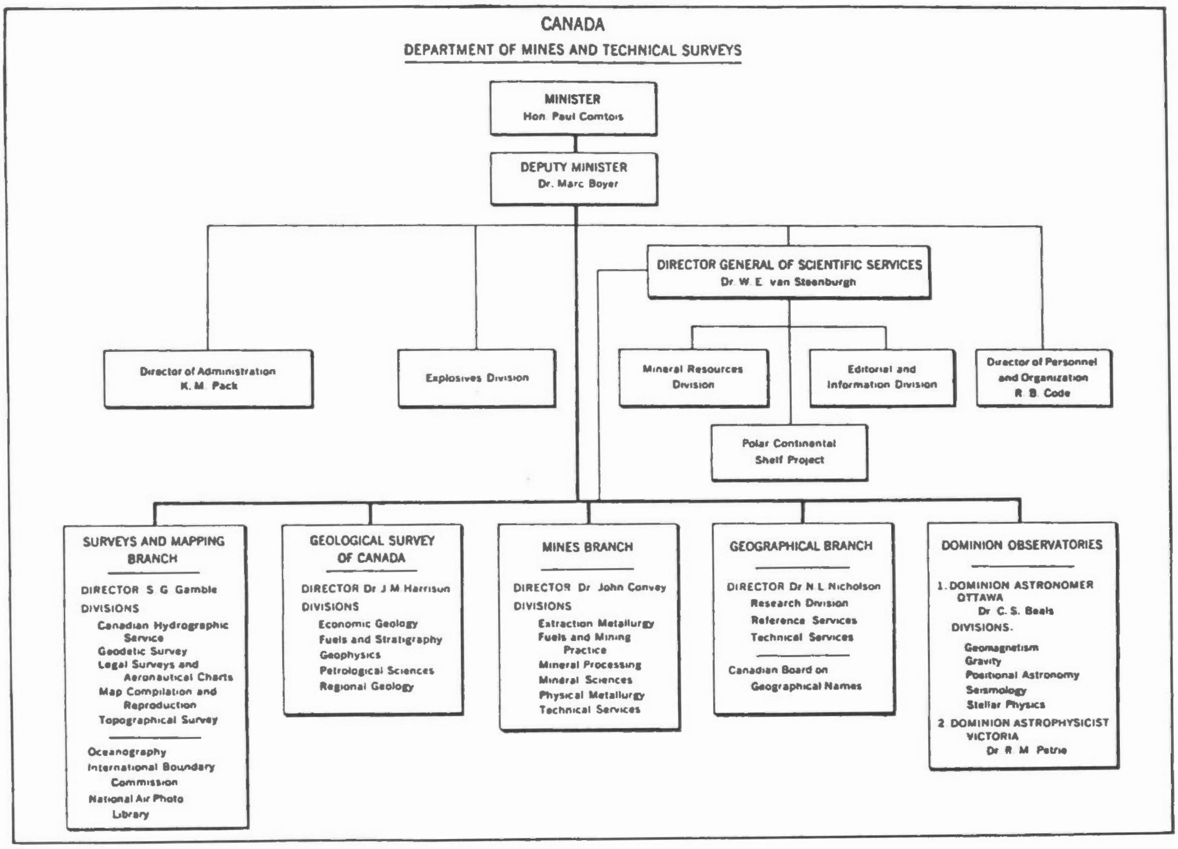
This represented a spectrum of resource study which colloquially expressed was "Canada - from the Universe to the Products of Mines and Metallurgical Plants".

Sections and parts of sections applying to the Mines Branch were spread throughout the text. These were Section 5 (previously quoted under explosives legislation), Section 6 sub-sections (a), (b), (d) and parts of (f) and (g), and Section 8. The text of the relevant sections other than Section 5 were as follows: Section 6. "The Minister shall (a) collect and publish full statistics of the mineral production and of the mining and metallurgical industries of Canada, and such data regarding the economic minerals of Canada as relate to the processes and activities connected with their utilization, and collect and preserve all available records of mines and mining works in Canada; (b) make detailed investigations of mining camps and areas containing economic minerals or deposits of other economic substances, for the purpose of determining the mode of occurrence, and the extent and character of the ore-bodies and deposits of the economic minerals or other economic substances; (d) make such chemical, mechanical, metallurgical and other researches and investigations as are necessary or desirable to carry out the purposes and provisions of this Act and particularly to aid the mining and metallurgical industry of Canada; (f) collect and prepare for exhibition such specimens of the different ores and associated rocks and minerals of Canada and other materials as are necessary to afford a knowledge of the geology and mineralogy and the MINING and METALLURGICAL RESOURCES and INDUSTRIES of Canada; (g) prepare and publish such maps, plans, sections, diagrams and drawings as are necessary to illustrate and elucidate any reports of investigations and surveys made pursuant to this Act 1949." Section (c) applied only to the Geological Survey of Canada and section (e) to astronomical observatories.

It will be noted that most of the sections were derived from the 1907 Department of Mines Act, with small changes of wording. In Section 6 (d), referring to the principal functions of the Mines Branch, the following changes were made from the 1907 Act. After the word "metallurgical" were added the words "and other researches and"; instead of the words "as are found expedient" the following were used "as are necessary or desirable to carry out the purposes and provisions of the Act and particularly ....".

The department lasted 16 years with eight ministerial changes; George Prudham served for seven years and Paul Comtois for four. There were two deputy ministers - Dr. Marc Boyer 1950 to 1962 and Dr. W.E. van Steenburgh 1963 to 1966. The senior position of director-general of Scientific Services was created at the outset of the department. Dr. George S. Hume was the first incumbent from 1950 to 1956, and van Steenburgh was the second with service from 1956 to 1963. When the position was abolished it was replaced by two positions - assistant deputy minister (Research) and ADM (Mining), created in 1964. Dr. J.M. Harrison filled the ADM (Research) position from 1964 to 1966, and Jean-Paul Drolet has been ADM (Mining, changed to Mineral Development in 1966) from 1964 to the present.

On June 26, 1956 the Mineral Resources Division was transferred by ministerial decision, after being a part of the Mines Branch for almost fifty years, to become a departmental unit reporting to the director-general of Scientific Services, and from 1964 through the assistant deputy minister (Mines, later Mineral Development). It became a branch at the formation of the Department of Energy, Mines and Resources in 1966.



Organization chart of the Department of Mines and Technical Surveys, 1960

Further departmental changes in line with the policy of the department and not requiring legislative action were made, to give emphasis to Earth and Marine Sciences. Thus, in 1958 the Polar Continental Shelf project was launched with a multi-discipline group representing all the sciences of the department with staff drawn from all the branches other than Mines, for the purpose of conducting surveys and scientific research in the Continental Shelf area of Arctic Canada. This unit reported to the director-general of Scientific Services and later to the assistant deputy minister (Research); its first co-ordinator was Dr. E.F. Boots, formerly of GSC. Furthermore, in 1962 the Marine Sciences Branch was formed from the long-established Canadian Hydrographic Service and the then recently formed Division of Oceanographic Research, units that were part of the Surveys and Mapping Branch.

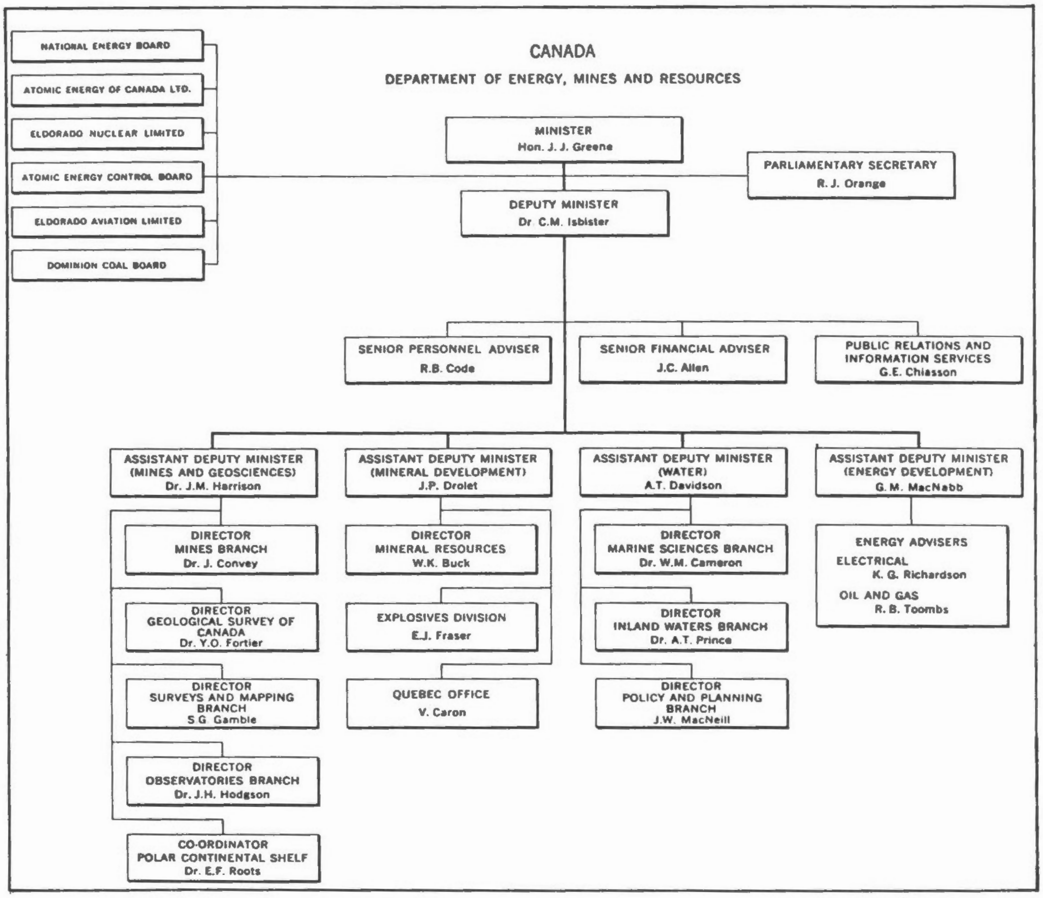
On September 7, 1965 the Industrial Waters Section of the Mines Branch was brought together with the Groundwater Section of the Geological Survey, the Glaciology Section of the Geographical Branch and Tides and Water Levels Section of the Marine Sciences Branch to form the Water Research Branch.

DEPARTMENT OF ENERGY, MINES AND RESOURCES, 1966 -

The Government Organization Act of 1966 reorganized the Department of Mines and Technical Surveys and the Department of Northern Affairs and Natural Resources resulting in changing names to Energy, Mines and Resources and Indian Affairs and Northern Development respectively. The Act came into force on October 1, 1966 and gave rise to the Resources and Technical Surveys Act amending the Department of Mines and Surveys Act and charging the reorganized department with additional responsibilities.

The section of the Act dealing with the scientific and technical functions of the old branches were almost identical with those in the Department of Mines and Technical Surveys Act, such as Sections 6 and 8, but only Section 6 (d) and parts of Section 6 (f) and (g) apply to the Mines Branch, as the Mineral Resources Division had been transferred in the previous administration to become a headquarters unit. It will be noted that through all the reorganizations and the accompanying Acts of Parliament, the principal functions uniquely applying to Mines Branch as expressed in Section 6 (d) (the designation being the same in all of the Acts) have never changed. The phrase "- - - to aid the mining and metallurgical industry of Canada - - -" expresses the role that the Mines Branch was expected by the legislators to play vis-a-vis the important mining and metallurgical industry of the country.

The Act introduced a new and important policy role for the department provided by the new Sections 8.A. and 8.B. which are quoted in full.



Organization chart of the Department of Energy, Mines and Resources, 1967-68

SECTION 8.A. - "Subject to Section 29 of the Government Organization Act 1966 respecting the duties, powers and functions of the Minister in relation to matters mentioned in that section over which the Parliament of Canada has jurisdiction, the Minister shall be responsible for coordinating, promoting and recommending national policies and programs with respect to energy, mines and minerals, water and other resources, and in carrying out his responsibilities under the section, the Minister may:

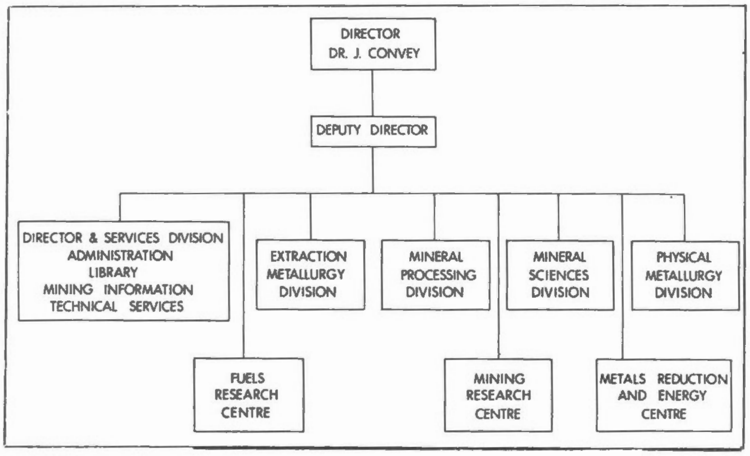
(a) conduct applied and basic research programs and investigations and economic studies in relation to such resources, and for that purpose maintain and operate research institutes, laboratories, observatories and other facilities for exploration and research related to the source, origin, properties, development or use of such resources; and
(b) study, keep under review and consider recommendations with respect to matters relating to the exploration for or the production, recovery, manufacture, processing, transmission, transportation, distribution, sale, purchase, exchange or disposition of, any such resources and matters relating to the sources thereof within or outside Canada."

SECTION 8.B. - "(1) In carrying out his responsibilities under section 8A, the Minister may formulate plans for the conservation, development and use of the resources specified in that section and for research with respect thereto, and with the authority of the Governor in Council and in co-operation with other departments, branches and agencies of the Government of Canada, provide for carrying out such plans.

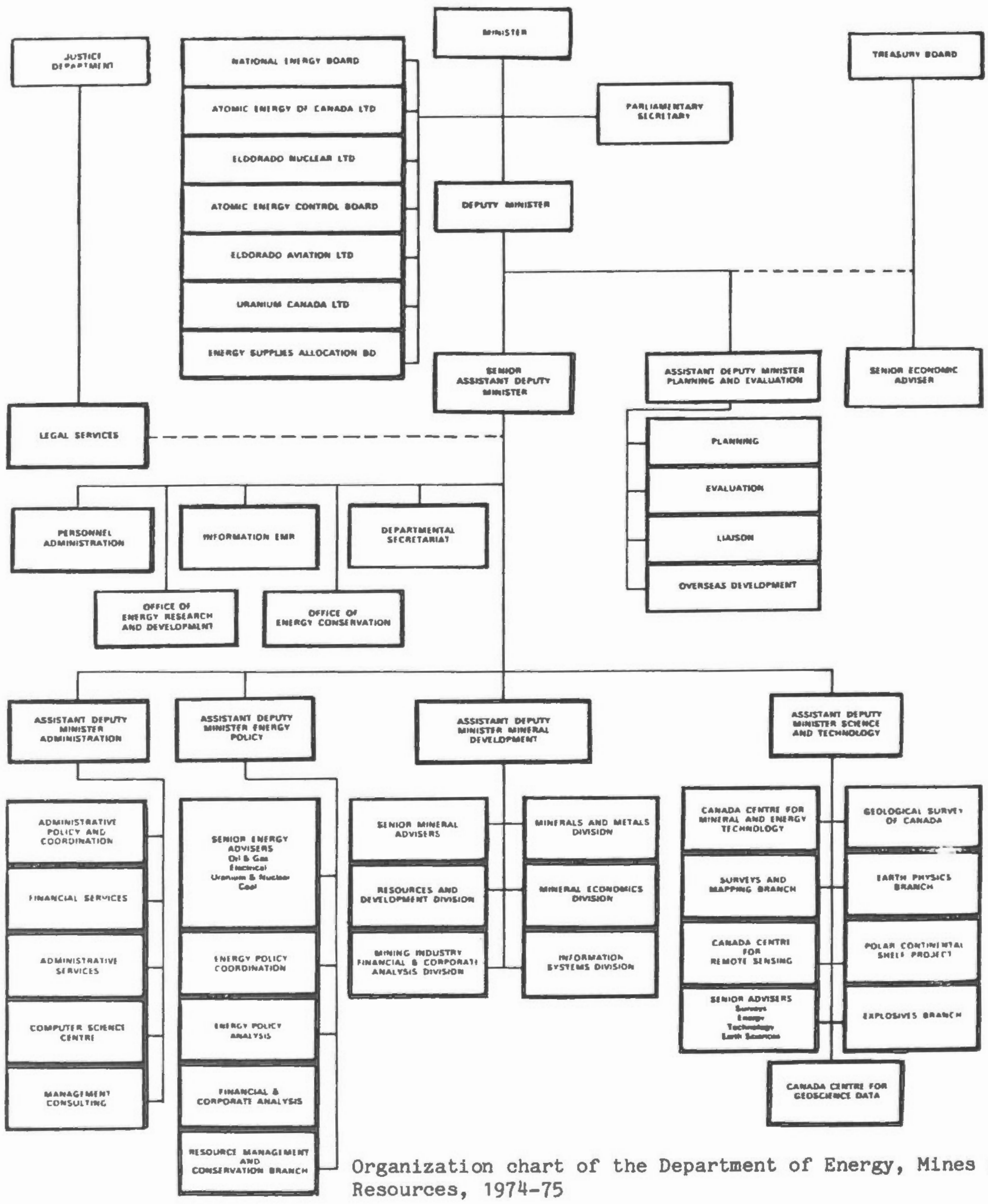
(2) The Minister may co-operate with the provinces and with municipalities in formulating and carrying out any plans under subsection (1).

(3) In carrying out his duties and functions under this section, the Minister may consult with and inaugurate conferences of representatives of producers, industry, the universities, labour and provincial and municipal authorities."

Consistent with the powers of the new Act, a headquarters policy (horizontal) organization was formed comprising the science and technology, mineral development, water, and energy sectors, with assistant deputy ministers in charge of each. The 1968 organization chart shows the important Water Group which included the Water Resources Branch transferred in 1966 from the Department of Northern Affairs and National Resources and its incorporation with the Water Resources Branch into the Inland Waters Branch. However, under the 1970 Government Organization Act the department's responsibility for Water, other than as an



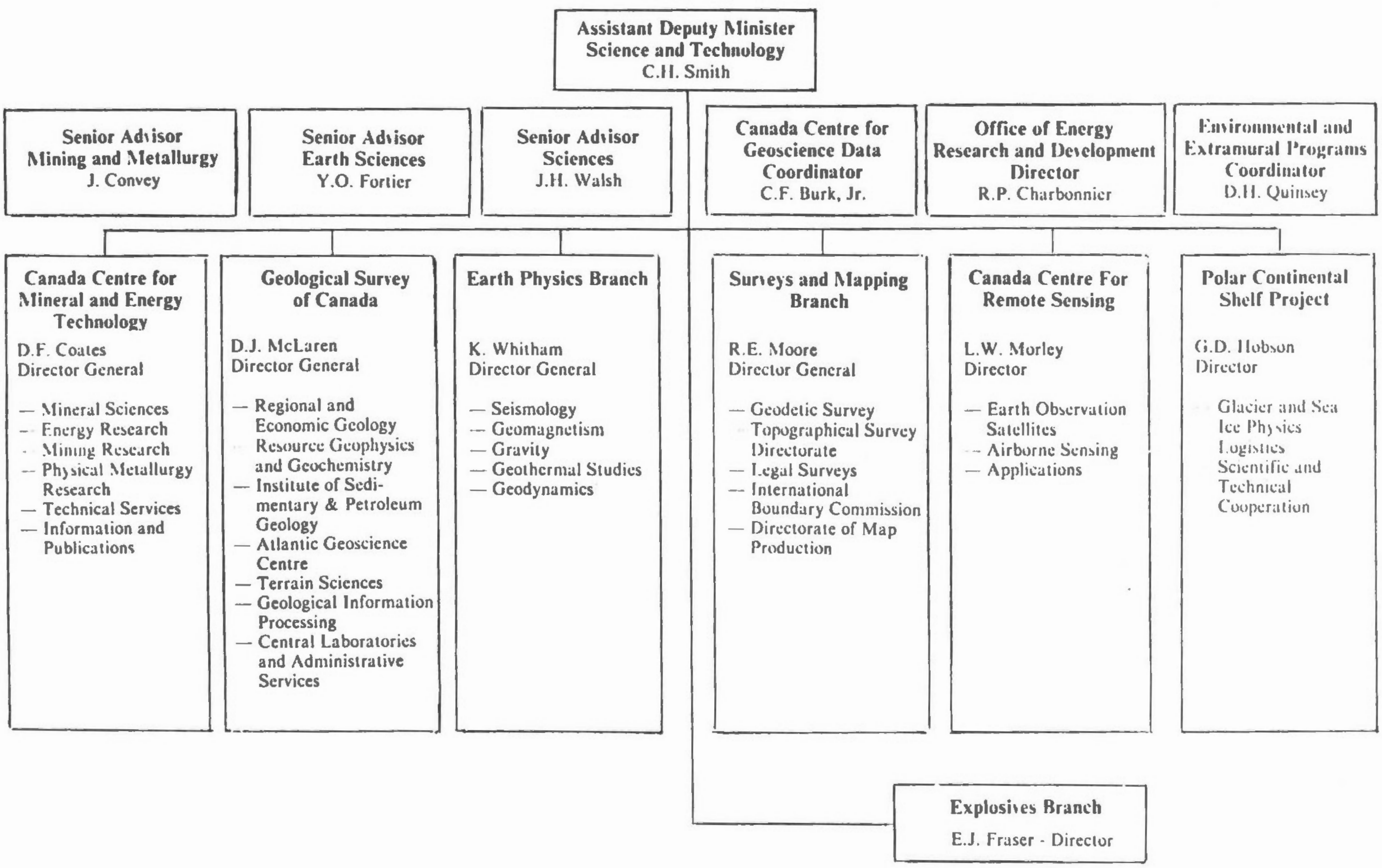
Organization chart of the Mines Branch, 1972



Organization chart of the Department of Energy, Mines and Resources, 1974-75 energy source was removed in 1971 and was transferred to the new Department of the Environment. In 1970, the astronomical and astrophysical staff and facilities, as well as the Time Service, were transferred to the National Research Council and the term "Observatories" was changed to "Earth Physics Branch". In 1971 the Geophysics Division of the GSC, led by Dr. L.W. Morley, was transformed into the Canada Centre for Remote Sensing, with Morley being the director to this date. The present organization chart reflects these changes. The departmental infrastructure has remained stable during the past 5 years, though reorganization in the branches has taken place to meet the challenges of this decade, particularly in the area of energy. The story of Mines Branch leading into "CANMET" will be told in the last chapter of this history.

There have been four ministers in charge since 1966 - Jean-Luc Pépin, J.J. Greene, D.S. Macdonald and A.W. Gillespie (current). There have also been four deputy ministers - C.M. Isbister, 1960 - 70, J. Austin, 1970-75, T. Shoyama, 1975, and G.M. MacNabb, 1975 to date. A position for a senior assistant deputy minister was established in 1971. The first incumbent was Dr. J.M. Harrison who served until 1972 when he retired from public service. His place was taken by Gordon MacNabb, who served until 1975. The present incumbent is Dr. C.H. Smith. The assistant deputy ministers of the Science and Technology Sector, which embraces CANMET, the Explosives Branch, the Geological Survey of Canada, etc. have been in turn Dr. J.M. Harrison, 1966-71; Dr. C.H. Smith, 1971-75, and Dr. J.D. Keys, 1975 to date.

Organization of the Science and Technology Sector



Organization chart of the Science and Technology Sector of the Department of Energy, Mines and Resources, 1974-75

Dr. Eugene Haanel - first head of the Mines Branch

CHAPTER 3

PART I - THE EARLY DAYS, 1901-1907

DEPARTMENT OF THE INTERIOR

EUGENE HAANEL - FIRST HEAD OF THE MINES BRANCH

Separation of the future Mines Branch from the Geological Survey of Canada, its parent organization, and launching of a new government venture under the watchful and critical eyes of both industry and bureaucracy required at its head a person of knowledge and determination. Clifford Sifton, then Minister of the Department of the Interior, and later knighted, selected Eugene Emil Felix Richard Haanel largely through the competence of his teaching and organizational capabilities at Victoria University where he was professor of Natural Sciences from 1873. Sifton was one of Haanel's early pupils.

C. Sifton

Dr. Haanel's entire career reflects an ambitious, capable and energetic character. He was born in 1841 in Breslau, Germany, now Wroclaw, Poland, in Upper-Silesia. He showed his independent spirit when at the age of 15, after attending Breslau "Gymnasium", he left home because of a disagreement with his father who held an important and influential government position. It will be recalled that in the latter part of the eighteenth century, Poland was divided by Russia, Germany and Austria. Young Haanel must have been imbued with a liberal outlook and a sense of adventure that influenced him to emigrate to North America. He stowed away in a packing-case in Hamburg, making the journey to the United States by sailing ship as a deck boy. He spent several years working in the southern States at tasks both menial, as a labourer, and intellectual, as a surveyor's apprentice. He returned to Germany for a short sojourn with his family before the American Civil War in which he was later involved on the Union side. He left the army with the rank of 1st Lieutenant after four years, at the age of 23. At President Lincoln's funeral he was one of the honour guards. After the war, Haanel travelled north to Michigan, where he was befriended by a Methodist minister, Benjamin Franklin Cocker, who later became Professor of Philosophy at the University of Michigan. Haanel was influenced by Cocker to follow a scholastic career, and through the latter's help, received an appointment to teach languages at Hillsdale College. Later he taught science at Albion College. The latter assignment was indeed difficult as his prior education was not technical. He applied himself with zeal, learning and teaching, but this resulted in overwork and illness. He was persuaded to return to Germany, ostensibly to be amongst his own people in case he did not survive. However, the ocean voyage and good care of a physician in Germany restored his health. He then decided to take a science course at the University of Breslau where he defended a thesis entitled "A galvanometric method for the determination of the earth's magnetism and its oscillations", for which he was awarded a doctoral degree at the age of 31. He returned to the United States for a short time.

In 1873 he was invited to Victoria University, Cobourg, Ontario, to establish a course in natural sciences. The first locale for his department was an unused barn at the back of the only university building. He proved to be a good and eloquent teacher, attracting many students from various parts of Canada. Through his efforts the Faraday Hall was built, reputed to be the first university building erected specifically for science in Canada. In 1889, when a move to affiliate Victoria University with the University of Toronto was proposed, he resigned. The Ontario Minister of Education, Sir George Ross, offered him the Chair of Chemistry and Mineralogy at the University of Toronto but he declined, accepting the professorship of physics at Syracuse University, New York State. His roots in Canada had by now become deep and he did not leave without hesitation. However, he was opposed to the Victoria University with its association with the Methodist Church being moved to Toronto, because in his view it would suffer from this change. Haanel found that the teaching of sciences at Syracuse was neglected. Once again his energy was directed to establishing laboratories and organizing science courses. During this time the Esther Baker Steele Hall of Physics was erected.

In 1900, Clifford Sifton visited Eugene Haanel in Syracuse and persuaded him to come to Ottawa to organize the future Mines Branch. In the following year, Dr. Haanel with his family took up abode in Ottawa.

Eugene Haanel was married in 1868 to Julia Frances Darling, daughter of United States Senator, The Honourable Henry D. Darling of Lakeridge, Michigan. They had five daughters and two sons. Their daughter Grace was later married to Dr. C.T. Bowles of Ottawa and their sons Kenneth and Jeffrey served the Mines Branch in later years. Dr. Haanel's eldest son, Benjamin Franklin, no doubt named after Dr. Cocker, was appointed chief of the Division of Fuels of the Mines Branch, which he served for nearly 42 years.

The foregoing biographical sketch reveals the ability and drive of Eugene Haanel. The fact that he was able to master the physical sciences and then teach them well and at the same time demonstrate his organizational skills after an early classical school education and an interregnum with a varied and difficult life on a new continent, speaking a different language from his own, bespeaks of his exceptional ability. These qualities must have been recognized by Clifford Sifton in attracting Eugene Haanel to the public service of Canada when he was already aged 60. Some critics suggested that the intimacy between the two men possibly allowed Haanel to aspire to higher positions than superintendent of mines in the Department of the Interior and the director of Mines Branch in the Department of Mines. Perhaps Dr. Haanel was demanding with his colleagues and associates. Whatever were his traits or initial disappointments with the public service, he proved in his 19 years of service in the two departments to be a leader of men as well as a good organizer. The achievements will be noted from the recitation of the history of the period in this chapter.

Dr. Haanel in his new appointment had to start from scratch. He entered the department in a position created for him with no specific budget or staff. For the next six years he had to build an organization within the central structure of the department in the face of expectations from the minister who hired him and the mining industry. Furthermore, he had to overcome the natural resentments of a large and "autonomous" department of the Geological Survey whose members, particularly those of the mines section, would consider him to be a competitor. There was competition between that section of the GSC and the fledgling group, particularly in the area of reports on mineral commodities, but there was also cooperation between these two groups as will be seen later. This friction was largely dissipated by creation of the Department of Mines in 1907.

On appointment in 1901 Eugene Haanel was given an office, possibly in the Langevin Block on Wellington St. to be close to Sifton, and Jessie Orme as secretary. Though his first project was concerned with gold mining in the Yukon he wasted little time before he embarked on a broad evaluation of the Canadian mining industry and its technical problems. His aim was to obtain as quickly as possible a review, a "state of the art", of Canadian mining and processing so the role that the various minerals could play in the economics of the regions and the country could be evaluated. It soon became clear that processing of minerals would be the principal problem. In succeeding years mineral commodities dominated the Mines Branch programs.

Langevin Block, Wellington Street, Ottawa

GOLD

The first task to which Dr. Haanel addressed himself on joining the Department of the Interior on June 5, 1901, was to complete installation of the Dominion of Canada Assay Office. This occupied rented premises on Hastings Street in Vancouver and opened its doors on July 26, 1901. J.A. Smart, deputy minister of the department, in his 1901 annual report referring to Eugene Haanel's appointment, mentioned the help he had given the department. In a matter of a few months the necessary equipment was purchased and installed, premises rented and a staff of five hired. This was essentially a bullion laboratory intended to encourage Yukon gold producers make their sales through Canada rather than through Seattle or San Francisco. The British Columbia producers dealt with the assay office to a fuller extent. Receipts of gold bullion varied considerably over the life of the assay office. In approximate figures - 70,000 ounces were received in 1901; following a decline, deposits for nine months in 1908 rose to 90,000 ounces; during World War I they rose to a peak of 240,000 ounces in 1918 and then declined again. It should be remembered that Canada possessed no Mint until 1908 and there were no gold refineries in Canada when the Vancouver assay office started. As a matter of interest, the approximate gold production in fine ounces by province in 1900 when the Yukon peaked at one million ounces and subsequently in 1922 when Ontario first reached that level is shown below.

Canadian gold production (fine ounces)

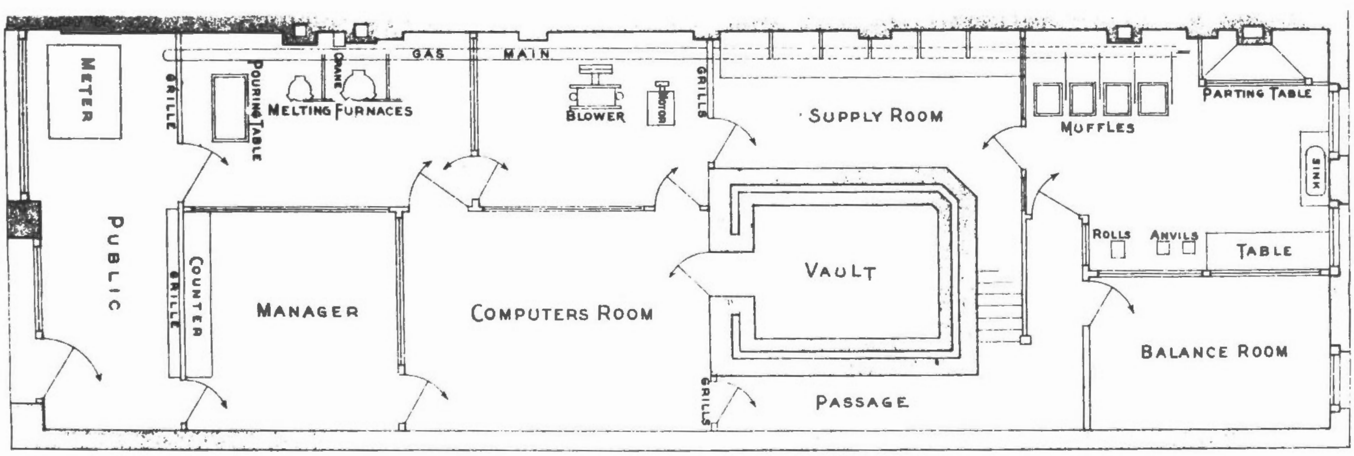
1900		1922	
Yukon	1,000,000	Yukon	73,000
British Columbia	229,000	British Columbia	207,000
Alberta	240	Ontario	1,000,000
Ontario	14,000	Nova Scotia	1,100
Quebec (1901)	145		
Nova Scotia	29,000		

Note: Alberta and Quebec had very small or negligible production in 1922.

The staff at the new Dominion of Canada Assay Office was composed of a manager, two assayers, a melter and a janitor. The first manager was Thomas McCaffrey and the melter, George Middleton, who in 1907 until his death in 1925 became the second manager. G.N. Ford joined the office as computer and book-keeper in 1909 and became manager in 1926. During Haanel's period of service there were one or two additions to the staff and he proposed that a special building be erected for the assay office. This was never done but the office was moved in July 1910 to the Public (Federal) Building at the corner of Pender and Granville Streets. Dr. Haanel gave considerable prominence in the early Department of the Interior reports to operations of the office, as the assay office employees for the first few years represented the largest proportion of staff employed by the fledgling Mines Branch. The office was transferred to the Department of Finance on January 1, 1933.

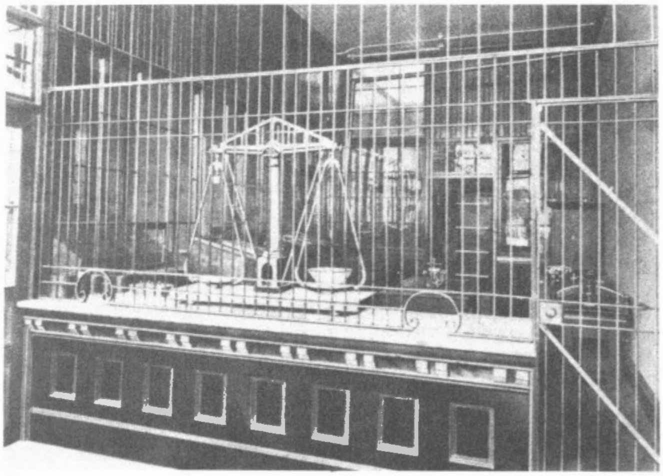
Eugene Haanel visited the Yukon in 1901, and Report No. 1 of the Mines Branch (MB Rep 1) on the mining conditions in the Yukon was published in 1903. He established contact with the Department of the Interior mining engineer A.J. Baudette stationed in Dawson. Baudette's reports were reproduced in Haanel's annual reports to the minister for the years 1902-3, 1903-4 and 1904-5.

Dominion of Canada Assay Office, corner of Granville and Pender Streets, Vancouver, B.C.



FIRST FLOOR

Floor plan of assay office, Vancouver



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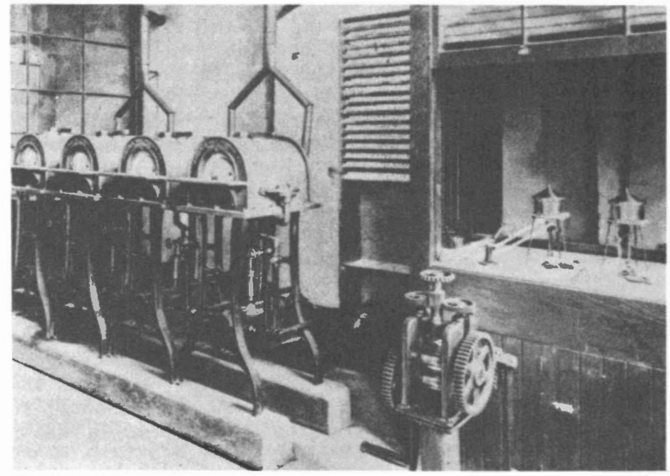


2

Vancouver Assay Office: 1 - Receiving and weighing room; 2 - Muffler room

IRON

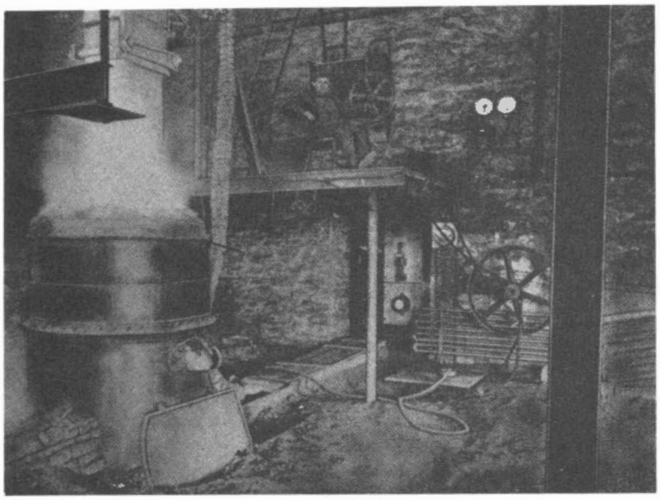
A second commodity that received Haanel's keen attention was Canadian iron ore, particularly in Ontario, Quebec, and the Maritimes. In his second report, dated 1903 to the minister for the two-year period from June 16, 1901 to June 30, 1903, he pointed out that most of the iron ore deposits in Canada were of a magnetic character and lent themselves to exploration and delineation by magnetometers (6). He prepared a report which explained the theory and practice of magnetometric surveying based principally on Swedish experience (MB Rep 5, 1904). This report was published in 1904 and was presented in condensed form at the Canadian Mining Institute annual meeting in March 1903.

In his third report for the fiscal year 1903-4 (Pt VIII, p. 5), Haanel drew the minister's attention to the large importation of ore and iron and steel products valued at $53 million during the same fiscal year (7). In the absence of cheap carbon but with a potential abundance of hydroelectric resources in central provinces, he proposed the investigation of Swedish or other electric smelting processes aimed eventually at continuous steel production. For resource investigation he hired in 1902, Eric Nyström, a Swedish engineer with a double degree in Mechanical and Mining Engineering who had field experience in Sweden and Sudbury with magnetic surveying. In the summer of 1903, he joined Dr. A.E. Barlow of the Geological Survey, well known for his work in the Sudbury Basin, in surveying and delineating the iron ore occurrences in the Lake Timagami region of northern Ontario. During the summer of 1904, Nyström examined an iron ore deposit in Charlotte County, New Brunswick and conducted a magnetic survey at the Calabogie mine, Renfrew County, Ontario. In the summer of 1905, B.F. Haanel, who was hired as a temporary employee, made a magnetic survey of a deposit in Leeds County, Quebec, and of the Wilborn mine, Lanark County, Ontario, as well as of the Belmont mine, Peterborough County, Ontario. Some of these surveys were carried out at the request of the owners of the properties. Haanel justified this activity in the phrase: "... since it is one of the functions of the Government to assist in the development of the country's resources by doing a class of work which owners of properties cannot do for themselves ..." (8); there is evidence that some of these requests came from the minister's office. A third employee, Einar Lindeman, conducted magnetic surveys during the summers of 1905 and 1906 in Ontario along the Kingston-Pembroke railroad that showed little promise in iron ore resource, and at Austinbrook, Gloucester County, New Brunswick that indicated promising possibilities.

During the summer of 1906, Haanel organized a campaign of systematic investigation of iron ore resources of Canada, selecting three areas and engaging three consultants for this work as follows: for Nova Scotia, Dr. J.E. Woodman, professor of geology at Dalhousie University; for Western Ontario, F. Hille, mining engineer, Port Arthur; for the Ottawa Valley, F. Cirkel, mining engineer from Montreal. These investigations were referred to in the 1906-7 annual report of the Department of the Interior and as separate reports (MB Rep 20, 22 and 23) published in 1909, 1908, and 1909 respectively. Investigations of iron ore resources in reasonably accessible areas were continued by the Mines Branch staff after the formation of the Department of Mines.

On the processing end, Haanel organized a "Commission" consisting of himself, E. Nyström, designer, C.E. Brown, electrical engineer, F.W. Harbord, metallurgist from the U.K., and D. Coté as secretary to visit Sweden, France and Italy from January 21 to April 16, 1904 to examine electrothermic processes. A report was published the same year under Haanel's authorship that had wide circulation not only in Canada but also abroad (9).

In January 1906, Haanel organized a test program at the Lake Superior Corporation, Sault Ste. Marie, Ontario plant by conducting experiments in an electric furnace designed by Dr. Heroult. The tests were carried out on a shift basis for about two months with a staff of four engineers not counting Dr. Haanel or Dr. Heroult. Two of these were E. Nyström and B.F. Haanel. During this campaign 150 casts were made yielding about 55 tons of pig iron from eight samples of which five were magnetite and one each of hematite,



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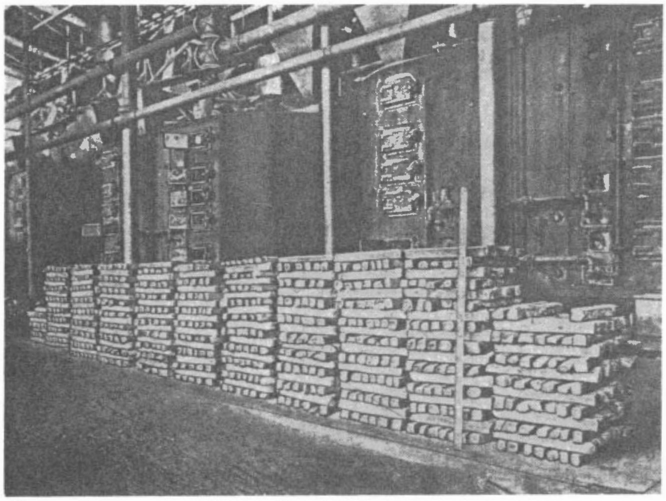


2

1 - Electric furnace showing measuring instruments and method of regulating electrode, Sault Ste. Marie, Ontario; 2 - pig iron produced during government experiments

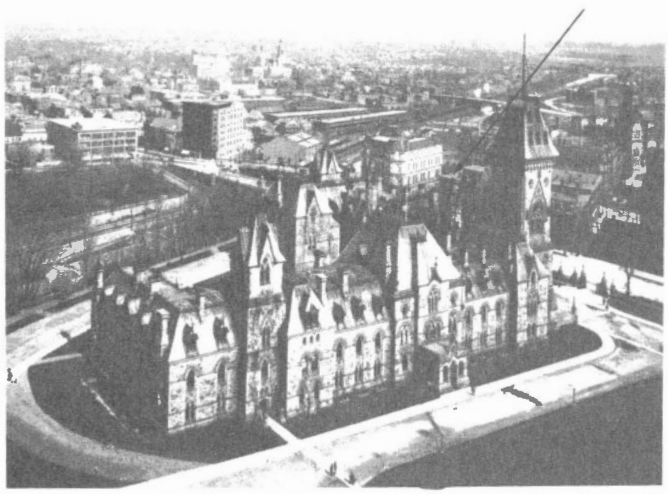
roasted pyrrhotite, and titaniferous iron ore. The experiments demonstrated that:

(1) Canadian magnetite ores can be as economically smelted as hematites.
(2) Ores of high sulphur content can be made into pig iron containing negligible amounts of sulphur.
(3) The silicon content can be varied as required for the class of pig to be produced.
(4) Charcoal, which can be cheaply produced from mill refuse or wood which could not otherwise be utilized, and peat-coke, can be substituted for coke without being briquetted with the ore.
(5) Ferronickel pig, practically free from sulphur and of fine quality, can be produced from roasted nickeliferous pyrrhotite.
(6) Titaniferous iron ores can be successfully treated; this conclusion is based on an experiment with an ore containing 17.82% titanic acid yielding a pig iron of good quality.

The results were published in a preliminary report in 1906 and in a final report in 1907 (10). Furthermore, in the annual report for 1905-6 the results were given for the experimental production of ferronickel pig obtained by the Lake Superior Corporation subsequent to the Mines Branch tests. Apparently there was little interest shown by the Canadian ferrous industry in this program. However, in his annual reports Haanel continued to draw the minister's attention to the various developments in the electrothermic reduction of ores.

In judging Eugene Haanel's considerable effort in evaluating Canadian iron ores and their electrothermic processing, it should be remembered that in the period under review the scale of possible operation was small and technology was limited. In fact, the present large-scale mining and metallurgical operations cannot be compared with that period. Haanel was certainly ahead of his time in electrothermic smelting.

When the iron program was started, Haanel and his small staff seemingly were located in premises at 193 Sparks Street, Ottawa. This probably took place during the fiscal year 1903-4 when the name Mines Branch appeared for the first time in print (Chapter 2). A laboratory was set up to train members of the staff in the use of magnetometers and in interpreting results. It was found that the electric cables running parallel to the rooms in Sparks Street caused heavy fluctuating currents producing a rapidly varying magnetic field and preventing the needle of the magnetometer from coming to rest. In 1905, new premises were rented in the Thistle Chambers at 26 Wellington Street where the laboratory and the director's office were moved. The Sparks Street office was retained for preparation of maps and storage and distribution of reports.



Thistle Chambers, 26 Wellington St., Ottawa, circa 1905 (Public Archives of Canada)

PEAT

Haanel's initial interest in fuel was apparently centred around the problem of providing a reducing agent for metallurgical processing related to his ideas on electro-thermic reduction of iron ores.

In the 1903-4 annual report, the director noted that Canada spent nearly $21,000,000 on the importation of coal and coke. He refers to the vast peat bogs of Ontario and Quebec and to the strides made in Europe in the use of peat because of the increasing cost of coal, describing developments in Holland, Germany, Sweden and Russia. Haanel used the opportunity of a visit to Europe by the commission investigating electrothermic iron smelting processes to attend the Berlin peat industry exhibition in February 1904. Here he was briefed on all forms of peat including briquettes and coke as well as on harvesting and processing equipment.

BASE METALS

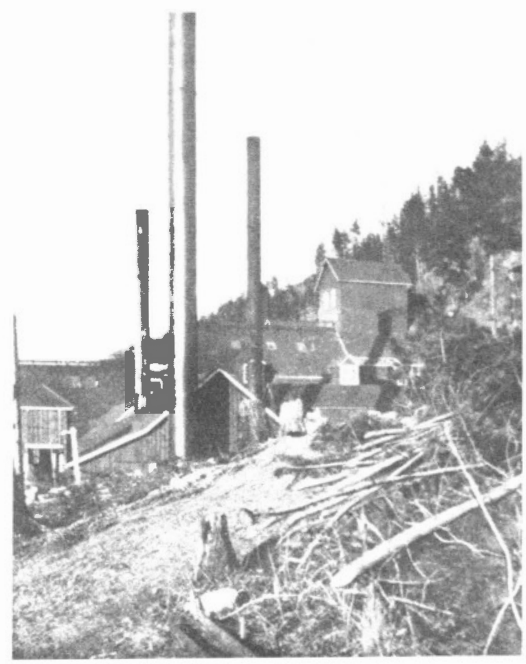
The first recorded interest in base metals by Haanel appears to have been in connection with his visit to the Yukon in 1902. Appendix 1 of the 1901-2 annual report gave a brief account of a visit to copper mines at the development stage, located a few miles to the west and southwest of Whitehorse. He included remarks on deposits of anthracitic and low-volatile or non-coking coals lying about 18 miles to the southwest of Whitehorse in which the Yukon and White Pass Railway was then interested for their own locomotives and ships. In this connection, he also mentioned the development of a market to replace the fast depleting timber resources, particularly in the vicinity of Dawson and in the Klondike district, as well as the then expected demand coming from smelting of copper ores.

In 1905, in response to a petition from the Silver-Lead Association and associated Boards of Trade of B.C., Haanel formed a commission with a chief of staff, W.R. Ingalls, editor of the Engineering Mining Journal, and two field engineers, Phillip Argall of Denver, Colorado, and A.C. Gardé of Nelson, B.C. Henry E. Wood of Denver, Colorado, was another member whose task was to determine the amenability of B.C. ores to magnetic, electrostatic and other forms of concentration. The commission was assisted by Dr. A.E. Barlow and J. Keele, who were seconded from the Geological Survey for investigating certain undeveloped deposits and prospects.

The apparent reasons for the enquiry may be summarized as follows:

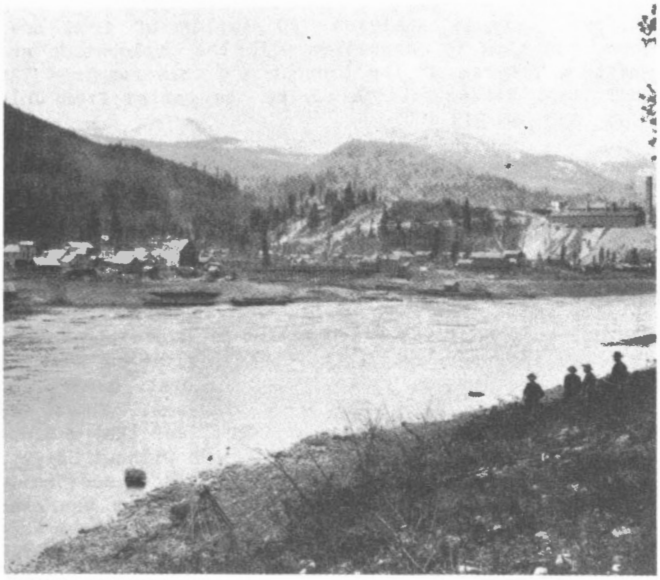
(1) the early practice of discarding zinc residues from the treatment of silver-lead-zinc ores of B.C., particularly of the West Kootenay district
(2) a penalty imposed by lead custom smelters on mixed lead-zinc concentrates when the zinc content exceeded 10%
(3) the increasing demand for zinc (spelter) in the last part of the 19th century
(4) the replacement of galena-blende (Pb-Zn) ores by blende at depth
(5) the desire for complete processing including smelting of lead-zinc ores in Canada.

Concentrator and smelter at Pilot Bay, B.C., circa 1905, treating crude ore from Bell mine

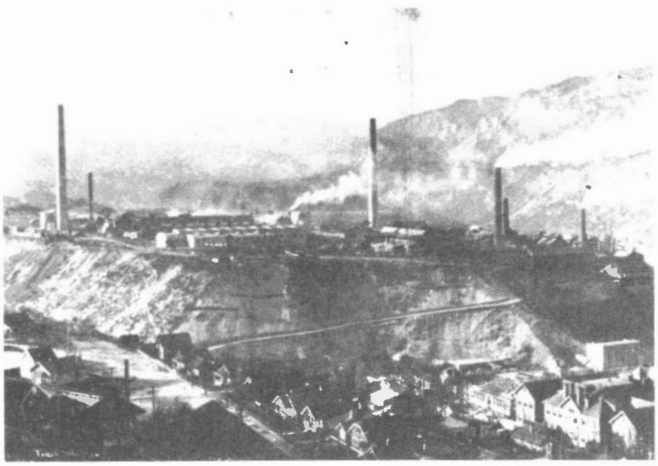


Boiler house, Sullivan mine, B.C., circa 1905

The report of the commission containing 399 pages is a good reference on all the lead and zinc mines and prospects of that period in B.C., and includes data on milling, smelting and national and international economics of zinc production (11). The concentration tests with magnetic and electrostatic separators were carried out at Denver, Colorado and the flotation tests by W.R. Ingalls in New York, all being described in the report. Raising the zinc content of concentrates to



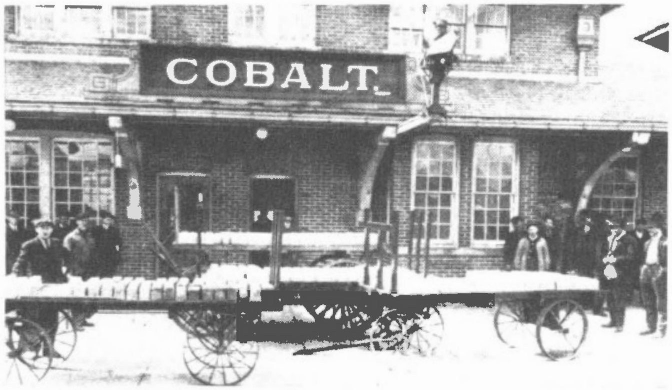
Trail Creek, B.C. in late nineties
(CMJ "Sixty years of Canadian Mining" Nov. 1939)



Trail smelter in 1928 (CMJ, Aug. 1929)

acceptable smelter levels was judged to be most successful by magnetic separation. Tests on flotation showed some promise but the sharp separation that yielded the desired results at mines such as Sullivan came into fruition only a decade later when differential flotation of lead and zinc was perfected.

In 1906, at the request of the minister, Dr. Haanel visited the Cobalt mining camp in northern Ontario as well as the U.S. where the complex ore was smelted. The purpose of the visit was to ascertain the existing position and future prospects of this community. He found that only silver was recovered and sold and that there was little or no demand for the cobalt. Mines Branch Report 17, "Report on the present and prospective output of the mines of the silver-cobalt ores of the Cobalt district" was published in 1907.



Silver bullion awaiting shipment at Cobalt, Ontario (CMJ, Aug. 1929)

INDUSTRIAL MINERALS

In his 1903-4 annual report to the minister, Dr. Haanel stated: "The Mines Branch has undertaken the publication of a series of reports on the economic minerals of Canada to bring the mineral wealth of Canada prominently before the investing public and thus aid in bringing capital into the country necessary for the development of its resources".

"While due consideration will be given in these publications to the geological features of occurrences of the different economic minerals, special attention will be paid to those topics which are of interest to the mining engineer and to those commercially interested" (12).

For these studies he hired consultants. Thus in 1904 he had J. Walter Wells (who was chief assayer in the Dominion Assay Office, Vancouver, for a period of seven months, resigning in April 1904 for reasons of health) spend three months in the field in Manitoba assessing: (a) the raw material resources for cement manufacture, (b) the industrial value of shales and clays, and (c) the occurrence of limestones and the lime industry. All three items were the subjects of three preliminary reports (MB Rep 7,8,9) published in 1905. These studies were undertaken primarily because of the high cost of construction lumber and were extended to cover raw materials for the manufacture of brick, tile, etc., and to other building materials. A survey of the lignite occurrences in the Pembina River Valley as a source of fuel for the kilns was also carried out but the results were disappointing.

In the same year, 1904, F. Cirkel, the Montreal mining engineer, was engaged to prepare reports on mica (MB Rep 10) and asbestos (MB Rep 11) - their occurrences, exploitation, and uses. The reports were published in 1905. Haanel reported that by 1906 the supply of these publications was almost exhausted.

A monograph on graphite was also prepared by the same author and published in 1905 (MB Rep 18). This was a tome of 307 pages profusely illustrated with nine maps. It should be noted that Haanel encouraged the generous use of illustrations for all these reports and monographs. This monograph on graphite was soon out of print and a new publication by H.S. Spence appeared in 1920.

General

From the foregoing review, commencing with the appointment of Haanel to the Department of the Interior on June 5, 1901 and ending on May 15, 1907 when the Mines Branch was transferred to the Department of Mines, it is possible to draw some conclusions from his direction of the research and development work in the newly formed organization. Aside from an initial concentration on the Yukon and the gold industry undoubtedly inspired by the Minister, his main thrusts were concerned with creating an information base and encouraging an integrated iron and steel industry in more populated areas, principally in southern Ontario and Quebec. He no doubt thought in the classical way that industrialization is normally based on a domestic supply of iron and energy. It should be noted that the young iron and steel industry in this period was importing a large proportion of its iron ore requirements and that there were no sources of fossil fuels in the central provinces of Ontario and Quebec. On the other hand, there were large potential hydroelectric resources. This prompted the director to concentrate on iron ore exploration and on an investigation of electric reduction of ores. He also found time to pay some attention to other mineral commodities that promised application in rapidly developing Canadian industries such as construction and electrical engineering.

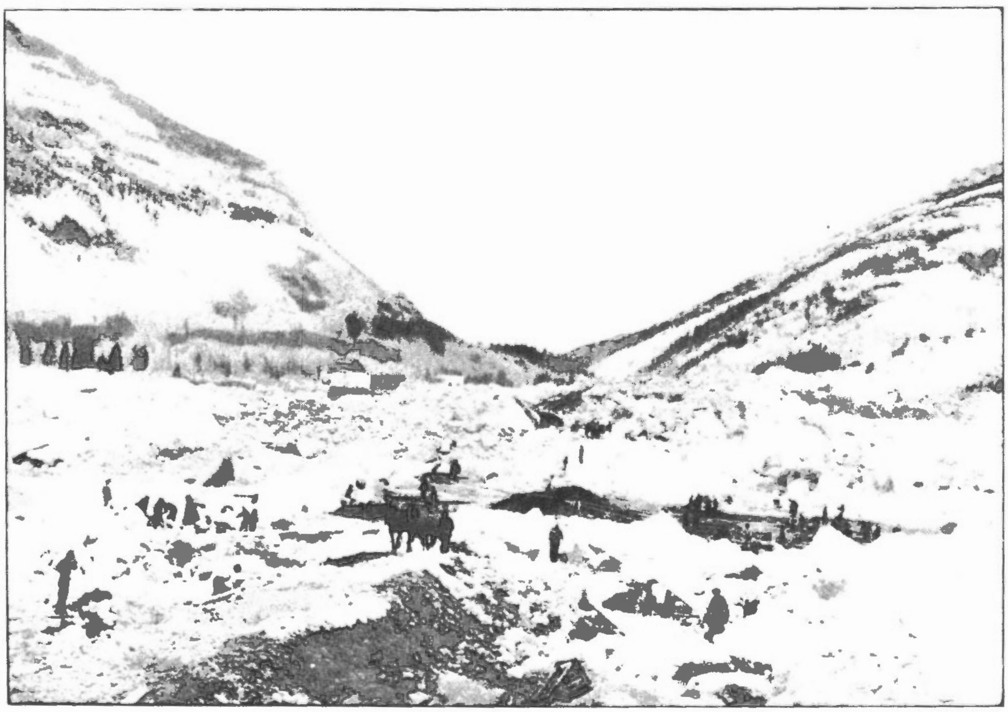
There was seemingly some competition and overlap of responsibilities with the Geological Survey but there was also cooperation. Dr. Barlow assisted in the iron ore projects in Ontario and in the base metal work in British Columbia. Dr. R.G. McConnell and Dr. R.W. Brock prepared a report on the Frank landslide disaster of 1902 (MB Rep 2, 1903). The director of the Geological Survey permitted H.A. Leverin, the first chemist to be hired by Mines Branch, July 1, 1906, to share the laboratory of M.F. Connor of the Geological Survey. Leverin analyzed 120 samples of iron ore, iron, and slag in connection with the exploration and smelting program of the branch, and this required 739 individual determinations during the period from July 1906 to March 31, 1907.

It is probably fair to suggest that the director was eager to "catch the speaker's eye", so to speak, by including (in the texts or appendices) of his annual reports descriptions of new metallurgical mineral-oriented chemical processes. He gave a detailed account in the 1905-6 annual report of the discussions at the 1904 American Mining Congress in Portland, Oregon, on the proposed Department of Mines and Mining in the U.S.A., possibly because the invitation from the Congress was sent to the Governor-General. Haanel and Barlow were the Canadian representatives. There may have been a desire on Haanel's part to see that a similar department be established in Canada without delay. However, all the foregoing activities also demonstrated a remarkable determination and vigour for a man over 60 years of age. All the considerable achievements were made with a very small "resident" staff and a few consultants.

When transfer to the Department of Mines eventuated on May 15, 1907, excluding staff of the Dominion Assay Office in Vancouver, there were the following:

Dr. E. Haanel - superintendent of mines, permanent
E. Nyström - mining engineer, permanent (resigned on March 31, 1909 to return to Sweden)
E. Lindeman, B.F. Haanel - mining engineers, temporary staff
H.A. Leverin - chemist, temporary staff
H. Roger - laboratory assistant, temporary staff
Miss J. Orme - steno-typist, temporary staff
A.F. Purcell - messenger, temporary staff

The Frank slide, 1902 showing the town of Frank before the slide and a similar view after (Canadian Mining Review, 1903)



PART II - THE BUILD-UP

DEPARTMENT OF MINES, 1907-1920 - WORLD WAR I

Dr. Haanel was appointed director of the Mines Branch by Order in Council of May 28, 1907. The appointment was retroactive to May 1, 1907. He remained in the Thistle Chambers, on Wellington Street, Ottawa from 1905 to 1912, when he moved to the renovated Geological Survey Building at the corner of George and Sussex Streets, after the Geological Survey transferred to the Victoria Memorial Museum. He occupied this office until his retirement in 1920.

By Order in Council of June 19, 1907, the statistics group of the Geological Survey Mines Section, comprising John McLeish, Mrs. W. Sparks and Miss G.C. MacGregor, were assigned to the Mines Branch. By Order in Council of November 29, 1907, the chemistry laboratory of the Geological Survey that included T. Denis, F.G. Wait, M.F. Connor and W.W. Leach, the latter returning to the GSC in June 1909, was also transferred.

Eugene Haanel in office at Sussex Street, Ottawa

Organization of Mines Branch

Mines Branch staff was built up in the next six years at a much faster rate than in the period 1901-07. Thus at the formation of the Department of Mines in 1907 there were 15 "inside service" employees including 7 transferred and 8 "outside service" in the Vancouver assay office for a total of 23; by 1913 employees numbered 48 and by 1920 the total staff amounted to 98. The proportion of professionals varied as the staff was built up; in 1921 professionals represented about a third of the total.

For the first three years, 1907-10, there was no formal infrastructure except for the division of Mineral Resources and Statistics, whose chief was John McLeish. The division changed names in the transfer from the Geological Survey from the Division of Mineral Statistics and Mines, founded in 1886 and popularly known as the Mines Section. Historically, the division can be regarded as the first division of the Mines Branch and it remained with the branch until 1956.

The 1911 summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1911 (1911 Sum Rep) indicates by means of the classified staff allocation the organization of the branch into an administrative and eight technical divisions for the "inside" service as follows:

Administration:
Director of the Mines Branch - Eugene Haanel
Secretary - Jessie Orme
Filing clerk - W. Vincent
Mailing and distribution clerk - G. Simpson
Technical "typewriter" - Miss B. Russell
Typewriter - Miss I. McLeish, Miss W. Westman
Messengers - A.E. Purcell, A.A. Ellement

Division of Mineral Resources and Statistics:
Chief of division - John McLeish
Assistant engineer - C.T. Cartwright
Assistant - J. Casey, Mrs. W. Sparks, Miss G.C. MacGregor
Typerwriter - B. Davidson

*Division of Fuels and Fuel Testing:
Chief of division - B.F. Haanel
Technical engineer - J. Blizard
Chemist - E. Stansfield
Assistant engineer - A.H.A. Robinson

*Division of Chemistry:
Chief of division - F.G. Wait
Assistant chemist - M.F. Connor, H.A. Leverin

*Ore Dressing and Metallurgical Division:
Chief of division - G.C. Mackenzie
Assistant engineer - F. Ransom

**Division of Metalliferous Deposits:
Chief of division - Dr. A.W.G. Wilson
Assistant engineer - E. Lindeman

**Division of Non-Metalliferous Deposits:
Chief of division - H. Fréchette
Assistant engineer - L.H. Cole, H.S. de Schmid

Explosives Division:
J.G.S. Hudson.
Note: This division was to be fully organized on the passage of the proposed Explosives Bill.

Draughting Division:
Chief draughtsman - H.E. Baine
Assistant draughtsman L.H.S. Pereira, A. Pereira

*Laboratory division
**The word "deposits" was interchangeable with "mines"

<u>Outside Service, Dominion of Canada Assay Office, Vancouver, B.C.:</u>
Manager - G.E. Middleton
Chief assayer - J.B. Farquhar
Chief melter - D. Robinson
Assistant assayer - A. Kaye
Computer - G.N. Ford
Assistant melter and janitor - G.B. Palmer

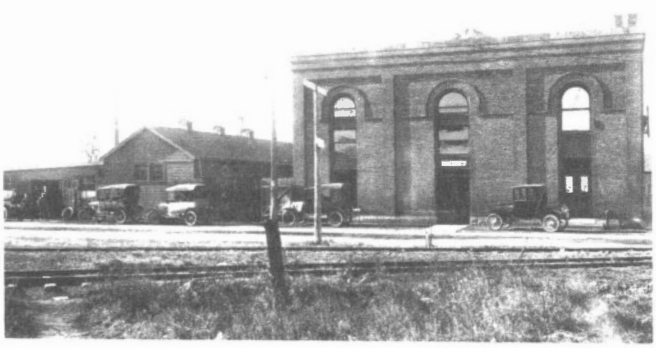
The staff totalled 33 in Ottawa including the director and 6 in Vancouver.

The branch structure was the director's creation, probably requiring only the minister's and deputy minister's assent. Further additions were made during Haanel's service: the Ceramics Division was formed in 1915 and the Road Materials Division in 1916. The latter two were combined in one division in 1922. The Explosives Division ceased to exist as a branch unit in 1916 and became a headquarters unit after World War I when the Explosives Act was passed. The divisions of Metalliferous and Nonmetalliferous Deposits were discontinued in 1921.

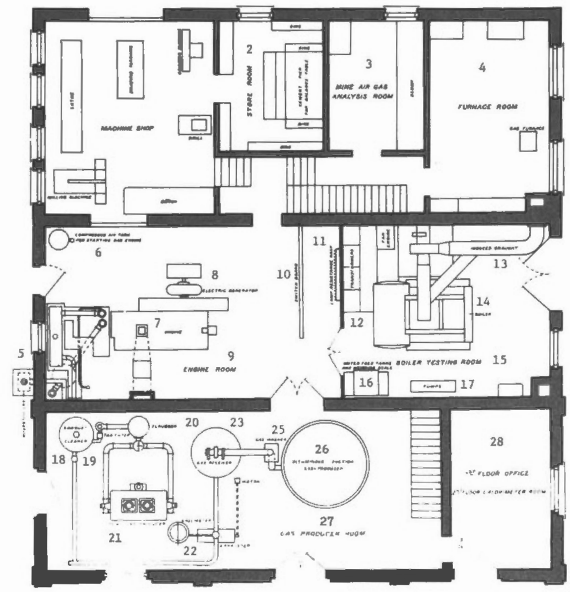
The listing of all classified (permanent) staff was given in the introductory section of the Mines Branch summary reports from 1911-1916 inclusive. Degrees were appended to the names in these lists, tables of contents, and in individual reports, possibly to publicize the qualifications of the staff inside and outside the government, in the former case to demonstrate the implementation of Sections 10 and 11 of the 1907 Act, relating to the technical officer category. Haanel encouraged the staff by giving prominence to their work by the individual reports under their names with the highlights in his introductory section of the annual summary reports. He allowed the use of separate letterheads of individual divisions. He used the accepted style of the day "Sir .... Your obedient servant" in letters of transmittal, in the annual report to the deputy minister, and in official correspondence within the department. The listing of staff, formal transmitting of letters, etc., ceased after the summary report of 1916.

In addition to the chemistry laboratories that had to exist between 1907 and 1913 in two locations - the Thistle Chambers on Wellington Street and the Geology Building on Sussex Street - a Fuel Testing Laboratory was built in 1909 at the corner of Division Street, now Booth Street, and Dolly Varden Street, until recently Lydia Street. The plant was installed in 1910 and in the same year the experimental magnetic iron ore concentration laboratory was installed in the Fuels Building in a room intended for repairs. In 1910 the Mines Branch had spread to five locations in Ottawa (13):

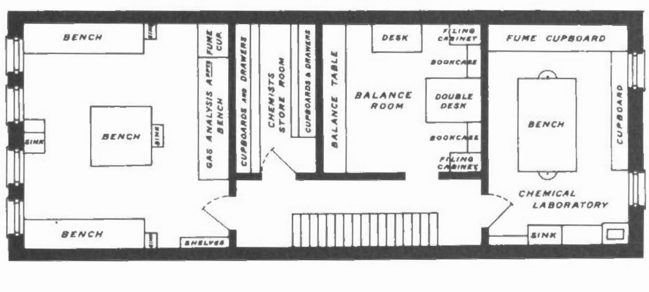
- Thistle Chambers, 26 Wellington Street: Headquarters; director's offices, Mineral Resources and Statistics Division, Explosives Division, General Laboratory (Magnetometric and Chemical)
- Geological Survey Building, Sussex Street: Main Chemical Laboratory
- Division (Booth) Street: Fuels Testing Station and Concentrating Laboratory



Fuel testing station, circa 1909, corner of Division Street (now Booth Street) and Dolly Varden Street (later Lydia Street)



Fuel Testing Station - ground floor: 1. Machine shop, 2. Store room, 3. Mine air gas analysis room, 4. Gas furnace room, 5. Antipulsator, 6. Compressed air tank for starting gas engine, 7. Engine, 8. Electric generator, 9. Engine room, 10. Switch board, 11. Lamp resistance rack, 12. Transformers, 13. Induced draught, 14. Boiler, 15. Boiler testing room, 16. Water feed tanks and weighing scale, 17. Pumps, 18. Sawdust cleaner, 19. Tar filter, 20. Scrubber, 21. Peat gas producer, 22. Gasometer, 23. Gas receiver, 24. Exhauster, 25. Gas washer, 26. Bituminous section gas producer, 27. Gas producer room, 28. Office



Fuel Testing Station - first floor

- 193 Sparks Street: Divisions of Metalliferous and Non-Metalliferous Deposits; Mapping and Drafting Division; storage and distribution of reports
- Victoria Memorial Museum: editor's and accountant's offices.

By 1913, with occupation of the whole of the Geological Survey Building on Sussex Street, and a later addition at the rear of the building, the Branch continued to operate in two locations - Sussex Street and Booth Street for the next 30 years.

The Geological Survey relinquished the Sussex Street building during the winter of 1910 but it took about two years to refurbish this building to accommodate the heavy equipment that the Mines Branch would be employing. L.H. Cole, who at the time of writing was 94, relates that he was involved in the remodelling of the building and he remembers the replacement of oak beams 40 ft long x 12 in. in section with steel beams. The Mines Branch moved in partially in 1912; the two chemistry groups were reunited in 1913.

There was no organized library in the Mines Branch until 1913. Mrs. O.P.R. Ogilvie, wife of a pioneer surveyor known for his work in the last part of the last century in the Yukon and in the Mackenzie area, was appointed on July 26, 1913. She investigated the practice at McGill University and attended a special course on "Library craft" at Columbia University, New York. She then recommended the use of the Dewey decimal system of classification, which is in use to the present day. Mrs. Ogilvie served until 1937. Haanel emphasized on all possible occasions the economic character of Mines Branch work. Thus in the case of the library, he stated "It was deemed advisable to establish a properly equipped reference library of technical books, etc., bearing on the economic work being done by the Mines Branch".

A secretary to the Mines Branch, M.M. Farnham, was appointed in 1913. Miss Orme had been secretary to the director but in all probability was "the boss" of the Administration Office in the early days. Farnham would be considered in present day classification as the administrative officer of the branch and Jessie Orme as private secretary to the director.

It is interesting to note that no departmental report was issued until the fiscal year ending March 31, 1921. Instead "Summary Reports" for the Mines Branch and the Geological Survey were published separately as the only documents outlining in considerable detail the annual technical work of the two branches. The initial report of the Mines Branch related to the fiscal year ending March 31, 1908, and Haanel explained that there were two reasons for not complying with Section 18 of the Mines and Geology Act requiring a summary report for the calendar year, namely - the return of field officers after December 31 and the returns from the Vancouver Assay Office being based on the fiscal year. Haanel corrected the position by issuing a nine-month summary report for 1908 to be coincident with the summary report of the Geological Survey, which was issuing reports by calendar year. Haanel apparently welcomed this change and states in his summary report to Dr. A.P. Low, the deputy minister, that "...the summary reports of both branches, viz, Mines Branch and Geological Survey Branch may be issued simultaneously and under one cover as a combined report of the entire department. The latter plan seems to be both logical and practical and its adoption would doubtless evoke greater interest in the general work of the Department of Mines" (14).

During this period under review the deputy ministers were all drawn from the Geological Survey, and there were staff loans or transfers in addition to those made at the departmental inauguration in the statistics and chemistry areas, such as the loan of Dr. D.D. Cairns who prepared a review on the mineral resources of the Yukon for a report on the mining and metallurgical industries of Canada, a 936-page tome published in 1908 (15). J. Keele, an expert on clays and shales, transferred to the Mines Branch Ceramics Division in 1916 as chief, returning to the Geological Survey in 1921. A joint editorial service was established in 1908. S. Groves was hired by the Mines Branch in March 1908 but was made departmental editor in May 1908.

The reader may be interested in financial data relating to this period of growth of the Mines Branch. The annual financial reports were prepared by the departmental accountant, P.R. Marshall, and two years are quoted, one at the start, 1907-08 and the other at the end, 1920-21, of Haanel's service in the Department of Mines.

The large unexpended balances demonstrated even in these early days that there were annual difficulties experienced by R & D institutions in spending statutory annual allocations without carryovers. In this instance the reason for the larger than normal unexpended balance in 1920-21 fiscal year was due to abnormal resignations in 1919 and 1920 following the World War as was the case in the Geological Survey. It is of interest to note the much smaller proportion of "inhouse" salaries and wages to the total expenditures in this early period of the Mines Branch compared with the pattern of later years.

From the outset in the Department of the Interior period as well as in the Department of Mines period,

Statement of Appropriation and Expenditure by
Mines Branch for the Year Ending March 31, 1908

	Appropriation	Expenditure
Amount Voted by Parliament	$55,000	
Civil Government Salaries		$ 3,991.66
Publication of Reports		246.24
Travelling Expenses		187.30
Beech Pulping Machine		297.57
Publication of Maps		409.22
Investigation re Gas Producers		236.53
Furniture Account		99.83
Investigations re Copper Deposits		30.40
Laboratory		2,161.31
Miscellaneous		338.97
Wages		17,987.25
Instruments		2,020.15
Printing and Stationery		1,045.29
Books and Periodicals		355.17
Investigations re Iron Ores		2,221.48
Investigations re Peat and Coals		1,282.52
Mineral Statistics		900.96
Mining and Metallurgical Industries		4,902.19
Mapping Material		258.32
Balance Unexpended and Lapsed		16,027.64
TOTAL	$55,000	$55,000.00

Funds Available for Work and Expenditure of the Department of Mines for the Fiscal Year Ending March 31, 1921

	Grant	Expenditure
Amounts Voted by Parliament	$429,660.41	
Civil Government Salaries		$102,607.56
Investigation of Peat Fuel Industry		32,415.17
Expenses of Fuel Testing Plant and Laboratory		30,386.97
Expenses of Ore Dressing and Metallurgical Plant		24,116.54
Cost of Living Bonus		21,682.52
Investigations of Ore Deposits and Economic Minerals		18,387.29
Wages of Temporary Employees		14,733.37
Publication of Reports and Maps		9,683.26
Chemical Laboratories		9,670.07
Sundry Printing and Stationery		4,436.19
Miscellaneous		3,246.67
Expenditure Chargeable to Superannuation Fund No. 4, Retirement Act		966.66
TOTAL	$429,660.41	$272,332.27
Unexpended Balance and Lapsed		157,328.14
TOTAL	$429,660.41	$429,660.41

Haanel built up the organization by acquiring in-house staff and resources as well as an expertise from outside sources. If he had relied only on building up the institution, the lead time would have been much longer and correspondingly the accomplishment would have been much smaller. He deliberately formed two non-laboratory divisions, "Metalliferous Mines" and "Non-Metalliferous Mines" divisions providing a core of field men engaged in evaluating Canadian mineral resources who could also participate in the analysis of external contract work done. The program concept was the all-important element in his thinking. There was a similarity, though tenuous, with the "matrix" system now in use in CANMET. The sequence of the narrative that follows reflects the priorities implied by the director during this period in presenting the mineral commodity program.

IRON

Haanel pressed on with field and process studies related to the extensive program on iron ore resources in accessible areas of Canada, previously started in the Department of the Interior.

Occurrences

Staff members involved in this work during Dr. Haanel's time were E. Lindeman, B.F. Haanel, H. Fréchette, G.C. Mackenzie and A.H.A. Robinson (transferred from the Fuels Division in 1913). Some external consultants were used but fewer than under the Department of the Interior and they worked on subjects of widened scope such as on metals for steel-alloying and other special uses. F. Cirkel worked on chrome-iron ore deposits of the Eastern Townships [MB Rep 29 (Engl), 1909; Rep 226 (Fr), 1912]; Professor T.L. Walker of Toronto on Tungsten [MB Rep 25 (Engl), 1909; Rep 156 (Fr), 1913] and molybdenum ores [MB Rep 93, (Engl), 1911; Rep 197 (Fr), 1912]; Professor A.P. Coleman of Toronto on nickel (MB Rep 170, 1913) and Professor J.E. Woodman of Dalhousie University on iron ores (MB Rep 20, 1909) in Nova Scotia.

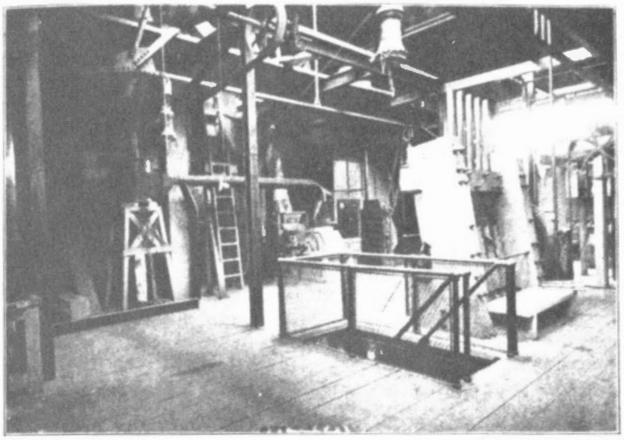
This program was undertaken in part because of the director's concern with the high proportion - about 80% or more - of imported ore used in Canadian blast furnaces. As an example, in 1910, 1,406,668 tons of ore was imported and only 160,290 tons of domestic ore was used. Only about 50% of the coke used was made from Canadian coal at this time. In 1910, the daily blast furnace capacity from 16 furnaces was 2,880 tons of pig iron.

Field studies comprised examination of ore occurrences requiring geological or magnetometric surveys and were largely confined to the same accessible locations in the Maritimes, Quebec and Ontario as were covered in previous years and included the still-producing area of Atikokan. One study by Lindeman was carried out in 1907 on Vancouver and Texada Islands in B.C., in the hope that availability of coking coal on Vancouver Island could lead to blast furnace pig iron production. The magnetometric surveys started to diminish towards the end of World War I and the last two maps were published in 1922. Four maps were published during the Department of the Interior period, and some thirty maps under the Department of Mines. There are preliminary reports on iron ore occurrences, some not progressing to final status, in all summary reports from 1907 to 1920 (except 1918), and there are ten separate reports during the period, the most complete being MB Rep 217 "Iron ore occurrences in Canada" (16).

Processing

Reports indicated that a high proportion of the iron ore occurrences had grades too low for blast furnace acceptance, and this led the director to undertake concentration tests. Arrangements were first made with Queen's University to conduct tests in 1909-10 on a high-sulphur iron ore from Bristol mine in Pontiac County, Quebec, a siliceous ore from Bathurst, New Brunswick, and a copper-nickel ore from the Worthington mine, Ontario. The last was selected with a view to separating copper to make a ferronickel concentrate for conversion to ferronickel pig. The results, which were satisfactory, were reported in a preliminary report in the 1909 summary report and published separately in a bulletin (Bulletin 5, MB Rep 82, 1910). Its author was G.C. Mackenzie, the first ore dressing specialist hired in 1909.

A decision was made to install a wet magnetic separator concentrating unit consisting of a crusher, ball mill and two Gröndal magnetic separators in the newly erected Fuel Testing Building on Booth Street. The installation was completed by the fall of 1910, thus inaugurating the Mines Branch Ore Dressing and Metallurgy Laboratory and becoming a division in 1911. Within two years, a 75-ft x 57-ft, 1-1/2-storey extension was added to the Fuels building to house a diversified ore dressing plant for wet and dry separation with adjuncts that included a chemistry laboratory, workshop, and a warehouse. Later, flotation, roasting and sintering facilities were added. These facilities were made available to the public and a variety of ores was submitted by industry for experimental treatment. Towards the middle of World War I, the emphasis on



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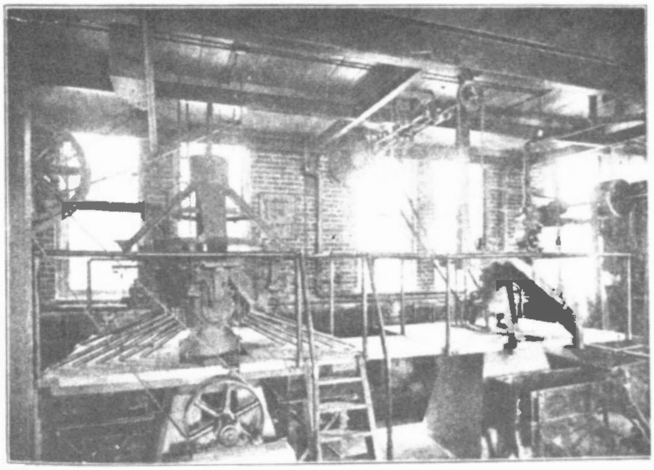

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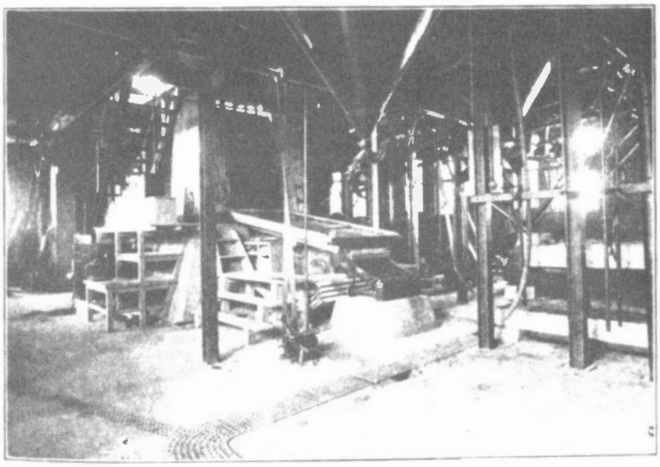

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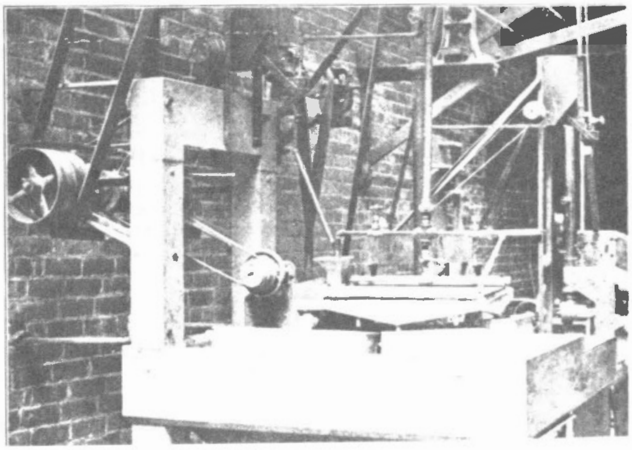

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Mines Branch Ore Dressing and Metallurgy Laboratory, Booth Street, circa 1911. 1 - Huff electrostatic machines, stamp battery, Gröndal cobber; 2 - Ulrich magnetic separator and Richards pulsator jig; 3 - Callow tanks, stamp battery and cyanide zinc boxes; 4 - Wilfley table

beneficiating iron ores waned and was replaced by treatment of ores such as molybdenum, tungsten, etc. Thus in 1916, of 12 ores tested, only one was iron, and four were molybdenum, two were tungsten and one each was zinc, lead, antimony, gold, copper and pyrites. Incidentally, the laboratory or division classified staff consisted in this period of G.C. Mackenzie, chief; H.C. Maybee, W.B. Timm, C.S. Parsons, and R.J. Traill. These last four were appointed in 1911, 1913, 1914 and 1916 respectively. Timm and Parsons became in due course the third and fourth directors of the Mines Branch. It is interesting, in terms of the calibre of the men, to note the first reports they produced. In the case of W.B. Timm, a detailed and illustrated, well written report on the Ore Dressing Laboratory must have been prepared a short time after his appointment and appears in Appendix II of the 1913 summary report. Timm had previous professional experience. C.S. Parsons started in 1912 as a student, worked under George Mackenzie in the evaluation of magnetic iron sands at Natashquan, Quebec, in the lower St. Lawrence area. In 1913 he was in charge of the party which undertook a drilling campaign, and his report is given in the 1913 summary report (p. 90).

G.C. Mackenzie (CMJ, Jan. 1921)

Electric Smelting

Haanel continued to pursue a personal interest in electrometallurgy, particularly in the smelting of iron ores. In the summary reports from 1907 to 1914, the director outlined the progress of electrothermic smelting, giving particulars of specific processes. Thus in the 1907 summary report, he described inter alia the Lash direct steel process at Niagara Falls. The 1908 report described his visit to Domnarfvet, Sweden, where accompanied by B.F. Haanel, he inspected the operation of a shaft furnace invented by Grönwall, Stalhane and Lindblad. He apparently was pleased to note that the recommended modifications for the Heroult furnace in which the Sault Ste. Marie experiments were conducted in 1906 were adopted for this 18-ft high furnace. These modifications were:

(1) top of furnace modified to reduce labour when charging,
(2) provision for utilizing carbon monoxide produced by reduction of ore, including prevention of fuel combustion on top of the furnace,
(3) automatic regulation of electrodes, and
(4) electrodes contained in side chambers and not in the main shaft for preheating and partial reduction in the main shaft.

It appeared that the first country other than Sweden interested in this furnace was Norway. A report was published in 1909 titled "Report on the investigation of an electric shaft furnace, Domnarfvet, Sweden" by Eugene Haanel, (MB Rep 32, 1909).

In the 1909 summary report, Haanel gave a table of electric furnaces used in steelmaking, pointing out that in 1904 there were only four whereas in 1908 there were 46 induction and arc furnaces. He noted that smelting furnaces are still in the experimental stage.

In the 1910 summary report, Haanel quoted progress in Sweden, Norway, and the U.S.A. In Sweden, one smelting furnace of 7500-ton annual production was completed at Trollhättan and another three to five furnaces were in the construction stage. In Norway near Odda in Hardanger, a 9000-ton per annum furnace was in construction and another planned. Haanel showed disappointment that there was no parallel development in Canada in spite of his pioneering work some four years previously. In the 1911 summary, he again quoted the progress made in Sweden and Norway, giving an excerpt from a report by T.D. Robertson on the Trollhättan furnace in which the Sault Ste. Marie results were confirmed by the Swedes in relation to its ability to smelt titaniferous ore. In the 1912 summary report, pp 107-120, H.T. Kalmus of Queen's University reviewed recent developments in the electrothermic production of iron and steel in 1911-1912.

The final comment on this subject by Haanel appeared to be in his 1913 summary report which read in part as follows: "With a view to preserving Canada's historic continuity in the development of the electrothermic process for the reduction of refractory iron ores - which began, practically, with the experiments at Sault Ste. Marie, Ontario, in 1907 - Dr. Kalmus of Queen's University carried on, during 1913, further investigation and researches into the electrothermic production of iron and steel..." (17). This seems to refer to "Copper-nickel steel", a note by Kalmus on pp 17-20 of the 1913 summary report. Towards the end of Haanel's summary report, a section entitled "Miscellaneous matters" has a short note on electric iron ore smelting in Sweden by H.A. Leverin which mentions that Sweden at that date had six furnaces working and three under construction. The final report on this subject was published in 1915 titled "Electrothermic smelting of iron ores in Sweden" by A. Stansfield of McGill University (MB Rep 344, 1915). This report also describes the Tinfos electric furnace at Notadalen, Norway.

The iron ore program could not have fully satisfied Haanel, particularly in the absence of industrial interest in the electrothermic process. His objective probably was to stimulate an entirely domestic integrated industry based on upgrading the 30 to 40 per cent iron ore, which was reasonably abundant at accessible locations, and smelting it close to the mines or within short rail hauls. In the period reviewed, the Canadian iron and steel industry was not unlike it is at present, though of course much smaller. Hamilton was already becoming the Ontario centre served by shipping ores from Michigan and Minnesota, and Sydney, Nova Scotia was provided with Newfoundland ore. In both cases, the ore and fuel were to a large extent both transported by water. Electric smelting and continuous steelmaking have still not attained the goal that Haanel and others had expected. Enriched feed to the blast furnace has become commonplace and the ageless high shaft blast furnace which has been transformed into a large production unit, is still with us.

SOLID FUELS

Haanel recognized the importance of energy as the principal sinew of industry. During the period under review to 1920, fuels on the whole received priority of treatment. The initial emphasis was on solid fuels, because of the population concentration and deficiency of fossil fuels in the central provinces.

Peat

Realizing that peat was abundant in the central Canadian region where energy was most required, Haanel had already evinced interest in peat as a fuel source for metallurgy during his service with the Department of the Interior. Furthermore, he must have conceived in those early days the establishment of comprehensive fuel testing facilities.

A petition dated June 12, 1906, signed by a large number of influential residents in different sections of the Dominion was addressed to Frank Oliver, Minister of the Interior (transferred to W. Templeman, Minister of Mines), which called for "the Mines Branch of your Department and ... to make a thorough investigation ... as may aid in the intelligent development of this valuable resource ..." (18). The valuable resource was peat. Haanel quoted the petition in full in his first 1907-8 summary report and referred in a response titled "Investigation ordered" to the petition dated May 5, 1907 (a mistake in date or 11 months in transmittal). He recommended in a memorandum on the same day, presumably to the acting deputy minister, Dr. D.M. Whiteaves, sending Nyström to Europe to make a complete survey of the peat industry of Sweden, Norway, Finland, Germany, Holland and Ireland. Nyström's report on his study tour was published in 1908 (19).

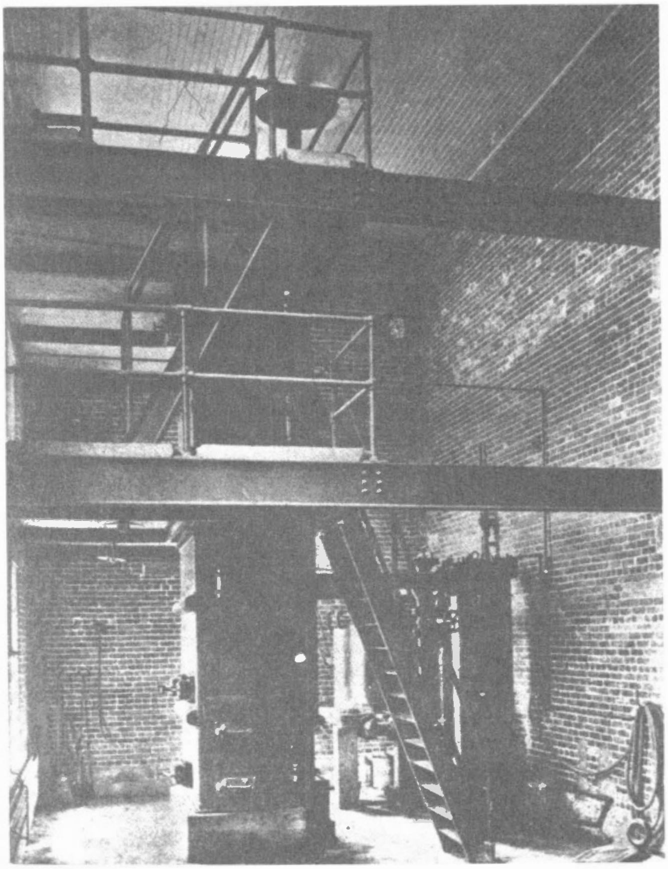
In 1907, B.F. Haanel went to the United States to visit a number of gas producers (anthracite and bituminous coal) plants and gas engine plants in the vicinity of New York City and the fuel testing laboratory at the University of Illinois, "in view of the proposed installation of an experimental fuel test plant in connection with the Mines Branch of the Department of Mines." Bituminous coal was emphasized "since this coal has a similar mode of action and combustion to lignite and peat, which fuels will be mainly experimented upon in the proposed fuel plant" (1907-8 Sum Rep p 52). In 1908, B.F. Haanel visited Berlin and vicinity as Germany was the leading country in using gas producers based on brown coal as well as on other grades. He also visited the Körting Brothers firm in Hanover, who were to supply the initial peat gas producing plant in Ottawa.

During the summer of 1908, E. Nyström examined and delimited peat bogs in Ontario. The field work included the preparation of about 70 tons of dried peat at Beaverton, Ontario for the peat gas producer to be installed in Ottawa. Nyström was assisted by Aleph Von Anrep from Sweden, who for a short time played a leading role in the peat development at Alfred bog. Anrep must have been hired in Sweden early in 1908 but he was listed as a classifed employee only in 1913. Nyström's and Anrep's report was in the press the same year as Bulletin No. 1 (Bulletins were also numbered as Mines Branch reports in the catalogue) (20). It should be noted that the general world emphasis at that time was on humified or fuel peat, though unhumified peat or peat moss, the layer of dead unhumified peat below the living layer and above the humified layer or peat fuel, was also being harvested on a small scale. Haanel in his 1909 summary report refers to this material as "moss litter" and its byproduct as "peat mull" in relation to its being useful for agricultural-horticultural purposes. Peat moss is regarded at present as a useful aerating and conditioning soil agent, particularly in horticulture. Several countries including Canada have important industries that have developed to harvest and market peat moss.

Acquisition of the Booth Street site for the fuel testing plant and establishing an experimental peat fuel plant at Alfred, Ontario were mentioned on pages 8 to 11 of the 1908 summary report and appear to be convincing recommendations. The Booth Street site is spoken of - under "general considerations" - as being selected and bought, designs for the plant prepared, and the necessary apparatus and plant purchased. Decisions and actions were certainly expeditious in that period.

Haanel showed considerable enthusiasm in the initial period of the peat development as expressed, for example, in his statement in the summary report for 1911. In prior reports the director showed interest in peat as a versatile source material for carbon as a reducing agent in metallurgy, for producing nitrates for fertilizers and explosives, and of course as an energy source for prime movers and the generation of electricity. He wanted to demonstrate on a large enough scale the feasibility of using peat in the latter applications provided that the cost of dried peat fuel was about half that of bituminous coal, which at that time cost about four dollars per ton.

One could say that the peat gas producer and engine installed so expeditiously at Booth Street inaugurated the R & D work in that Ottawa locality.



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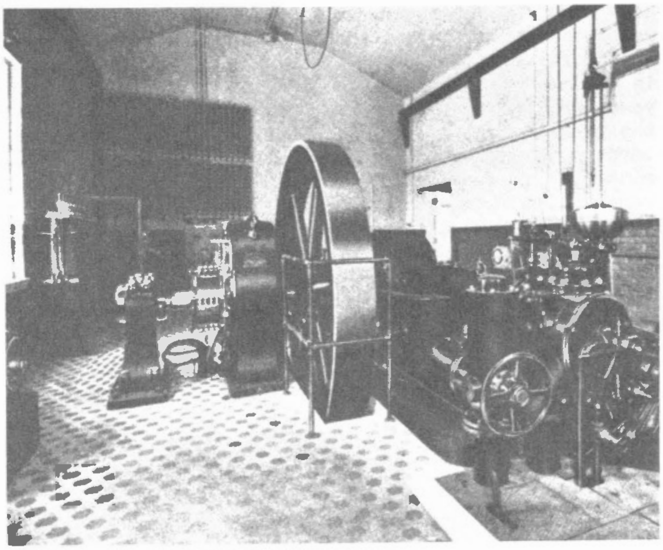

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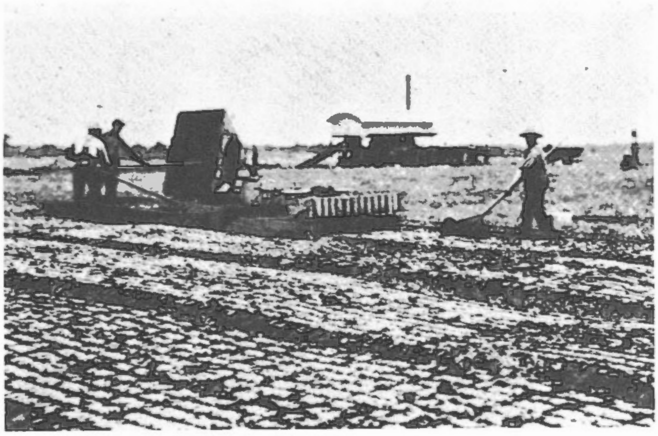
1 - Peat gas producer in fuel testing station, and 2 - Körting gas engine on Booth Street



Peat plant at Alfred, Prescott County, Ont.

The continuous presence in Booth Street of the Department of Mines and its successors remains as a monument to the actions taken in 1907 and 1908 by Haanel. Incidentally, a direct current generator driven by the gas engine in the Fuels building enabled power to be supplied to the magnetic separating pilot plant installed in 1910 and which provided the initial nucleus for a later diversified ore dressing pilot plant.

When operations started at the Alfred bog in the spring of 1910, Anrep was in charge, using excavating, macerating and spreading machines of his design, but the following season the bog was placed under the management of a Karl Bengtsson; Anrep continued to examine bogs in the various provinces of Canada. In 1918 he was transferred to the Geological Survey where he continued to work until he left in 1932.

After the seasons of 1910 and 1911, when production reached about 1800 tons, there was no further reference to the Alfred bog until 1918, when a peat committee composed of two each from the federal and Ontario governments respectively was formed. B.F. Haanel was the secretary. The reason for setting up this committee was the fuel shortage experienced in Ontario during the war and to determine whether labour-saving equipment could be designed, as Anrep's original model was demanding in manpower. A final Canadian design using Anrep's excavating and E.V. Moore's spreading mechanisms was adopted, and the equipment was tried out over three seasons, 1919 to 1921, producing up to 6,000 tons in 1920. Mostly household sales were made in Ottawa and to some extent in Montreal, and as far away as Peterborough. However, dried peat fuel could not compete with the imported coal, mostly anthracite. The Report of the Peat Committee to Dec. 31, 1919 is given in the summary report for 1919 and a well documented preliminary report with recommendations is given in the Appendix to the summary report for 1920.

Coal

In 1902, the Geological Survey published a report by T. Denis, providing comprehensive information on the Canadian coal industry including lists of mines, operating methods, production, markets, chemical analyses, bibliography, and maps of the coal areas. At the formation of the Mines Branch in 1907 Denis was transferred from the Geological Survey and continued his field work, principally on coal. He left in 1910 for a senior appointment in the Quebec Department of Colonization, Mines and Fisheries.

McGill University

Some time in 1906 Dr. A.P. Low, director of the GSC, approached McGill University to undertake a systematic investigation of the properties of Canadian coals. The program was taken over by Mines Branch in 1907 and Haanel, with his usual enthusiasm, launched and developed this extensive program on coal upgrading and utilization at the same time as he was developing the peat program. This study was organized by Dr. J.B. Porter, professor of mining. McGill was probably selected for this research as Porter and R.J. Durley, professor of mechanical engineering, had done research on coal at the University.

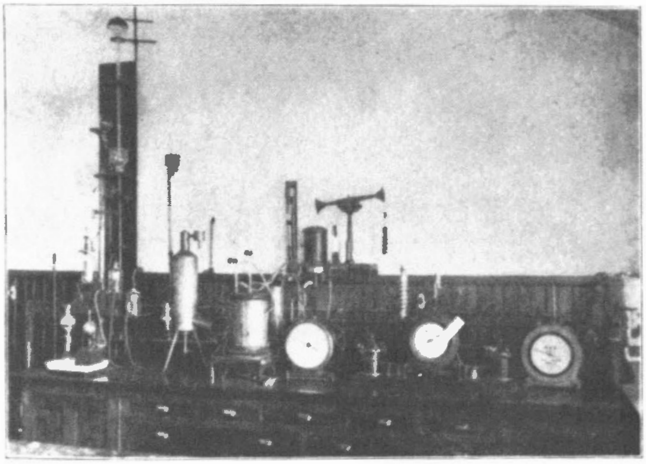
Laboratory work was organized to include crushing, sampling, washing tests and coking tests, supervised by Professor Porter, and boiler tests and producer gas tests supervised by Professor Durley. A special chemical laboratory was established. A staff of some 20 was allocated to this work of whom a number were specially hired; three such persons, E. Stansfield, J. Blizard and J.H.H. Nicolls, subsequently joined the Fuels Division of the Mines Branch in 1910, 1911 and 1914 respectively. In the McGill program, Stansfield headed up the Chemistry Laboratory and Nicolls was one of his assistants. Blizard worked on the boiler tests.

Thirty-four samples of coal each weighing from one-half to ten tons were taken mainly by Denis in Nova Scotia, Saskatchewan, Alberta and British Columbia, and another 50 samples ranging from 2 to 500 pounds were procured from various parts of Canada including the Yukon. The sampling program was largely the responsibility of Denis. In the washing tests, washability of coal was established by heavy organic liquids and the washing itself was performed by a specially built two-compartment jig. The boiler tests were conducted in the boiler testing room of the Mechanical Engineering Department. In relation to the producer gas program, preliminary tests were made on an anthracitic-type producer from the United Kingdom as well as on a bituminous-coal type of Canadian origin, but these producers were found to be unsatisfactory. Based on his experience, Professor Durley designed a down-draft type furnace which enabled the group to obtain comparative results of a wide range of coals from semi-anthracite to lignite. Coking tests were carried out after the boiler and producer tests were completed. Coking was done in Nova Scotia in commercial ovens, slot as well as beehive, by inserting steel boxes containing 50 pounds of coal. It should be pointed out that at this time there were no standard tests for evaluating coking coals on a laboratory scale. There is indication that Professor Stansfield of the Metallurgy Department of McGill was consultant on the development of small-scale cokeability tests, though there is no record of this in Mines Branch literature.

This work was completed over a period of approximately two years and a comprehensive report of six volumes was published in 1912 and 1913 (21). A further volume "Weathering of coal" was published in 1915. This monumental monograph of over 1800 pages including 4 appendices represented the first comprehensive

Canadian record of properties of coals for specific applications. This information was timely for the 12th International Geological Congress held in Toronto in 1913. For this, D.B. Dowling of the GSC, assisted by W.W. Leach, who was with the Mines Branch from 1907 to 1909, prepared the first estimate of coal resources of Canada - 1.23 trillion metric tons - that was included in a three-volume book "Coal resources of the world", edited by Dr. W. McInnes director of the Geological Survey from 1914 to 1920. In this work the estimates for coal were carried to a depth of 4,000 feet. For many years this was the standard reference for world coal resources.

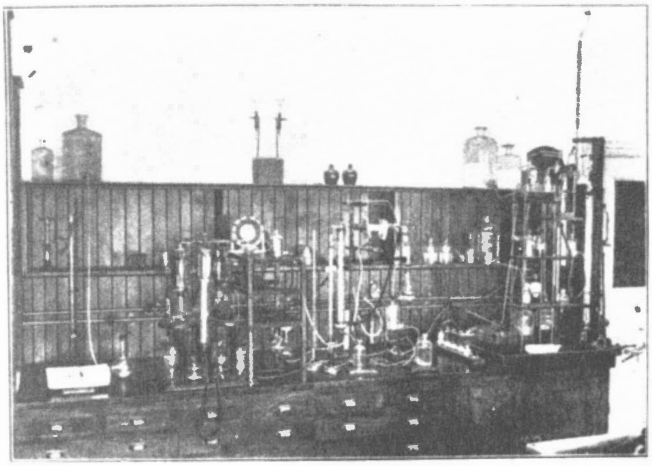
It may be interesting to note that McGill University had shown a continued interest in coal science and technology right up to the depression years of the 1930's, and it was thought that the university would establish formal courses on the model of some of the European and U.S. universities. A Canada-first symposium on coal was held at McGill in 1931; however, interest in coal waned and no such courses were ever established there or at any other Canadian university.



Gas calorimeters

Fuels Testing Laboratory

Independently of the McGill test program, coal samples were analyzed under the direction of F.G. Wait in the Chemistry Laboratory on Sussex Street, which was transferred from the Geological Survey to the Mines Branch in 1907, and this practice continued until 1912. There were no analytical facilities for coal at Booth Street nor was there a chemist until 1910, when Edgar Stansfield was appointed. He was immediately involved in setting up analytical facilities for the peat producer gas tests though he was also able that year to analyze 40 samples of peat, 15 samples of coal and one of coke. The apparatus used at McGill was transferred, and 42 samples of peat and 30 samples of coal were analyzed in 1911. During 1912, additions to the Fuels Laboratory were made possible by extending the Fuels building to enlarge the original iron ore concentration facilities into a diversified ore dressing pilot plant. The changes in Booth Street coincided with the refurbishing of the Sussex Street Chemistry Laboratory, which closed in late December 1911, the operation being transferred to the Thistle Chambers on Wellington Street. In 1913, both laboratories united in better quarters. Dr. F.E. Carter was appointed on July 1, 1913, to assist E. Stansfield as assistant engineering chemist, a term apparently coined at this time for some of the Fuels chemists. Stansfield had the temporary services of a student, W.B. Meldrum, from June to September 1913. The enlarged and refurbished Mines Branch laboratory on Sussex Street was opened on May 1, 1913, and the Fuels testing laboratories became self-contained in the same year. The analytical work for the ore dressing plant was carried out in the first few years in the Fuels laboratories. T.W. Harvey and J.H.H. Nicolls were appointed as assistant chemists on October 10 and November 6, 1914. Carter resigned in 1916 and V.F. Murray and R.C. Cantelo were appointed in the same year. The summary reports of the period spoke of the large load of samples to be analyzed, and the additions to the analytical staff support this claim. It should be noted that in those days establishing positions was a difficult matter, as the governments of the day were more frugal than was the case in the years following World War II. Some employees also remained on temporary status for long periods of time.



Fuels testing station, Booth Street, laboratory for gas analysis

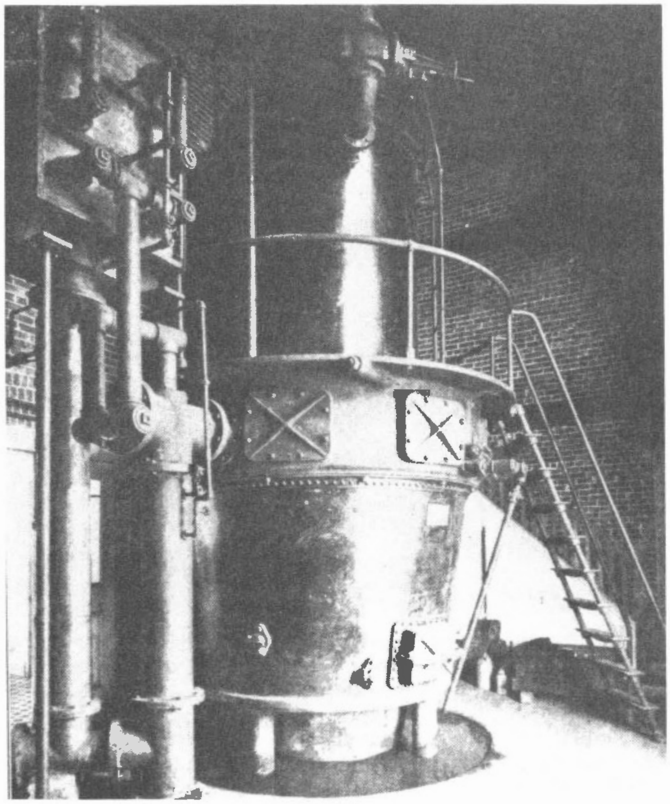
Before the close of Haanel's service, a first "Analyses of Canadian fuels" was published in 1918 by E. Stansfield and J.H.H. Nicolls in five Bulletins, No. 22-26 (MB Rep No. 479-483, 1918) covering regions from the Maritimes to British Columbia and the Yukon. Bulletin 25 for Alberta and the Northwest Territories included Appendices A - on distillation tests of crude petroleum and its products, and B - classification of the products of oil distillation. A second edition of this bulletin was printed in 1921.

H.C. Mabee was appointed in 1914 as the first chemist in the Ore Dressing and Metallurgy Division. He worked in the Fuels laboratory until 1917, receiving assistance from some of the fuel chemists. In 1916, R.J. Traill joined him as an assistant and A.K. Anderson was hired in 1917 and allocated to the pilot plant, which was then considered to be in the "outside" service of the Mines Branch.

Coal Mining

A mining engineer, J.G.S. Hudson, was hired in August 1908, and the appointment made permanent in 1910, to make a comprehensive technological and economic review of coal mining in Nova Scotia. This appointment may have been related to the concern Haanel may have had in regard to accidents in mining in general and with explosives in particular. In the 1909 summary report, he alluded to the concern and recommended that a central station for testing explosives be built in Ottawa similar to facilities in the United Kingdom and the United States. The director included in the 1909 summary report a preliminary report by Hudson on accidents in mines. The director had intended Hudson to be the first head of the Explosives Division; however, his career worked out somewhat differently. In the period under review he was called upon to investigate mine accidents and disasters, but he also assisted in collecting field samples, etc.

Returning to Hudson's original project of coal mining in Nova Scotia, in the 1909 summary report he stated that his manuscript had 1621 pages with numerous photographs, drawings and maps. It was mentioned as being in preparation in the summary report for 1910 under report number 91; apparently it was never issued. A short report, No. 227, published in 1913, titled "Sections of the Sydney coal fields", contained six pages, 15 plates and one map. There were two reports on coal mining in the Maritimes issued in 1917; MB Rep 430 by F.W. Gray "The coal-fields and coal industry of Eastern Canada: a general survey and description", and MB Rep 432 by J.F. Kellock Brown entitled "The mining of thin-coal seams as applied to the eastern coal-fields of Canada". Both authors were senior officers of the Dominion Coal Company and these reports were possibly commissioned because of the growing shortage of fuel in central Canada.



Fuel testing station, Westinghouse suction bituminous coal gas producer

Producer Gas

The interest in a gas producer must be viewed in the context of the energy situation at the turn of the century. Electric power was generated by small, scattered enterprises with little or no inter-connection. Industry was mostly on a small scale using water, steam or gas power for driving prime movers. It is not surprising that Haanel and his contemporaries thought that the lean gas using low-grade fuel could supply energy reasonably economically in the most populated parts of Canada devoid of high-grade fossil fuels as an alternative to water power or steam, the latter being less efficient than gas. Unfortunately, there seems to have been an underestimation of the cost of producing peat in the form that it could be used, so interest of the Fuels Division turned to coal as the principal solid fuel deserving its research attention (22).

A Westinghouse double-zone bituminous suction gas producer was installed at the Booth Street Fuels testing laboratory in 1911 for testing Canadian coals, particularly those of low rank, these being the cheapest to produce with a good gas yield. In 1912, J.G.S. Hudson secured five 20-ton samples of sub-bituminous coal from Alberta (four from underground mines at Edmonton and Drumheller, and one from an open pit mine at Tofield). During the same year, a Saskatchewan lignite was tested with satisfactory results in the Westinghouse producer. The Alberta coals were tested by John Blizard in 1913, both in the Westinghouse producer and the Korting producer, and the results were deemed satisfactory. It should be recalled that the Korting gas producer had operated earlier on peat. It did not give satisfactory results in that tar was not adequately removed before entering the gas engine. The manufacturers made some improvement but further experimentation by the Fuels staff was required to devise a more foolproof gas cleaning system. In 1914, four low-rank coals from Alberta were tested for producer gas yields, and in 1915 five coals, two of which were high-rank were also tested. This seemed to have completed the producer gas program based on coal. Investigations of the foregoing lignite and coal samples from Alberta were reported on in two publications - MB Rep 331, 1915 and MB Rep 565, 1921, the latter supplemented MB Rep 331, 1915, and was itself the last of the Bulletin Series (No. 33).

Boiler Tests

A 200-hp Babcock-Wilcox marine water-tube boiler with induced draft was installed in the Fuels Building on Booth Street and commissioned early in 1914. An assistant technical engineer, E.S. Malloch, was appointed in December 1914 to aid John Blizard in conducting boiler as well as gas producer tests. Eleven samples of commercial coal, nine of low-rank sub-bituminous or lignitic and two high-rank bituminous and anthracitic, one from Canmore Mines which is still operating, were obtained from Alberta, and boiler tests commenced in 1914. In the following year, eight commercial samples of coal from Alberta, including four each from low and high-rank coal mines and one peat sample from the Alfred bog, were investigated. By the end of 1917 the boiler tests were completed and a report on the results of forty-one steaming tests was in preparation, but it was not published until 1920 (23). On the other hand, a report by John Blizard on burning peat in the boiler was issued in 1917, and this completed the investigation concerning the value of peat for the production of power (Bulletin 17, MB Rep 447, 1917).

In 1919, Blizard investigated pulverized fuel firing of boilers in the United States and Canada and Malloch evaluated the feasibility of a central electric power generation station at Estevan, Saskatchewan. A report by B.F. Haanel was submitted to the Dominion Power Board.

John Blizard resigned in 1920 and took up a position with the Bureau of Mines in Washington, D.C.

Carbonization

There was concern about scarcity of fuel in Saskatchewan and Manitoba in 1916. It was known there were substantial deposits of lignite, particularly in Saskatchewan, but the poor storage properties of this material militated against its widespread use. This led to formation of the Lignite Utilization Board in 1918, with sponsorship of the Honorary Advisory Committee for Scientific and Industrial Research of Canada formed in 1916. The name was changed in 1924 to the National Research Council which turned to the Mines Branch for some of the technological solutions to problems of use.

R.E. Gilmore joined the Fuels Division in 1917 and assisted E. Stansfield in this project. A large portion of the staff was allocated to this work. This study comprised designing special apparatus, first for small-scale tests with lignite briquettes weighing five to six grams, and second, larger-scale laboratory tests with charges of 1,000 to 2,300 grams of lignite "peas" in different size retorts using a range of carbonization temperatures. Lignite from Saskatchewan was compared with that from Alberta. Small-scale tests were also conducted on Alfred peat and reported on in the 1920 summary report. A report on western carbonization of the lignite was included in the 1918 summary report by E. Stansfield and R.E. Gilmore, assisted by J.H.H. Nicolls, T.W. Hardy, R.C. Cantelo, and others, and continuation of this work was reported in the 1919 summary report under the same authors (1918 Sum Rep, pp 87-105; 1919 Sum Rep, pp 30-39). A shed was erected on Booth Street by the Lignite Board where semi-industrial carbonization and briquetting equipment was installed comprising a retort designed by Stansfield, a mixer, and a press. From October 1, 1918, the services of E. Stansfield were loaned to the Lignite Utilization Board. He resigned in 1921 and was appointed as industrial chemist at the University of Alberta and later as chief chemist of the Alberta Research Council. R.E. Gilmore and T.W. Hardy resigned in 1919, though Gilmore returned in 1923 to become the second chief of Fuels Division in 1947. The Lignite Utilization Board constructed a commercial plant near Bienfait, Saskatchewan in 1924 and it operated under the Board's auspices until 1927 when it was disposed of to industry.

HYDROCARBONS

The period of 1907-1920 was at the dawn of mass production of hydrocarbons and of the general use of internal combustion engines. However, at this time industry, commerce, and the residential community were dependant on coal and manufactured gas and limited hydroelectric power and natural gas.

At the formation of the Department of Mines, there was a small Canadian oil and natural gas industry largely based in western Ontario where production of oil dates from 1857 at Oil Springs. However, depletion was becoming evident in the latter part of the first decade of the century. It was not surprising therefore that Haànel's attention was directed to alternative sources - oil shales, and later oil sands, whose existence was known but whose magnitude and economics had not been evaluated.

Oil Shales

The Geological Survey had been studying petroliferous sediments since the last century. Dr. R.W. Ells had made studies of the Albert oil shales in New Brunswick which were considered to be richer on the average than the then intensively exploited Scottish shales. In April 1908, Haanel received a letter in the form of a petition from the Albertite Oilite and Cannel Company requesting a representative from the Department to witness tests in Scotland on 45 tons of shale sent from Albert, New Brunswick, and to prepare an independent report. Ells was asked to undertake this assignment in that year. The results in an experimental retort yielded about 40 gallons of oil per ton and were deemed satisfactory. A joint report with the Geological Survey was published in 1909-10 (24).

Related to these studies, H. Leverin in 1909 set up a destructive distillation apparatus to estimate the yield of crude oil and another apparatus to determine the yield of ammonium sulphate. In his 1909 summary report, Haanel referring to the oil shale industry, said "Next to the electric smelting of iron ores and the solution of the peat fuel problem, no subject has evoked such commercial interest recently as the prospective supply of mineral oil from the bituminous shales found in various parts of the country, notably in New Brunswick and Nova Scotia" (25). He also referred to the introduction of mineral oil as oil fuel into the British Navy implying its use in a prospective Canadian navy.

In the 1911 summary report, Haanel expressed disappointment that no commercial development had started. He spoke of using ammonium sulphate as fertilizer in agriculture and "spent shale" from retorts in combustion with lime and gypsum from nearby beds to make portland cement. With this in mind, he sent a sample of the materials to a United States expert, R.R. Meade, who gave a favourable report.

No further developments related to oil shales other than the receipt of occasional samples took place until 1918, when B.F. Haanel inspected a Wallace retort in East St. Louis, Illinois, where a sample of Albert shale was sent by the Lieutenant Governor of New Brunswick, W. Bugsley. The results confirmed the yield obtained at the Fuels testing station.

A.A. Swinnerton was appointed to the Fuels testing laboratories in May 1919 and a chemical investigation of oil shales from New Brunswick and other parts of Canada was recommenced, using the 2,300-gram retort employed earlier in lignite carbonization. Progress was slowed by staff resignations at the time and by the necessity for Swinnerton to undertake gas analyses. A preliminary report by Swinnerton was published in the 1921 summary report, wherein he stated that 101 samples were examined, of which 43 were collected in New Brunswick by W.J. Wright of the Geological Survey, 21 by S.C. Ells from Manitoba and Saskatchewan, and the balance by individuals from various parts of Canada (1921 Sum Rep, pp 239-252).

The general conclusions at that time regarding oil shale resources of Canada were similar to the present opinion that mining costs together with a low content of oil were major constraints to their economic exploitation in comparison with well-produced oil. However, the potential resource was considered important enough to continue the evaluation of occurrences during the next ten years or so.

S.C. Ells (Northland Trails by S.C. Ells, Burns and MacEachern, Toronto, 1956)

Bituminous sand pavement laid by S.C. Ells in Edmonton, 1915

Oil Sands

This resource was known previously as tar sands or bituminous sands because of its tarry appearance and first application to pavement of highways. In the present era, there is every expectation that this valuable resource may become the basis of Canada's self-sufficiency in oil. Dr. Haanel first mentioned this potentially valuable resource in the 1912 summary report. He referred to the history of the Peace and Athabasca River country dating to 1778 and that many travellers had noted the presence of "tar sands". In later years this included officers of the Department of the Interior and of the Geological Survey whose organized explorations reported on these "extensive" deposits. This information apparently was haphazard and duplicated by the absence of coordinated effort. Casual samples indicated 12 to 18 per cent bitumen content in numerous outcrops along the Athabasca River. Dr. Haanel stated "whether they (sand deposits) may more properly be considered as the possible source of various more or less refined products, or whether as a source of supply for paving materials is yet to be determined" (26). He favoured a step by step program of evaluating the extent of the resource and the physical and chemical properties of the bitumen. Many years had to elapse before satisfactory separation and refining methods evolved. Hence at that time, commercial application of the commodity was directed to highway paving as the building of the Northern Alberta railway made the oil sands accessible.

In 1913, S.C. Ells, the son of R.W. Ells of the Geological Survey, was hired and assigned to the Division of Nonmetalliferous Deposits. He made a reconnaissance survey that included the recording of 250 outcrops and the collection of some hundreds of samples. The survey was continued in 1914 and included the securing of about 60 tons of sand for laying of an experimental roadway on Kinnaird Street in Edmonton. In 1915, systematic surveying was done of the Athabasca tributaries where many of the outcrops were found. The experimental roadstrip was also laid. The condition of the roadway at the end of 1916 was reported as satisfactory by A.W. Haddon, acting city engineer for Edmonton.

In summarizing the results, Ells stated in the 1916 summary report that (a) in the McMurray District of Alberta there was a large and continuous body of bituminous sand in an area of not less and possibly more than 750 square miles. Owing to the heavy overburden and lack of uniformity of sand quality, about 80 per cent of the area represented by the outcrops could be eliminated from further consideration at that time; (b) by using a properly designed plant for heating and mixing and observing reasonable care in the manipulation of materials, the bituminous sand could be used in construction of asphaltic wearing surfaces either as sheet asphalt or in combination with various rock mixes; (c) cost data indicated that bituminous sand against imported asphalt would be restricted by freight charges to relatively local use within the narrow limits of Western Canada. Any extensive development of the McMurray deposits would then depend largely on a successful separation process (1916 Sum Rep, pp 56-58).

On the basis of these findings, Ells suggested the investigation of such a process at the Mellon Institute of Industrial Research at Pittsburgh, Pa. After trying centrifugal separation he devised a method of using hot water and flotation that could be claimed as the forerunner of the present separation method employed (27). No action by Mines Branch was seemingly taken to follow up the Mellon Institute work.

A report by an independent engineer, G.C. Parker of the Ontario Department of Public Highways, was commissioned in 1918. Parker reviewed the possibilities of using the McMurray bituminous sand to surface rural roads and he agreed that such a program be tried out in close cooperation with the province.

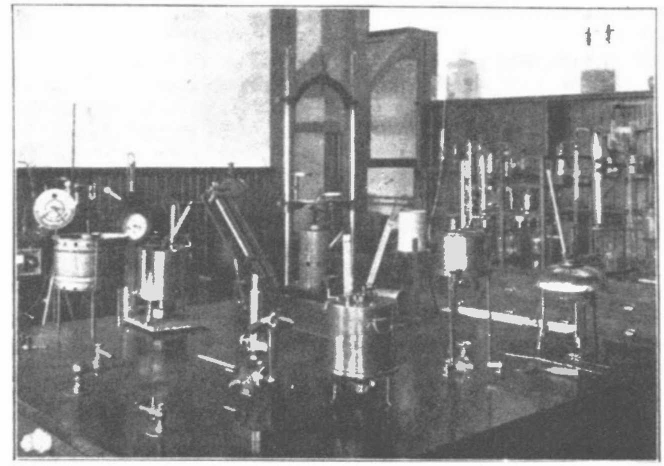
Ells returned to field work on bituminous sands in 1920, examining and testing by pits an area reserved for the Parks Branch of the Department of the Interior on the Horse River tributary of the Athabasca River. He also classified bituminous sand outcrops according to thickness and character of the overburden and its disposal, quality of sand, and accessibility of transportation. Ells continued to devote his career to evaluating bituminous sand resources until his own retirement, long after Dr. Haanel's retirement.

Petroleum and Natural Gas

Apart from the annual Canadian mineral production reports of the Mineral Resources and Statistics Division, the first reference to petroleum and natural gas is contained in a note given by Haanel in his 1911 summary report. This dealt with oil and gas developments in Albert and Westmoreland Counties of New Brunswick, where a British company, Maritime Oilfields Limited, acquired leases previously held by the New Brunswick Petroleum Company. The new company embarked on a comprehensive drilling campaign that gave promising results. Production was evaluated at 35 million cubic feet of natural gas per day. The distribution of natural gas to Moncton was to be undertaken by the Moncton Tramways, Electricity & Gas Company, the control of which was taken over by T.S. Brendall, the largest independent gas producer and distributor in the United States, who also controlled Dominion Gas Co. in Ontario (1911 Sum Rep, pp 33-35).

In the 1912 summary report, Haanel mentioned "the growing significance of gaseous and liquid hydrocarbons in the various industrial applications present consideration of far-reaching importance" (28). He further stated that in 1911 the U.S.A. consumed 62 million barrels of fuel oil for railways, manufacturing and metallurgical works.

It is striking to note that in 1912, total United States petroleum production amounted to 220 million barrels and that of the world to 351 million barrels. On the other hand, U.S.A. consumption in 1975 was nearly 16 million barrels per day, with a domestic production of 10 million barrels per day. World production in 1975 amounted to 55 million barrels per day. By comparison, Canada's total production in 1912 was 243,614 barrels. Most of this was from Ontario, with production peaking in 1900 at 913,498 barrels. A decline started because of depletion of reservoirs, particularly from 1907. Natural gas production on the other hand showed consistent increases from year to year except during the depression periods. In 1912, production had reached 15.2 billion cubic feet of which Ontario accounted for 12.5, Alberta for 2.5 and New Brunswick for the remaining 200 million cubic feet. In contrast, the production and consumption of oil in Canada in 1972 was 1,735,000 barrels per day, with 800,000 barrels per day exported and about the same quantity imported for use in Eastern Canada. Canada's consumption of natural gas in 1975 amounted to 1.8 trillion cubic feet. The spectacular increase in the consumption of hydrocarbons in Canada dates from the post World War II period.



Apparatus for oil analysis - Fuels testing station, chemical laboratory

F.G. Clapp of Pittsburgh was hired in 1912, to make a detailed report on the petroleum and natural gas resources of Canada. Aided by L.J. Huntley, he spent three months in field work during the seasons of 1912 and 1913. A preliminary report was published in the 1912 summary report. In November 1913, Clapp accepted private work in China and made arrangements with Dr. D.T. Day of the U.S. Geological Survey and with several contributors to Volume I, to complete the work. However, technical and other editing was required and this was done by Dr. A.W.G. Wilson, chief of Metalliferous Deposits in the Mines Branch. The 782-page monograph dealt not only with a description of the resources across the land in Volume II, Parts 1 and 2, but also with the development, production and properties of petroleum in Volume I (29).

The 1912 summary report gave the first reference to the examination for physical properties such as viscosity, etc., of lubricants for the Naval Service; this work was done by the Chemical Division. In 1914, the Fuels testing laboratory started to receive samples of mine air methane, oxides of carbon, etc. The Hillcrest mine explosion in Alberta, causing the death of 189 men in 1914 and investigated by J.G.S. Hudson, had no doubt influenced Haanel to establish this service. In 1915, the laboratories were equipped with distillation apparatus to deal with oil samples. In that year, 32 oil or gasoline samples were analyzed for the Department of Public Works and the Defence Department, as well as 172 mine air samples. In 1916 there were 377 mine air, 75 oil and 2 each of natural gas and oil shale samples analyzed.

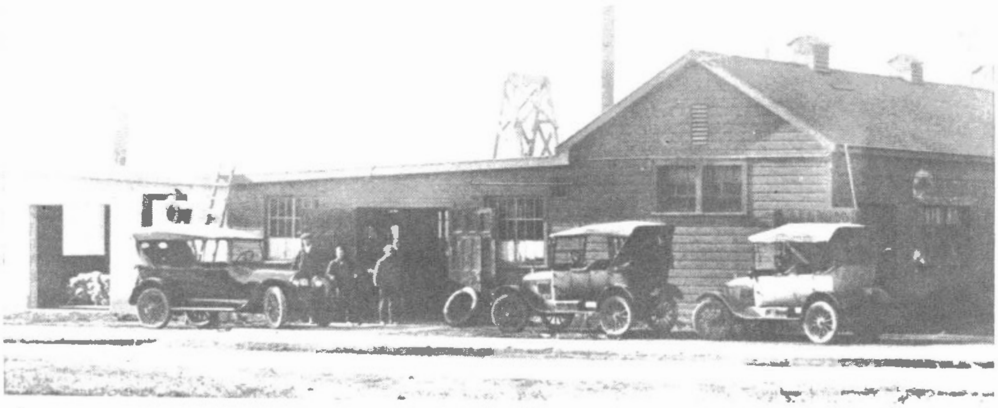
In 1916, Stansfield and Murray were sufficiently involved with oil analysis and specifications that they published in the summary report for that year a type specification for the purchase of oils, gasoline, etc. using marine engine oil, as an example. More space became available for this facility in 1917 by transferring the ore dressing chemical staff to the adjoining pilot plant building, and a separate oil laboratory was established with additional analytical equipment.

Departmental Workshops

A workshop was established at the Fuels testing laboratory on Booth Street in 1914. A.W. Mantle was appointed mechanical superintendent reporting to B.F. Haanel. All laboratories were serviced from the central workshops. It is of interest to note that in 1914 the top wage rate for toolmakers and experienced machinists was 48 cents per hour, and the lowest rates were 28 to 20 cents per hour for millwrights and fitters. Workshop reports were given in the annual summary reports but this practice ceased with the 1919 report, the last one to be prepared under Haanel. In 1915, all of the prevailing rate (hourly) employees at the Sussex Street and Booth Street facilities, including journeymen, pilot plant, and some laboratory assistants and labourers, were placed in the "outside" service as was the Vancouver Assay Office. Mantle apparently was the supervisor of outside services in Ottawa.

Blasting Explosives

An allusion is made earlier under "Coal mining" to a preliminary report by Hudson on accidents in mines that was included in the 1909 summary report, pp 124-133. It cited the accident rate in Canadian coal and metal mines as being much higher than in the U.K., e.g., over a 10-year period, 1899-1908 Nova Scotian coal mining had an average rate of 2.67 per thousand employed and B.C. coal mining an average of 9.21, whereas an average over the same period in the U.K. was 1.29. Hudson further stated that nearly 59 per cent of all mine accidents in Ontario metal mines were due to explosives, and the comparable figure in B.C. metal mines was 52 per cent. He suggested that the Geology and Mines Act be amended "giving to the Mines Branch authority to call for the immediate reporting of accidents; powers to cooperate with mining authorities in the formulation of an efficient code of laws and regulations relating to mining and the use of explosives; and with sanction to verify statements and to investigate causes" (30). He also stated that Canada was unique in not having an explosives act, commenting



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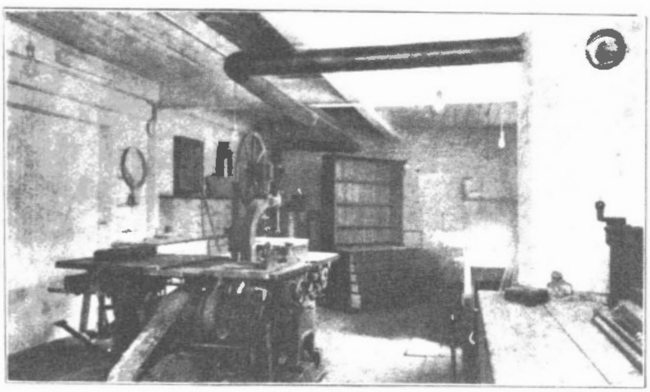

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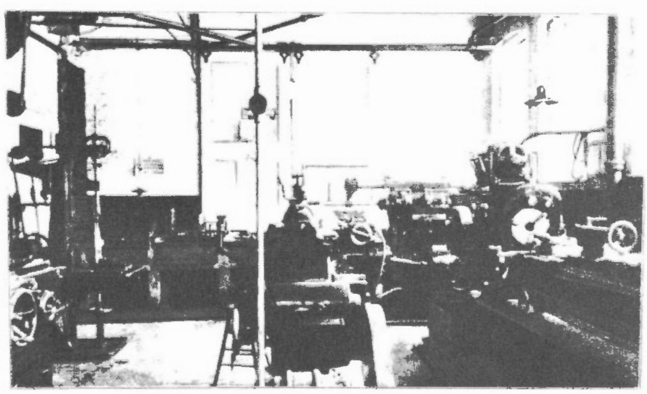

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1 - Machine shop and store hutments on Booth Street, circa 1920; 2 - carpenter shop, Sussex Street; 3 - machine shop in fuel testing station, Booth Street

that all European countries based their laws on the British Explosives Act of 1875, modified to suit local conditions. Furthermore, he stated that the United States appointed in 1908 a special commission of foreign experts to investigate mine accidents. This commission was composed of three members - Victor Watteyne, Inspector General of Mines, Belgium; Carl Meissner, Counsellor for Mines, Germany; and Arthur Desborough, His Majesty's Inspector of Explosives, Great Britain. President Roosevelt ordered the commission's report to be widely distributed amongst the coal mine operators and miners of the U.S. The first recommendation of this report marked "A" was headed "Selecting the explosives to be used", which in effect recommended the use of "permissible" explosives. The U.K. term is "permitted".

Haanel, in his own statement in the 1909 summary report, said "I have recommended that a central station - similar to those established in England and the United States - be built in Ottawa for the testing of all explosives; and that an explosives act be passed effectively regulating the manufacture and sale of explosives, their use in mines, and in blasting operations generally" (31).

Little time was wasted by Haanel. In 1910, Captain Desborough was invited to Canada and after making a tour he prepared a report in Ottawa making recommendations. This report is dated October 1, 1910 and is reproduced in the 1910 summary report (pp 120-133). The general tenor of the report was condemnatory although courteously expressed. Hudson accompanied Desborough throughout the visits to explosives plants and mines in Ontario, Quebec, Nova Scotia, and British Columbia. Discussions were held with provincial authorities, railways, and mine staffs. Following these visits, a two-day conference under the chairmanship of Haanel was held in Room 16 of the House of Commons on September 23 and 30, 1910 with an audience of representatives of provincial government, explosives manufacturers, the Dominion Iron, Steel and Coal Company, and the Bureau of Safe Transportation (New York and Toronto). At this conference, Captain Desborough first gave an account of the principles guiding the British Inspectorate in applying their Explosives Act. Then followed a question and answer session which continued into the second day. The proceedings of the two-day conference were reported as "Digest of proceedings" in Appendix II (pp 183-223) in the 1910 summary report and did demonstrate that there was a free exchange of views. It may be noted that Thomas Gibson, deputy minister for Ontario, gave full support to the Dominion Government's proposal for a Canadian Explosives Act.

Dr. Haanel introduced Captain Desborough as H.M. Inspector of Explosives in England, "who for many years had administered the English law and who was at the head of the testing station in England". Desborough in his review mentioned that the testing was done by "chemical advisors", Messrs. Dupré, who strangely enough at that time were paid by fee, a practice not recommended by Desborough in his report of October 1, 1910. It seems that Dr. Haanel was anxious to have the Mines Branch identified closely with all steps in the evolution of the regulation of explosives in Canada. As indicated earlier, he established the Division of Explosives with J.G.S. Hudson, who participated in all the foregoing activities as chief.

Dr. Haanel surely was aware that the major role of the Mines Branch was to be in testing and not necessarily in administration of the Act. Possibly for that reason he provided for a comprehensive testing facility that included not only testing for authorization of explosives but also for the safety of "permitted" explosives in the presence of coal dust and methane for coal mining. In the U.K. the latter facility had operated under the Home Office since 1897; it was being moved to Eskmeels, Cumberland, at the time of Desborough's Canadian visit and was later transferred again to Buxton, Derbyshire. In a letter to the minister dated October 17, 1910, Dr. Haanel submitted a detailed list for his consideration "Estimates for 1911-12 for the administration, buildings and equipment necessary for the establishment of the Explosives Division, Mines Branch, Ottawa". These estimates amounted to $72,400. The list included a 24-ft x 45-ft chemistry laboratory, a 20-ft x 15-ft testing room and storehouse, an explosives magazine, and two testing galleries, one for gas and coal dust explosions, 50 ft long x 6 ft 4 in. internal diameter, and a smaller gallery for testing coal mine safety lamps. An additional cannon was also suggested in connection with the explosion gallery. All standard equipment for testing explosives - cannon, pendulum, impact machine, Bichel gauge test, Trauzl lead block, calorimeter, etc., were also included in the estimates. The suggested staff was a chief inspector, two inspectors and two assistant inspectors, one explosives chemist, one machinist, and one clerk. The salary of the chief inspector was not fixed but recommended by Desborough at $6,000 to $7,000 which was twice the salary Haanel started at in 1901.

It should be noted that Desborough's "Report on the explosives industry in the Dominion of Canada" and the House of Commons conference were widely publicized in MB Rep 92 and 89 respectively which were printed in four successive editions. A copy of Bill 79 - An Act to Regulate the Manufacture, Testing, Storage and Importation of Explosives - was prepared by the Mines Branch in consultation with Desborough and in accordance with advice of the Department of Justice; it was included as Appendix III of the 1910 summary report. Ten years had to pass before the Act came into force.

The next six years gave witness to Haanel's arguments for an Explosives Act and improved industrial safety.

In his field report on the tour he made with Desborough, contained in the 1910 summary report, Hudson wrote there were two explosions in the Ottawa Valley prior to the arrival of Desborough in Ottawa on July 22, 1910. On May 8, 1910, there were 10 deaths and 20 injuries at General Explosives Company Ltd. in Hull, Quebec, in manufacturing potassium chlorate powder "Virite"; on July 11, 1910 three deaths and eight injuries occurred at Dominion Explosives Company Ltd., Sand Point, County of Renfrew, Ontario, manufacturing "Blaster's Friend", a nitrated cassava flour powder marketed for its non-freezing properties as a substitute for nitroglycerine explosive. At the Bellevue mine in Alberta, there was an explosion of fire damp (methane) on December 9, 1910, when 31 men died. All three reports, with the Hull disaster supplied with map and photographs, were contained in the 1910 summary report.

In 1911, Hudson investigated a further three explosions at explosives plants as follows: a second accident with the death of four employees at the Dominion Explosives Company Ltd. at Sand Point, Ontario; four dead (three dying later) and one injured at the Canadian Explosives Company, now C.I.L., at the Beloeil

Works, Quebec; and an explosion occurred in a packing-house where four men were killed in a mixing house at the works of Curtis and Harvey of Canada at Rigaud, Quebec, manufacturing a nitroglycerine-based 60% dynamite. Hudson remarked that it was the first time the department was called by telephone to investigate an accident at an explosives works but that the department was in an awkward position without the backing of an Explosives Act.

In the 1912 summary report, Dr. Haanel still anticipated the passage of legislation. In 1913, Hudson discussed with the chief inspectors of mines and the attorney generals of the western provinces their views on the various clauses of the Explosives Bill. Earlier in the year on January 15, an explosion took place in the Nanaimo harbour on the steamer Oscar, loaded with 19 cases of dynamite and 50 kegs of black powder. Hudson was sent to investigate this disaster. Haanel mentioned this accident in his 1913 summary report, indicating that Hudson's report was to be published in a separate bulletin - probably to publicize his preoccupation with delays in passing of the Explosives Act - but the bulletin was not published.

The Explosives Bill of 1911-12 was reintroduced in Parliament on May 5, 1914, by the Minister of Mines, Louis Coderre, and was read for the first time on May 12, 1914. The Bill was in the Committee of the whole House on May 16. Small amendments were made to the original bill and the third reading passed without discussion on May 19; the Senate passed it on May 30, 1914. It was assented to on June 12, 1914, but was not proclaimed until March 1, 1920. A copy of the Act was included as an appendix in the summary report of 1914.

To reinforce his arguments about the high rate of metal mining accidents due to explosives, he quoted in the 1914 summary report that such accidents in 1913 in Ontario accounted for nearly 44% of the total mine accidents, and in British Columbia for 1914, the figure was 67%; he appealed "that action in carrying out the expressed legislative will of the people should not be much longer delayed" (32).

The worst coal mine disaster in Canada occurred on June 19, 1914, at Hillcrest mine in Alberta, when an initial ignition of fire damp was followed by a coal dust explosion, causing the death of 189 men. Hudson reported on his inspection and subsequent inquiry in Calgary, for which information is given in the 1914 summary report. No definite cause was established as all potential witnesses perished. However, the inquiry commissioner recommended the cessation of shotfiring until dust control was improved. In the 1915 summary report, two further coal mine disasters were reported, both in the Nanaimo district of Vancouver; the first at Wellington mine on February 9, 1915 was caused by inrush of water from the adjoining abandoned Southfield mine, with the loss of 19 lives. The second occurred on May 27, 1915, at the Reserve mine, where 22 men were killed in an explosion. Hudson was asked by T. Graham, chief inspector for B.C., to give expert evidence at the inquiry. His conclusion was that an outburst of coal had taken place with ignition that followed because of the breakage of an oil safety lamp. There was disagreement on the initial point of ignition.

No further mention of activities of Hudson or of the Division of Explosives appeared in summary reports to 1919, the last to be published during Haanel's time. However, in the initial report of the first chief inspector of explosives, Lt. Col. G. Ogilvie, for the calendar year 1919, he stated that "concurrently with my appointment, the services of J.G.S. Hudson, explosives engineer, Mines Branch were made available and placed at the disposal of the Division", which had assumed departmental status.

It seems appropriate to quote excerpts from the historical and introductory section of Lt. Col. Ogilvie's 1919 report which paid tribute to the determined efforts of Haanel and the Mines Branch to have Canada establish its own Explosives Act. "The frequency with which accidents occurred, particularly in mining and railway construction work, ... and the necessity of having some independent guarantee of the quality of the explosives offered for sale, that in 1909 the whole question was taken up by the Department

Result of accidental explosion of "Virite" at Hull, Que., showing evidence of force of blast

Lt. Col. Gordon Ogilvie, first chief inspector of explosives of Mines with the cooperation of manufacturers and others ...."

"In Canada, on the other hand, the figures given in the Labour Gazette and taking the pre-war period 1904-13 (inclusive), it appears that the total number of fatal accidents was 39% in excess of those reported in the United Kingdom, notwithstanding that at a fair estimate the quantity of explosives manufactured or used in Canada would probably not exceed one-third of the corresponding quantity in the United Kingdom."

"This general condition, realized as it was throughout by him, led the director of the Mines Branch not only to take the initial steps for the consideration of the subject and to urge in each annual report the necessity of introduction of the Act, but to do what, in the absence of legislation, was possible in the way of making inquiries regarding accidents and promulgating useful information in reference thereto .... The cooperation which the Department has already enjoyed with representatives of the industry and with others of knowledge and experience of the conditions obtaining in the various activities concerned with explosives, the system that has been derived from their counsel, give a happy augury of the progress which should result from the continuance of unity of effort."

BASE METALS

Iron was Haanel's preoccupation in the Department of the Interior period and during the first three years of the Department of Mines. His principal staff members involved in the iron ore resource evaluation (including magnetometric surveying) were Nyström and Lindeman, supplemented by B.F. Haanel and Fréchette. External consultants produced reviews on "associated" metals used in steel alloys such as nickel, chromium, tungsten and molybdenum. Other than zinc, which received early attention in regard to processing problems because of appeal from industry, there was little opportunity to devote time to base metals from 1901 to 1909 because the small staff was fully engaged on the ferrous program.

Following Nyström's resignation in 1909, Dr. Alfred W.G. Wilson was appointed on May 1, 1909. He spent the summer studying copper mining in Quebec as well as visiting an abandoned antimony mine at Nicolet and iron ore, soapstone and talc occurrences near Megantic Lake and reported in the 1909 summary report, pp 69-81. H.S. de Schmid and L.H. Cole were appointed as mining engineers in May and August 1910 respectively. de Schmid was allocated to non-metallics. L.H. Cole's first assignment was on metallics, investigating a reported occurrence of tin near Arnprior, Ont. which turned out to be imaginary. Cole's samples showed nil for cassiterite but he did find some scattered zinc blende. He visited the Cobalt silver camp, the Gowganda-Elk River and Shiningtree-Rosey creek silver districts close by, as well as the Porcupine gold district. These reports were given in the 1910 summary report, pp 93-101, indicative of the rapid publication of the branch activities in those days.

Though the divisions of Metalliferous and Nonmetalliferous Deposits were apparently formed some time in 1910, it was not until the 1911 summary report that the official announcement was made. At the outset, the Metalliferous Deposits Division had two classified officers - A.G.W. Wilson, chief and E. Lindeman; the Non-Metalliferous Deposits Division had three officers - H. Fréchette, chief, L.H. Cole and H.S. de Schmid. Wilson in succeeding years was, with his staff, responsible for most of the base metal resource evaluation. The B.C. zinc problem that occupied the attention of the branch for some five years was mostly in the hands of an outside consultant.

Zinc

Following publication of the zinc report in 1905 and the 1906-07 reports on the electrothermic smelting experiments on iron ore at Sault Ste. Marie, Haanel maintained a parallel interest in the electrothermic smelting of both mineral commodities. In the 1907 summary report, p 12, he referred to the installation of an electric induction furnace in Nelson, B.C. for the combined production of lead bullion and spelter. In the 1908 summary report, pp 6-7, he mentioned that, because of his concern to find a satisfactory process for the reduction of large resources of refractory ores of B.C., he obtained particulars of the De Laval electrothermic process when he visited Sweden that year on electric smelting of iron ore. Apparently one plant was handling large quantities of ore at Trollhätten, the same location as the electric iron ore smelter mentioned earlier. On his way home Haanel stopped in London, where he learned that an improved De Laval zinc smelter was nearing completion in London. Furthermore Lord Strathcona, the High Commissioner for Canada, requested him to examine in Swansea an Australian chemical (bisulphite) process producing zinc oxide invented by Sulman-Picard-Hommel, but time did not allow him to do so. However, he obtained particulars of all these processes which he had to accept on a confidential basis because of the competition between the various inventors and so could not publish them. Yet another process - Côté and Pierron - was brought to his notice which he mentioned in the 1909 summary report.

The following developments are recorded by Haanel in his 1910 summary report, pp 11-15. Zinc producers of East and West Kootenay addressed a letter in the form of a petition dated April 7, 1910 (this might have been a misprint and should have been 1909) to the Minister of Mines, outlining the smelting difficulties of their industry. These were:

(1) Adverse transportation and tariff conditions: long hauls by sea to Europe or overland to U.S. smelters and impending increase in the U.S. tariff.
(2) Mixed character of the ores with zinc containing most of the silver; with increase in mining depth, zinc replacing lead component.
(3) Retorting requiring a two-step operation: first recovering zinc, then silver. The double treatment and double losses prevented smelters from paying more than half of the value of silver.

The commercial retort set up earlier at Frank, Alberta and near the Crowsnest coal supply, had to close down due to these difficulties.

Small-scale electric smelting tests were carried out by the industry at Vancouver and were sufficiently promising to have encouraged the operators to set up a semi-industrial furnace at Nelson, B.C., operated by The Canada Zinc Company with a 10-ton per day capacity, where they were able to produce lead-silver bullion, some spelter, and a matte. After spending $70,000 on a plant and $50,000 on operations, funds were exhausted. The producers requested the government for funds to complete the experimental work. Haanel's recommendation was to use $50,000 of unallocated funds earmarked for payment of a federal bounty authorized by Parliament to stimulate domestic production of lead for investigation of the zinc smelting processes invented in Europe, mentioned above, rather than continuing the Canada Zinc Company experiments at Nelson. He suggested that the funds be made available to the Mines Branch to carry out the investigation and then install and try out the plant at Nelson that promised the best commercial success.

A resolution was placed before the House by the Minister of Mines on March 21, 1910, and was adopted. This led to Bill 182, amending the Act "respecting the payment of bounties on lead contained in lead-bearing ores mined in Canada and to promote the production in Canada of zinc." The Bill was passed on April 8, 1910.

Haanel turned to W.R. Ingalls of New York, the central figure in the earlier Zinc Commission, to undertake an investigation for the discovery or development of a method for the economic treatment of the mixed zinc-sulphide ores of Canada in the production of metallic zinc or a marketable zinc product. The proposal was accepted by Ingalls on June 7, 1910.

In the same 1910 summary report, p 15, under the heading "Pending processes for treating zinc ores", Haanel stated candidly that he had received a letter dated July 4, 1910, from F.W. Harbord the "eminent" metallurgist of London, England who was a member of Haanel's Commission of Inquiry into electrothermic smelting of iron ores in Europe in 1904, to the effect that none of the processes which Harbord was engaged to study were as yet ready for investigation. These processes, which are briefly mentioned above, were the same that Haanel recommended to the minister for the investigation by Mines Branch.

A letter dated August 23, 1911, from Ingalls to Haanel was given in the 1911 summary report, pp 14,15. Ingalls stated that a large number of experiments have been made with several forms of furnace in the metallurgical laboratory of Prof. Albert Stansfield at McGill University. These experiments were directed toward discovering the metallurgical conditions that prevented a satisfactory condensation of zinc as molten spelter. He mentioned that there were two zinc electric smelting furnaces operating in Scandinavia, one of 7,000 hp at Trollhättan, Sweden, and the other of 4,000 hp at Sarpsborg, Norway. According to Ingall's information, these furnaces had operated for five or six years without achieving commercial success, and only recently was it claimed that spelter had been produced from ore on an industrial scale. Absolute secrecy was maintained regarding these operations. He emphasized that electric smelting of zinc ores was in the "infancy of the experimental stage".

In the 1912 summary report, pp 8-10, a further lengthy letter from Ingalls of January 13, 1913 was reproduced which emphasized the difficulty arising from "blue powder", a condensate which forms more abundantly in electric than in ordinary smelting. Harbord reported that the electric power consumption at Trollhättan in 1911 in smelting 537 tons of ore was over 2000 kWh per ton of ore, explaining that the high figure was due to the necessity of resmelting two tons of blue powder for every ton of ore smelted. Many countries in Europe were experimenting with electric zinc smelting and this work cost many hundreds of thousands of dollars. In spite of the unpromising indications, Ingalls however ends his letter saying there was a challenge with mixed sulphides as smelters recovering zinc were only extracting 55 to 60 per cent of the lead content and 60 per cent of the precious metals. He was hopeful that the small-scale experiments would lead to a trial in 1913 of an improved system on a larger scale. Ingalls presented a paper on the electro-smelting of zinc at the annual meeting of the Canadian Mining Institute in March 1912 at Toronto.

The McGill tests were completed early in 1913 after experimenting with 32 modifications of the furnace at the experimental scale of a 200- to 250- pound charge in 24 hours. Ingalls recommended a scale-up at Nelson. Meanwhile, an American company was negotiating with the Department of Mines to continue the experimentation with a view to converting the "Canada Zinc" experimental furnace to a commercial plant. The negotiations did not succeed and the Ingalls project proceeded. Prof. Stansfield of McGill retired from the investigation and in his place E. Dedolph, who was his assistant throughout the McGill program, was sent to Nelson to inspect the condition of the existing plant. D.C. Paleologue was specially hired as an electrometallurgist and he was soon joined by George C. Mackenzie, head of the Ore Dressing and Metallurgy Division, who was placed in charge of installing the Ingalls plant. By the end of 1913 the Ingalls proposal of a preheating furnace and an electric smelting furnace and a small Wetherill plant to make zinc oxide was completed. Tests were run to the end of April 1914. The 1914 summary report, pp 4-5, stated that the report of the whole zinc investigation comprising the McGill tests, the large-scale tests at Nelson, and a test of the Johnson electric furnace in Hartford, Connecticut, which were witnessed by B.F. Haanel, Mackenzie, Parsons and Leverin of the Mines Branch, were to be published.

No such report was published but MB Rep 428 by A.W.G. Wilson in 1916, "The production of spelter in Canada", reviewed the economics in Canada and the United States. He concluded that a zinc smelting plant was not feasible and indicated that electrolytic processing, if successfully proven, might be suitable for B.C. ores. At that time an electrolytic plant was under construction at Trail and commenced operating in 1916. The total expenditure of this program, spread over three years from 1912 to 1914, was $46,682.

Aside from the foregoing major investigation of electrothermic zinc smelting, the branch had little involvement with this metal. Less than ten samples of zinc or zinc-lead ores were investigated in the Ore Dressing Laboratory in the ten-year period from 1910 to 1920. Conventional gravity and magnetic separation techniques were mostly used in these investigations. It was not until the following decade that sufficient progress was made in differential or selective flotation techniques to solve separation problems of mixed sulphides.

Molybdenum

Canada had little or no mining of molybdenite prior to World War I, but in 1915 the Colonial Institute of London, England, a resource institution, circularized the British Empire countries in regard to molybdenum. This action arose because Britain required increasing amounts of tough steels for the war effort and there was evidence that there would be insufficient amounts of tungsten.

The concentration of molybdenum ore became a priority project of the Mines Branch. W.B. Timm made a tour of more promising mining prospects and secured samples. The treatment of these ores had to be worked out. Various methods were tried: gravity, electrostatic, and because of the nature of molybdenite being "mica like" flakes, even a wind machine. Eventually the water film flotation gave best results. A modified Woods of Denver separator was adopted. In 1917, dry grinding and water film concentration was replaced by wet grinding and oil flotation in Callow pneumatic cells. A special molybdenite mill was assembled and operated on a commercial scale on Booth Street. Thus in 1916, 2,397.4 tons were treated with the recovery of 43.6 tons of molybdenum sulphide, and in 1917, 1,657 tons were treated with a recovery of 40.5 tons of molybdenum sulphide. The Ottawa office of the Imperial Munitions Board entered into an arrangement whereby the Mines Branch became the millers and assayers to the Board pertaining to the supply of metallic ores and minerals for the war effort. The Board had separate contracts with the larger mines, for example, the International Molybdenum Company of Orillia, Ontario. The ore treatment charge was $5.65 per ton and the value for molybdenum sulphide was set at $1.00 per pound.

Separately from the foregoing project, some 30 molybdenite samples were tested in the Ore Dressing Laboratory between 1910 and 1920. This was the largest number of any mineral investigated, the next largest being 25 samples of iron ore and 10 samples of tungsten ore, the three together representing 40% of all ores investigated which amounted to 140 by the end of 1920 when Haanel retired.

Cobalt

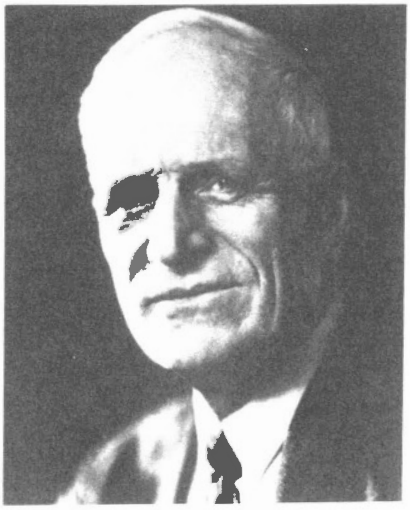
Haanel inaugurated research on cobalt and its uses in 1912 - possibly influenced by failure of industry to credit the value of cobalt in the mixed silver-cobalt ores mined at Cobalt, Ontario, which Haanel visited in 1906. He made an arrangement in 1912 with Dr. H.D. Kalmus, director of the Research Laboratory of Applied Chemistry and Metallurgy at the School of Mining, Kingston, to undertake a comprehensive research study. It can be said that this research inaugurated Mines Branch interest in physical metallurgy.

The program entailed the following projects: (1) preparation of metallic cobalt by reduction of the oxide, (2) physical properties of metallic cobalt, (3) electroplating with cobalt, (4) cobalt alloys with non-corrosive properties, (5) magnetic properties of cobalt and of ferrocobalt. Some of the projects were reported in a preliminary form in the summary reports for 1912, on pp 94-107, for 1913 on pp 99-101, and for 1914 on pp 131-143, but the whole work was published as five separate Mines Branch reports from 1913 to 1916. Kalmus employed up to four assistants and the total cost was approximately $33,580. (MB Rep: English texts 259, 309, 334, 411 and 413; French texts 210, 310, 335, 412 and 414.)

Copper

On his appointment in 1909 at the age of 36, Dr. Alfred W.G. Wilson was given the task of examining the Canadian copper industry with the eventual publication of a monograph on the industry. As his qualifications and appointment to that date were second only to those of the director, and because of his 32 years' service with the Mines Branch, it may be appropriate to give a resumé of his training and experience before he joined the Mines Branch. Wilson was born in Cobourg, Ontario in 1873, where he attended Victoria University and the University of Toronto, graduating in 1893 with a Bachelor of Arts (Honours and a Gold Medal) in Natural Sciences. He had training for a further year at the University of Toronto in assaying, petrography, chemical analysis and industrial chemistry. He then taught science in Ontario high schools after graduating from the Ontario Normal School. From 1898 to 1901, he received post-graduate training at Harvard University in geology and graduated with a Ph.D. degree. He received training in mining engineering at Columbia University, New York, and this led to an appointment for four years at McGill University, teaching geology and taking a course in applied geology. During this period he was engaged in private practice in the summer months, mostly on engineering problems. From 1906 to 1909 he was engaged full-time in consulting work. A large part of his work was connected with railways and included the evaluation of various mineral prospects. He had considerable personal mechanical skill which led him to make a practical contribution in World War I by a new process for making shrapnel balls.

Immediately on appointment, he inspected the copper mines and prospects in the Eastern Townships of Quebec, the only operating mine then being the Eustis mine. His conclusions were that the abandoned mines and prospects did not contain ore in commercial quantities. If there were to be profitable mining, only the richer pockets should be worked and the ore smelted at a central custom smelter. He also inspected the



A.W.G. Wilson, head of Metalliferous Deposits Division (later Mineral Resources Division) abandoned Nicolet antimony mine and some magnetite and hematite occurrences near Megantic Lake. In 1910, his surveys on copper ore were in the Maritimes and Ontario. He also visited the mining fields of Newfoundland from where cupriferous ore was being shipped to the U.S.A. and Wales. He recommended in his report (contained in the 1910 summary report, pp 67-75) that detailed geological surveys and maps be prepared for three areas in Ontario - (1) Central Ontario, embracing the northern portion of Hastings County, (2) the north shore of Lake Superior and (3) the east shore of Lake Superior (Keweenaw). In regard to the latter, Dr. A.C. Lane, previously Michigan State geologist, cooperated with Wilson in providing information on holes drilled by the Calumet and Hecla Mining Company at Port Mamainse, Ontario. This information was published in 1911 in Bulletin 12, MB Rep 111, with Lane as author and an introduction by Wilson. In 1910, Wilson also visited mines and smelters in the United States where the copper ore was similar, and Quebec and other parts of Eastern Canada.

In the following five years, Wilson divided his time between collecting data for a monograph on copper and obtaining information on pyrites as a source of sulphur. Other assignments arising from requests to Haanel were on an ad hoc basis; for example, in the 1912 summary report, Wilson reports on mineral deposits (iron, copper, coal) in the St. Mary's Bay, Nova Scotia area. This investigation was done at the request of C. Jameson, MP of Digby, and did not indicate the presence of economic minerals. In the 1913 summary report, there are reports by the director (p 7) and Wilson (p 26-27) which gave particulars of an investigation Wilson made at a mine and described prospects in the vicinity of Nelson, B.C. The ore was supposed to contain platinum but the samples taken by Wilson showed that neither platinum nor the platinum group metals were present in these samples. In the 1915 summary report there was a report, pp 26-35, on the mining of antimony ores.

As regards the monograph on copper, it was planned to produce two reports, one dealing with mining and processing and the other with smelting. The latter subject was prepared in a report issued in 1913 and was well received in Canada and abroad (33) . The report on copper production was not published because of the exigencies and fast-changing condition brought about by the war. Thus the copper production in 1914 was about 74,000,000 pounds, rising to 103,000,000 pounds in 1915. Wilson also prepared a preliminary report, pp 13-25, for the 1915 summary report entitled "Possibility of producing refined copper in Canada" which contained sections on copper production, the pros and cons of refining in Canada, and the organization of a refinery. The copper production in British Columbia at that time was nearly two thirds of the Canadian total, which included Ontario and Quebec. Wilson indicated that the B.C. coast offered a strategic location for a refinery because of the large proportion of copper production coming from the Britannia and Anyox mines on Howe Sound and Portland Canal respectively. He would have preferred a Canadian-owned company like Cominco to own such a refinery. Trail had a lead electrolytic refinery since 1902 and zinc and copper refineries were built by 1916, the first in Canada.

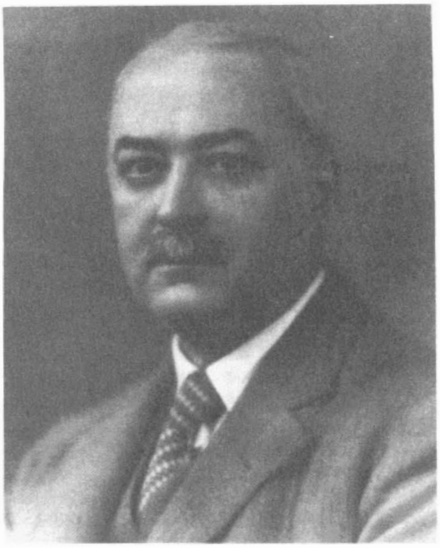
Pyrites

Though pyrites is a metal sulphide, its primary interest to Canada was as a source of sulphur in the era up to post World War II - prior to the large production from sour natural gas.

As early as 1909, Wilson on his first visit to Quebec on his study of copper, was struck by the large quantities of pulpwood or wood pulp being exported, mainly to the U.S.A. He was thinking, of course, of the potential requirements for sulphur in a domestic pulp and paper industry. In the 1909 summary report, he gave figures for the export of wood and wood pulp which amounted to nearly $9,000,000. One of his statements is revealing in the light of the presently expressed opinions: "It is only within very recent years that many of our Canadian commercial organizations have recognized the principle that is almost fundamental to successful operation - that the profits which accrue in any enterprise are greatest when the same organization markets finished products - the source of raw material as well as the manufacture being controlled by the same organization" (34).

Wilson returned to the study of pyrites in 1911 owing largely to a rising import demand by the U.S. industry mostly for sulphuric acid manufacture. Much of the pyrites ore imported into the United States at that time came from Spain. The Canadian picture during the period from 1906 to 1911 showed that Canadian production, largely from Ontario and Quebec, rose from nearly 43,000 to nearly 83,000 tons, but that only 32,302 tons were exported in 1911. Wilson thought there existed a potential export market for more than 200,000 tons. He considered that a pyrites producers' association would help the small producers market their product. He wondered about the possible development of a large domestic market for sulphur in a Canadian pulp and paper industry. He recommended that a report on pyrites be prepared, and this was issued in 1912 (35). Wilson reported on the Hall process for desulphurizing sulphide ores by distilling the sulphur to elemental form in a reducing atmosphere with the minimum production of hydrogen sulphide and sulphur dioxide (1913 MB Sum Rep, pp 27-30). The process was patented in many countries and was to be tested at a copper smelter in California, but no further information was published in the Mines Branch literature. As part of his duties during the war, he attended a meeting in St. Louis, Missouri, in 1917 of the War Minerals Committee of the U.S. at which additional quantities of pyrites from Canada for the U.S. requirements were discussed.

It should be noted that A.H.A. Robinson with two years in the Fuels Division joined the Metalliferous Deposits Division in 1913, working with E. Lindeman on evaluation of iron ore occurrences until the latter's resignation in 1915. Wilson for part of the 1918 season, and Robinson for the whole season, investigated pyrites and pyrrhotite deposits in Ontario, Quebec and the Maritimes. In Quebec, Robinson found that no new discoveries had been made in the Eastern Townships subsequent to the publication in 1915 by J.A. Bancroft of the Quebec Bureau of Mines of "Report on the copper deposits of the Eastern Townships in the Province of Quebec". In the Maritimes, he found no evidence of promising prospects other than a pyrrhotite deposit near St. Stephen, New Brunswick. He spent most of his time in northern and northwestern Ontario. His report in the 1918 summary report is divided into five sections: deposits accessible from the Canadian Northern Railway from Fort Frances to Sudbury; an active iron pyrites mine at Nickel Lake, Sudbury district; deposits accessible from Canadian Pacific Railway from Kenora to Sudbury; deposits accessible from the National



A.H.A. Robinson, assistant engineer

Transcontinental Railway, Winnipeg to Cochrane; and deposits accessible from the Temiskaming and Northern Ontario Railway, North Bay to Cochrane (1918 MB Sum Rep, pp 15-46).

A second edition of "Pyrites in Canada" was anticipated but never published.

GOLD

Lode Mining

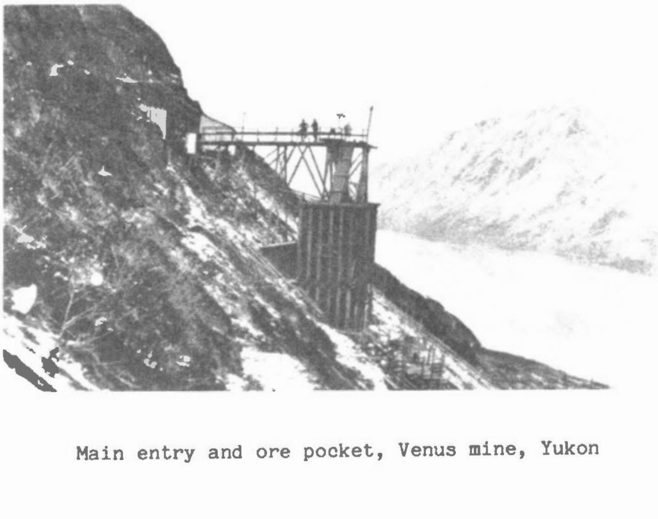
It is not surprising that Haanel, in view of his early interest in Yukon mining and the downturn in placer gold mining since the peak of 1900, commissioned in 1912 a Montreal mining engineer, T.A. MacLean, to report on Yukon lode mining, particularly in the Dawson mining district, the centre of the "gold rush" some 15 years previously (36). Two seasons were spent on this assignment in 1912 and 1913. There were many quartz mining claims staked out, some dating to the previous century, but the results had been disappointing. The Yukon mining association appealed to the Dominion Government for assistance in evaluating the prospects of lode mining in the territory. It may be noted that placer gold production, peaking at about 1 million ounces in 1901, had dropped to about 250,000 ounces in 1912 with lode mining accounting for only about 500 ounces; this latter production was derived from the one Lone Star mine. MacLean visited 48 properties in the Dawson mining district, the majority showing haphazard mining and no more development than the mining claim assessment work required. Two hundred and eighty-nine samples were taken, showing spotty coarse free gold with much of the quartz barren, supporting the geologists' general view of the detrital character of placer gold. No high-grade ore was indicated.

He also visited the Dublin Gulch area in the Duncan Creek mining district some fifty miles northwest, a good part by trail from Mayo, in later years to become the centre of high-grade silver-lead-low-zinc mining situated 168 miles up the Stewart from its confluence with the Yukon (Lewes) River. Prospecting was being done on six groups of properties, all showing complex, finely disseminated gold in an ore containing iron and arsenic that MacLean considered would be difficult to process. This factor and the poor accessibility led him to suggest that economics would require an $8 ore compared with a $3 or $4 ore or less in the Dawson area. There is no evidence that these prospects ever became producing mines. On a second visit to this area in 1913 he inspected a rich argentiferous lead discovery in Galena Creek, a tributary of the McQuesten River, 17 miles off the road to Dublin Gulch. He secured information from the property that was mentioned in the summary report for 1913, p 38, but not in his final report. Seventy-seven samples were taken and reported on in the final report.

MacLean also visited the Whitehorse and Conrad Mining Districts of southern Yukon where copper and lead ores with values of silver and gold occurred. The Grafter mine in the Whitehorse district which showed the largest development at the time of Dr. Haanel's visit in 1901 had advanced somewhat but the principal mine in 1912 appeared to have been the Pueblo which was expected to ship 30,000 tons of ore that year.

Six samples were taken on the Whitehorse copper belt with one from the Valery prospect assaying nearly 19% copper and 12 samples from gold quartz prospects

Dumping ore from open cut into chute, Lone Star mine, Yukon



Main entry and ore pocket, Venus mine, Yukon ten miles east of Whitehorse which only showed traces of gold.

MacLean then visited the Conrad mining district south of Whitehorse near the B.C. border where he took 59 samples from prospects and mines in the Wheaton and Windy Arm sections. In the first area, prospecting was limited possibly because of poor accessibility and high transportation costs. In the Windy Arm section which is closer to the Yukon and White Pass railway, more prospecting and some mining had taken place, particularly at the Venus property where a mill had been erected which ran for several months. Col. J.H. Conrad and Associates were reputed to have spent several hundred thousand dollars between 1905 and 1912 when the properties were abandoned. No clear reason was advanced for this decision.

The ore here occurred in quartz veins carrying gold and silver with galena and other minerals. In the Windy Arm section, argentiferous galena predominated with some high values in silver.

Seemingly, the publication of the assays of samples collected in this project was to rekindle the interest in these areas and stimulate further systematic sampling and development, and to bring in mines on promising prospects. However, there appears to have been no subsequent activity in any of the districts reviewed in MacLean's report.

MacLean visited the White River area in the southwest of the Yukon, taking an arduous trail from Dawson City to Canyon City where gold and silver were reported as well as amygdaloid copper ore. The area prospectors were requesting the Dominion Government to build a railway to exploit the copper ores. MacLean found no development of any consequence in the area but did not rule out future economic mining.

Special Studies

Wilson had to share his departmental duties with service to the wartime agencies from 1915 to 1919; in 1915 he was appointed consultant to the Canadian Shell Committee and soon after as advisor to the War Trade Board, specifically on pyrites and sulphur but also on other technical matters. For example, on the initiative of the War Trade Board, Wilson and S. Barr of Canada Cement Company inspected 11 installations in the United States where potash was being recovered from flue gases. Bulletin 29 (MB Rep 507) by Wilson was published in 1919.

In 1916, Haanel placed Wilson in charge of the preparation of a special volume on molybdenum and its industrial applications as well as of a preliminary investigation of the chemical industries of Canada, with particular reference to the role of minerals in these industries. The latter study was of special importance to the wartime agencies. However, the two reports were published much later, one on the chemical industries in 1924 (37), the other on molybdenum in 1925 (38). In the 1920 summary report, pp 5-8, Wilson gave a preview of the study under the title "The development of chemical and metallurgical industries in Canada". In this preview he postulated many arguments that one hears today, such as the importance of the mineral industries in increasing the country's wealth, the large proportion of products in common use that originate from the mine, and the small percentage of the population that produces the initial mineral supply. He pointed out the large importation of mine products (estimating it at half of the total imports of all commodities and goods which in 1919 amounted to nearly $920,000,000) and he suggested there should be scope for greater domestic utilization of Canadian mineral resources, the latter being a principal reason for such a study in peacetime.

It should be noted that after Haanel's retirement and reorganization of the branch that took place in 1921 under a new minister and deputy minister, A.W.G. Wilson became chief of the Mineral Resources Division.

INDUSTRIAL MINERALS

Haanel continued his policy of the Department of the Interior period of devoting quite a proportion of Mines Branch effort to non-metallic minerals. He recognized there was a variety of non-metallic minerals in Canada that lent themselves to mining and processing for domestic use and export.

At the time of the formation of the Department of Mines he had only three professional engineers - Nyström, and E. Lindeman and B.F. Haanel, temporary - who were busy on metals and fuels. He therefore continued to hire consultants for the investigations on non-metallics. His instruction to them was to prepare informative reports that dealt not only with occurrences and properties of the minerals but also their conversion to products of specific use.

In the period 1907 to 1909, two more professionals, Howells Fréchette and A.W.G. Wilson, were hired, and in 1910, H.S. de Schmid and L.H. Cole were appointed. Fréchette, a dedicated and modest man, served the Mines Branch for 38 years, having started in 1908 in the program on iron. de Schmid was assigned to study mica in Quebec and Ontario, and Cole spent his first season on metals in Ontario. In 1911, when formal organization of the Mines Branch was set up, Fréchette became chief of the Non-Metalliferous Deposits Division, with Cole and de Schmid as assistant engineers. S.C. Ells was appointed to this division in 1913. As previously indicated, he was concerned from the start principally with studies of the bituminous sands of Alberta.

Analysis of small samples was done in the Central Chemical Laboratory but large samples for treatment tests were investigated in the Ore Dressing Laboratory. Of the 140 large samples examined in the period from 1911 to 1920, 19 could be described as industrial minerals - six graphite, two fluorite, four sulphur (pyritic), and one each of corundum, garnet, silica, sandstone, magnesite, barite, and rare earth (euxenite). These samples were received largely towards the end of the period.

On his appointment to the position of chief of the Division of Non-Metalliferous Deposits in 1911, H. Fréchette made an evaluation of non-metallic minerals used in the manufacturing industry of Canada. A questionnaire was sent out by agreement with the Canadian Manufacturers Association to a large number of its members. At that time there was no single complete list of manufacturers. The Mines Branch contacted and visited 1313 firms of which 1097 were true manufacturers, and of these 740 used non-metallics, representing 50 distinct industries. The numerically leading min-

H. Fréchette, chief of Non-Metalliferous Deposits Division, (CMJ, 1930)

H.S. deSchmid, assistant engineer (later changed name to H.S. Spence (CMJ, 1930)

L.H. Cole, assistant engineer

eral was graphite with 198 firms using this commodity in the manufacture of their market products; moulding sand was next with 192 firms. Fire clay mineral was in third position of use. The data for a covering report were being refined until the outbreak of World War I, but the report was never published.

Asbestos

In the early period from 1901 to 1907, F. Cirkel of Montreal, who produced the first reports on mica, asbestos and graphite in 1905 was commissioned in 1907 as one of the contributors to the Ontario section of the proposed report on the mining and metallurgical industries of Canada. In 1908, he was also asked to update the 1905 report on asbestos, largely because of a petition sent under cover of a letter dated July 11, 1908, from P. Anger, Quebec City notary, representing parties interested in the development of the asbestos industry in Quebec, requesting a competent engineer to (1) delineate the new Broughton asbestos belt and (2) issue a new edition of the 1905 monograph on asbestos, embodying the new survey and prevailing conditions governing the industry. The petition mentioned that the industry had benefited by the early monograph. At that date there were three mines and mills with a total capacity of 800 tons of asbestos ore per day, and two other mines were under construction that would add 600 tons per day to the output. The new monograph was published in 1910 (39).

Gypsum and Salt

W.F. Jennison of Jennison and Dahl was hired in 1907 as contributor to the Nova Scotia and New Brunswick sections of the report on the mining and metallurgical industries of Canada. In 1908, on completion of this assignment, Jennison was asked by the director to make a survey of the gypsum industry in Nova Scotia and New Brunswick, including the Magdalen Islands in Quebec. This was done over the two seasons of 1908 and 1909 and reported in MB Rep 84 in English, and 233 in French. At the time of the survey, most of the gypsum was produced by U.S.A. companies with the raw product shipped to that country for further treatment.

L.H. Cole was assigned to the study of gypsum and salt in 1911. He spent 1911 and 1912 in the field in central and Western Canada as well as in the Maritimes. The studies resulted in two separate monographs - one on the gypsum industry published in 1913 (40), and one on the salt industry published in 1915 (41). In 1913 he spent part of a season on the salt springs of Manitoba, reported in the 1913 summary report, pp 50-53.

Mica

Immediately on his appointment in 1910, H.S. de Schmid was given the task of updating information on mica for a second edition of the monograph on this commodity by Cirkel, which was published in 1905 and was out of print. Accordingly, he spent the summer of 1910 in Ontario and Quebec procuring new information. He visited some 200 properties, most of which were in Quebec and were closed down due to drop in demand for mica. The second edition of the mica monograph was published in 1912 (42). In 1913, de Schmid reported on mica occurrences in the Tête Jaune Cache and Big Bend districts of British Columbia at high altitudes and in poorly accessible terrain.

Building Stone

Dr. W.A. Parks of the University of Toronto was engaged in 1910 to make a survey of the building and ornamental stones of Canada that included granite, marble and limestone and this work continued over seven seasons, resulting in a five-volume monograph published in separate reports from 1912 to 1917 (43). This seemingly considerable effort demonstrates Haanel's concern to publicize the diversified nature of Canadian mineral resources and the emphasis he placed on the domestic use of mineral products.

Phosphate and Feldspar

H.S. de Schmid spent part of the 1911 season and the whole of 1912 in evaluating the mining and competitive position of phosphate and feldspar in Canada. In 1911, a small phosphate production associated with mining of mica was mostly derived from the Lièvre River near Buckingham, Quebec; phosphate was supplied in 1911 to two firms in Buckingham - the Electric Reduction Company and the Capleton Chemical and Fertilizer Company. The price of Canadian phosphate was more than twice the American price, hence there was little incentive to expand. There was a progressive reduction in phosphate production from about 20,000 tons including a small production in Ontario, to 1478 tons in 1910 and 621 tons in 1911.

The position with feldspar was the reverse. The principal producer was the Kingston Feldspar and Mining Company with mines in Portland and Bedford, Ontario. The company had mined up to 100 tons per day of high-grade feldspar, which was mostly shipped to the United States. The Canadian white feldspar could compete although the price was higher than the less pure material available south of the border. Canadian output in 1910 was 15,809 tons, and in 1911, 17,723 tons. Other mines and prospects were inspected by de Schmid in Ontario and Quebec but their products were not of the same high purity. The monograph on feldspar in Canada by de Schmid was published in 1916 (44).

In 1915 de Schmid followed up a reported discovery of phosphate rock near Banff. It had been hoped that this was an extension of the rich Montana beds but it turned out that the bed was thin and low in phosphoric acid. Bulletin 12 was published on this investigation titled "Investigation of a reported discovery of phosphate at Banff, Alberta" by H.S. de Schmid, [MB Rep 385 (Engl) 1916; Rep 386 (Fr) 1917]. In 1916, de Schmid with an assistant, C.W. Greenland, carried out a reconnaissance survey south of Banff towards the Montana border by the Spray Lakes, the Kanasaskis Lakes, and Elk River to Michel, British Columbia, with a side survey of the Blairmore-Frank rocks. The phosphate bed discovered at Banff was traced to Tent Mountain, B.C. near the Crowsnest Pass. Unfortunately, the bed was much thinner and the phosphoric acid content much lower than at Banff. Practically all the shales, including those containing the coal measures such as the Fernie shales, showed the presence of phosphoric acid. A report "Phosphate in Canada" by H.S. Spence was deferred because of the war but published in 1920 (45).

Limestone, Sand and Sandstone

For a period of five years, Fréchette and Cole were busy compiling field data on limestones, sands and sandstones. Fréchette was responsible for the limestones and carried out his field work extensively in Quebec and Ontario. He also reported on magnesite in Quebec. This work was reported in the summary reports for the years 1914 to 1918 inclusive.

Cole spent the 1914 season in evaluating sand deposits in the Ottawa and St. Lawrence Valleys of Quebec. Only three of about 160 samples were deemed satisfactory for foundry application and none for glass manufacture. In 1915, Cole made surveys of the Eastern Townships, the section from Lachute to Ottawa, and the Gatineau Valley. One hundred and eighty-seven samples of sand were procured. The rest of the season was taken up with the installation of apparatus in the Ceramic and Structural Materials Laboratories which were placed in the basement of the Sussex Street Mines Branch Building. In the Structural Materials Laboratory there were inter alia the following Olsen machines: a 200,000-lb compression machine and a 2,000-lb automatic cement testing machine for both compression and transverse tests.

Cole spent most of the 1916 season studying test procedures and the uses of sand and associated minerals. A good part of his time was also taken in preparing and equipping the proper testing laboratory and testing the samples of sands taken during the 1914 and 1915 seasons. He visited a number of laboratories in the United States and also the Toronto-Hamilton Highway Commission on their methods of testing the sands. Furthermore, he examined and sampled some of the sands in the vicinity of Hamilton.

Cole studied the uses of sands according to a tentative division of sands, crushed sandstones, and quartz into classes according to use.

(1) silica sand, crushed sandstone, quartz and quartzite
(2) moulding sand
(3) building sand
(4) sand for brick making
(5) sand for miscellaneous use.

This key list enabled Cole to study the application details in each of the five classes:

(1) <u>Silica sand</u>:
Applications for glass manufacture, ceramics, silica sands for moulds and metallurgy, silica brick, manufacture of ferro-silicon, carborundum, and as dusting material for roofing papers.

(2) <u>Moulding sand</u>:
A thorough review of all properties and tests required for moulding sands was made. He had assistance in testing from Alex Fleck Foundry and the brass foundry of Lawson Brothers, both of Ottawa. The moulding sand came from a site 2.5 miles west of Brockville, Ontario. A paper on the foregoing entitled "The occurrence and testing of foundry moulding sands" was presented by Cole at the annual meeting of the CIM in March 1917.

(3) <u>Building sand</u>:
For use in concrete or in mortar.

(4) <u>Sand for brick making</u>:
As an addition to clay to prevent high shrinkage, parting sands to dust the brick and tile moulds to prevent sticking.

(5) <u>Other uses</u>:
Blast sand, sand for sand-lime brick, abrasives and grinding sands, sweeping compound, filtration plants, friction sands to ensure gripping on slippery rails, and for mixing with asphalt.

Cole considered that all these uses could be satisfied from domestic deposits. He spent the 1917 season in Nova Scotia investigating the sandstones for "pulpstones" and the rest of the time in Quebec and Ontario on sands and sandstones. The Nova Scotia work was reported in Bulletin 19 (MB Rep 466, 1917). The summer of 1918 was spent on silica and moulding sand resources of Ontario, Quebec and all three Maritime Provinces. While in Nova Scotia he visited the location of the first discovery of rock salt in Canada near Malagash, Cumberland County. In 1919, Cole assisted Keele, chief of the Ceramics Division, on the survey of structural materials in the St. Lawrence River Valley.

Graphite

In 1916, de Schmid examined an occurrence of graphite near Cranbrook, B.C., reported in the 1916 summary report, pp 34,35. He found this to be impure. There was at that time a substantial demand for graphite flake for war purposes by the U.S. market, which Canada could not satisfy. de Schmid, who had changed his surname to Spence, was requested in 1917 to investigate the cause of this shortfall. He found that (a) there was no suitable concentration method; (b) insufficient development work had been done at the mines to ensure that a mill would be economically viable; and (c) that remote location of the mines was a deterrent. The Ore Dressing Laboratory of the Mines Branch was carrying out concentrating tests on graphite ore and found that oil flotation gave good separation. However, the war was ending and the demand for graphite was considerably reduced. Spence continued to collect data for a monograph on the graphite industry which was published in 1920 (46), replacing the 1905 report by Cirkel which was out of print.

Miscellaneous Minerals

In addition to the industrial minerals described above that received emphasis, when a staff member was available Haanel would have him make field enquiries on other non-metallic minerals, and at times even metals were covered by the same individual. Thus, de Schmid spent the 1914 summer season on the following minerals described in the 1914 summary report, pp 53-59:

(1) Actinolite:
A variety of amphibole and a substitute for asbestos with deposits in Hastings and Lennox Counties of Ontario.

(2) Barytes:
Largely in Nova Scotia and mostly exported to the United States; occurrences in New Brunswick and Quebec (Hull) as well as in Ontario. In spite of an annual domestic consumption of 3500 tons by 35 firms, over 80 per cent was imported.

(3) Fluorspar:
Produced in Nova Scotia at Cheticamp and in Ontario at Madoc. Annual consumption by 25 firms was 10,540 tons of which 10,500 tons was being imported and only 40 tons supplied domestically.

(4) Infusorial earth:
Infusorial earth, or tripoli, chiefly used for abrasive and polishing powders. Only one company in Nova Scotia produced and exported the product. Some 150 firms used small amounts, importing their entire requirements.

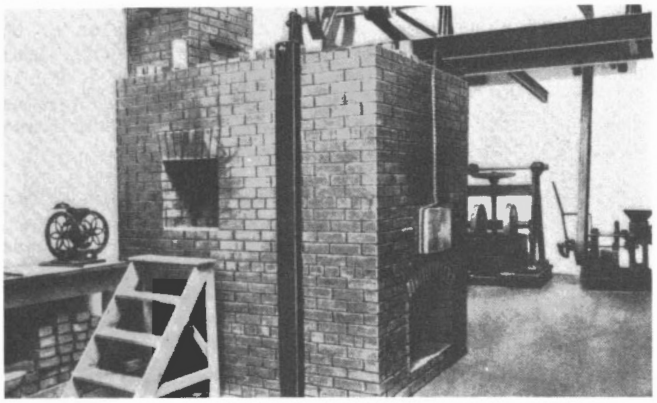
(5) Talc:
Two producers in Hastings County, Ontario had a combined output in 1913 of over 12,000 tons. There were 170 firms in Canada that used talc and they consumed 4000 tons of domestic and 750 tons of imported mineral. In the foregoing list, talc was the only mineral that was supplied entirely from domestic production.

(6) Manganese and Tungsten:
These metallic ores were included in the survey probably because of the potential demands created by World War I. Small-scale mining of pyrolusite or manganese dioxide had taken place at the end of the past century in Nova Scotia and New Brunswick but had ceased because of the lower-cost imports from Russia and India. At the time of de Schmid's visit to the Maritimes, the Isabella mine in Richmond County, Cape Breton, was reopened by the Dominion Iron and Steel Company to meet the requirements of their own steel plant in Sydney. There was also a mine at New Ross in Lunenburg County, Nova Scotia, but at the time of de Schmid's visit it was not operating, though a large new mill building had just been constructed. Schmid's conclusions were that, while the deposits were small, they were also rich and could supply the battery, glass and varnish trades. As regards prospects for tungsten in the Maritimes, these were disappointing.

In 1919, Spence resumed the review of various industrial minerals presumably considered to have some potential value for internal or external markets; first he reviewed talc and soapstone, barytes, celestite (strontium sulphate) and strontianite (strontium carbonate), and in 1920, he covered barytes, celestite, talc and bentonite. Emphasis was placed on procuring data on barytes and strontium, the latter presumably because celestite can be a substitute for barytes in the paint and rubber industries. A monograph on barium and strontium in Canada was published in 1922 (47).

Ceramics

Haanel, in many allusions to the objectives of the Mines Branch activities, used the words "practical", "economic" and "commercial". He was not satisfied with stopping at the treatment stage of raw mineral resources; he required to know the end use of these resources. All monographs and reports on mineral commodities included chapters on the vendible products that could be made from the commodity in question. His concern usually was connected with the importation of merchantable products made from mineral resources available in Canada. Thus, in the 1913 summary report, Haanel included a letter he addressed to Minister Coderre justifying the establishment of a Ceramics Division. He pointed out that in 1912, $17 million was spent on clay products in Canada, 68% of which was imported. He recalled his early interest in the Department of the Interior period on surveys made on clays and shales in Manitoba and also on the report commissioned by the Geological Survey in 1909 on the clay and shale resources of Canada, the author being Professor H. Ries of Cornell University assisted by Joseph Keele of the Geological Survey. Haanel referred to an application from Principal Falconer of the University of Toronto for a grant to assist the univer-



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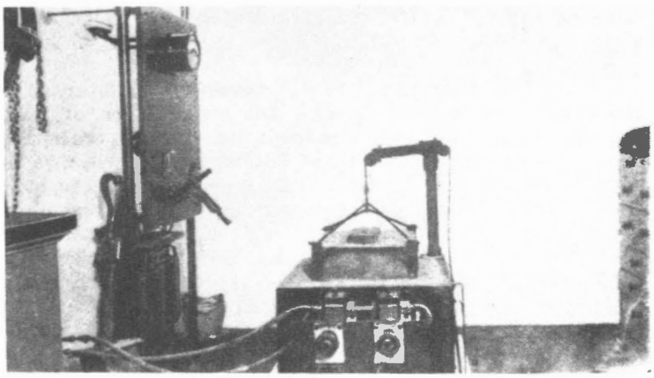

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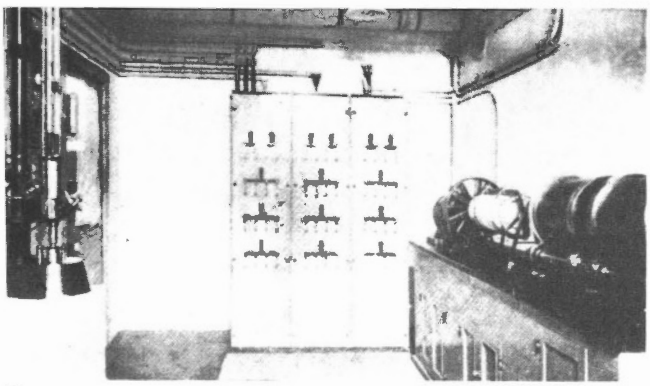

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Ceramic Laboratory, Sussex Street, showing; 1 - cement and brick kilns; 2 - Hoskins electric furnace for testing refractory clays; 3 - impact machine and pebble grinding mills

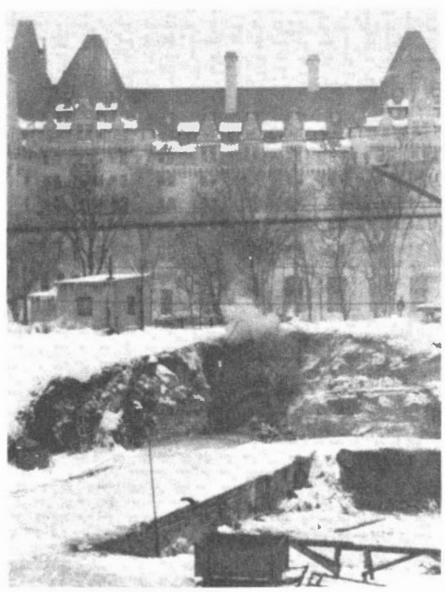
sity in "demonstrative" work being carried out at the college laboratories. He argued against the grant, as it would not help the development of a Canadian clay industry, and expressed himself in favour of a laboratory at the Mines Branch.

A laboratory was established in the basement of the Sussex Street building in 1915. Joseph Keele was appointed chief of the division and N.B. Davis, assistant engineer. Keele managed the same year to make a survey of clay and shales in the Moncton area of New Brunswick and in northern and western Ontario. Davis spent the summer of 1915 in southern Saskatchewan principally in studying fine clays, and completed the survey in the 1916 season. A separate report was published in 1918 (48). Davis resigned from his position in 1917. No appointment to fill this vacancy was made until 1920 because of the unavailability of a suitable candidate. Keele was assisted by having samples provided by officers of the Geological Survey and Mines Branch. He himself was a hard worker as attested to by his individual reports in the summary reports from 1915 to 1921. In these reports he reviewed the countrywide occurrences of clay and shale as they came to light, giving details on the specialized clays - structural, pottery, kaolin and refractory materials, for ceramic and metallurgical uses.

At the request of the Power Board of Canada in 1919, Keele assisted by Cole carried out a survey of structural materials along the St. Lawrence River between Prescott and Lachine. The objectives of this study were to inquire into the character of bedrock as well as of the overlying and unconsolidated formations as they would affect storage of water, or deepening and deflecting the canal system. The work resulted in a report published in 1922 (49). Keele returned to the Geological Survey in October 1921.

Road Materials

Dr. Leopold Reinecke of the Geological Survey started a survey of road materials in 1913, urged by the Ontario Highway Commission on account of the growing automobile traffic. At first the necessary testing of materials was done by laboratories outside the department. This led Dr. Haanel in 1916 to build a two-floor annex at the rear of the Sussex Street Mines Branch building. The road testing laboratory was equipped to test materials according to tests specified by the American Association for Testing Materials. Field work was started in the same year by K.A. Clark and two assistants, R.H. Picher and H. Gauthier, along



Building annex to Sussex Street Mines Branch building the proposed highways between Toronto and Montreal from Port Hope to the Quebec border and from Hull to Montreal. Samples were also taken from quarries supplying the Montreal area. Reinecke provided samples from the Rideau waterway and from Saskatchewan. During 1918, investigations were carried out in Manitoba, the Rocky Mountains Park in Alberta, and British Columbia. Samples of rock, gravel, and bedrock were collected from these provinces as well as some from Nova Scotia. In addition, soil samples were examined to test their adequacy as a road surfacing material. The report on Alberta bituminous sands for rural roads by G.C. Parker (see Bituminous Sands) was included with the 1918 report of the Division, pp 194-200. In 1919, road and soil conditions were investigated at Winnipeg and Brandon, Manitoba. Further work was done in the Rocky Mountains Park. Some additional sampling was also carried out in connection with the investigation by Keele and Cole for the Power Board of Canada along the St. Lawrence Valley from Morrisburg to the Quebec border, as well as in the counties of Chateauguay and Beauharnois, Quebec and at Renfrew, Ontario. Clark resigned in 1920 and Gauthier was placed in charge, writing the report of the division for that year. Bulletin 32 by Picher on his work from the Quebec boundary to Cardinal, Ontario in the St. Lawrence Valley, was published in 1920 (50).

Chemistry Division

Haanel, as stated in several annual summary reports, regarded the Chemistry Division as an important part of the Mines Branch contribution to the mining industry of Canada. He apparently did not consider the central Chemistry Laboratory as a purely supporting service. He appreciated that the complexity of minerals would require complex analytical procedures. From the start, chemists like Wait, Connor and Leverin were regarded as consultants for the particular minerals in which they were specializing. The director also realized the importance that chemistry played in evaluating the economic or commercial limits of resources - quality evaluation of resources was a principal role for the Mines Branch throughout its history. Hence he gave the chemists the full status of a division which lasted until the demise of the Department of Mines in 1936.

At the formation of the Department of Mines in 1907, there were two chemistry laboratories: the original laboratory specializing in complex rock analysis and belonging to the Geological Survey on Sussex Street with E.G. Wait as senior chemist, and M.F. Connor as assistant chemist; and the Mines Branch laboratory in Thistle Chambers on Wellington Street, with a lone chemist, H.A. Leverin specializing in iron ore, gold and silver analyses. There is no evidence that these men had permanent laboratory assistants, and for five years they laboured with a constantly increasing workload. In his annual reports Wait used words of high praise for the work of these assistants. In the peak year of 1909, 875 samples were dealt with requiring several thousand determinations. A scale of charges was established on January 29, 1909 to divert purely commercial samples and avoid competition with private laboratories.

In December 1911, the Sussex Street building was closed for internal reconstruction and remained inoperative for nearly eighteen months. During this period two groups had to work in cramped quarters in Thistle Chambers where all the chemical samples of the branch were analyzed including coal, copper, iron, etc. but not producer gas samples which were handled at the Booth Street site from 1911 on. In November 1912, a chemist, N.L. Turner, previously at the Bureau of Mines of Ontario, was added to the staff.

In May 1913, the Chemistry Division comprising the two original laboratories was transferred to a modern laboratory on the third floor of the Sussex Street building. This laboratory occupied 2,961 square feet of which the main laboratory accounted for 1,133 square feet. There were ten additional rooms that included laboratories for assaying, water analysis, special research, and spectroscopy, a balance room, library and chemists' offices, storage and supply room. It should be remembered that separate laboratories for the engineering needs of the Fuels Division and the Ore Dressing and Metallurgical Division on Booth Street were already in operation.

In the summer of 1914, research was started on the mineral waters of Canada, the consumption of which was in vogue for the treatment of various maladies. Dr. John Satterly, Associate Professor of Physics at the University of Toronto, assisted by R.T. Elworthy, from London (England), carried out these investigations, the latter staying on and becoming a permanent employee of the Mines Branch in 1915. An interesting feature of this investigation was determination of the radioactivity of the waters which were sampled mostly from springs but also from wells. As half of the "radium emanation" (radon) decays within a few days, three locations were set up to handle samples: Mines Branch, Ottawa, the bottling works of Caledonia Springs Company, Ontario, and the Macdonald Physics Building of McGill University.

Electroscopic facilities were set up for expeditious determination of emitted radiation at each of these three locations. A list of springs visited and sampled was given in the 1914 summary report, pp 155-156. Analyses were also made of samples reported in "Artesian and other deep wells of the Island of Montreal" by Dr. F.D. Adams of the Geological Survey. The full chemical analyses including dissolved radium

F.G. Wait, chief, Division of Chemistry

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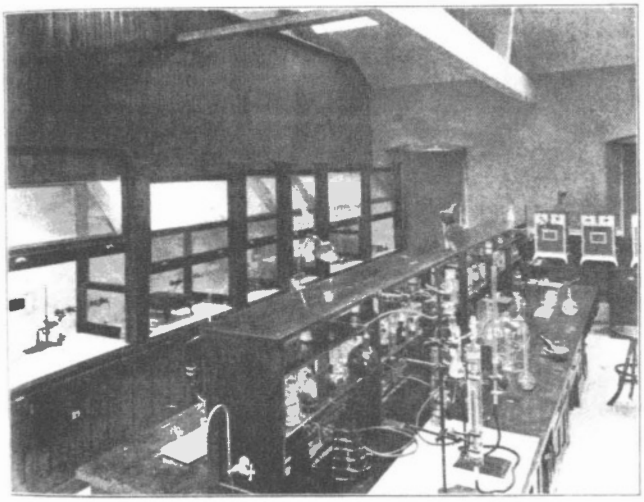

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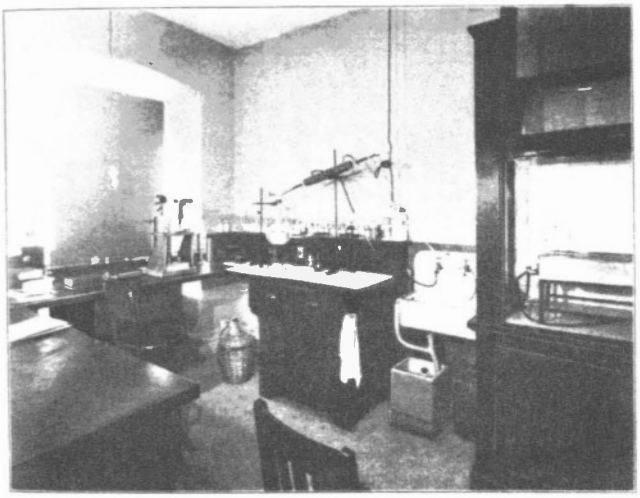

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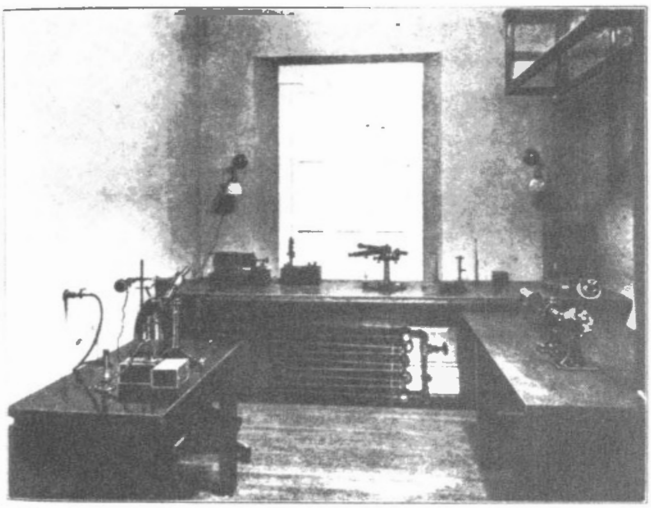

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Chemistry Division, Sussex Street: 1 - Main chemical laboratory showing work table; 2 - draught cupboards; 3 - water analysis laboratory, and 4 - spectroscopic laboratory

salts were determined at the Mines Branch. Bulletins 16 and 20 were published in 1917 and 1918 respectively (51).

A revised schedule of fees was issued on December 1, 1911. No fee exceeded $25 and this was charged for a complete analysis of an iron ore, or a complete analysis of a clay or shale, or the ultimate analysis of coal. Most single and simple analyses were $2 - $3 each.

By 1916 the laboratory found itself in considerable demand for analyses of war materials by both Canadian and British government agencies directly concerned with the prosecution of World War I, such as the War Purchasing Commission, the Canadian Munitions Resources Commission, and the Imperial Munitions Board. An increase in analyses of metals such as ferro-alloys and steels took place during this period.

Laboratories of the Mines Branch in 1917

It may be appropriate to review the laboratories that by 1917 had been set up during Haanel's period of service. The central Chemistry Laboratory was on the third floor of the Sussex Street building. In the basement were three adjoining laboratories - the Ceramics Laboratory for testing clays and for fabricating samples of ceramic ware; the Structural Materials Laboratory for testing concrete, concrete-making materials, asphalts and sands for foundry purposes and glass manufacture; and a Metallographic Laboratory for examination of steels and alloys. In 1916, a Road Materials Laboratory was housed and equipped in a small annex specially constructed adjoining the Ceramics Laboratory which shared some of the space in the new laboratory.

In the Booth Street area, there were two ad-

New headquarters of the Mines Branch of the Department of Mines at corner of Sussex and George Streets, Ottawa

joining buildings housing (a) the Fuels Testing Laboratories including analytical laboratories for analyzing solid, liquid and gaseous fuels and mine air as well as conducting bench-scale conversion tests, together with a semi-industrial pilot plant for conducting boiler and producer gas tests, and (b) the Ore Dressing Laboratories including a chemistry laboratory for ore and mill product analysis and a pilot plant laboratory equipped with bench and industrial-scale apparatus. The preliminary laboratory scale determined the appropriate flowsheet to be adopted in the industrial-scale tests. The design of the plant allowed ore dressing combinations with as little handling of the ore as possible. This equipment comprised crushing, sampling and grinding facilities, magnetic and electrostatic separation, hydraulic and pneumatic jigs, concentrating tables, amalgamation, cyanidation, oil and water flotation, and in a separate laboratory, roasting and sintering.

Haanel recognized the importance of having analytical laboratories in close proximity to the scaled-up plants for treatment and conversion of large samples. From 1917 on, the Fuels Laboratory remained separated from the Inorganic Chemistry laboratories. Laboratories other than the Road Materials Laboratory are described in some detail in Bulletin 13, published in 1916 (52).

Division of Mineral Resources and Statistics

It will be recalled that this unit of the Mines Branch was inherited from the Mines Section of the Geological Survey. One of its principal responsibilities to the Department and the Government since 1886, was the annual collection and publication of statistics relating to mineral production in Canada - prices, markets, imports and exports, etc.

It may interest the reader to note the growth of the Canadian mineral industry from 1901 to 1907 and 1919, the latter showing a downturn from 1918, the peak war year. The value of Canadian mineral production in 1901 was $65,804,611, in 1907 it was $86,183,477 and in 1919, $176,686,390.

In more detail, the 1907 figures break down approximately as follows:

Metallics	$42.4 million
Non-metallics	31.2 million
Structural materials	12.2 million

The leading minerals in the metallics group were: copper at $11.5 million, nickel $9.5 million, gold $8.2 million and silver $8.3 million; in the non-metallics, coal was first at $24.5 million, followed by asbestos $2.5 million, petroleum $1 million and natural gas $0.75 million. The foregoing figures were preliminary for that year.

In 1919, almost at the end of Haanel's service, the total value of Canadian production was $176,686,390 of which metallics accounted for $73.3 million, a fall of 36% from 1918, non-metallics accounted for $76 million and structural materials for $27.4 million. The leading minerals in the metallics group were nickel at $17.82 million, silver at $17.80 million, gold at $15.85 million and copper at $14.02 million. In the non-metallics group, the leading minerals were coal at $54.4 million, asbestos at $10.9 million, natural gas at $4.2 million, salt at $1.4 million, gypsum at $1.2 million, petroleum at $0.75 million. It should be noted that some increase was due to inflation in price of commodities.

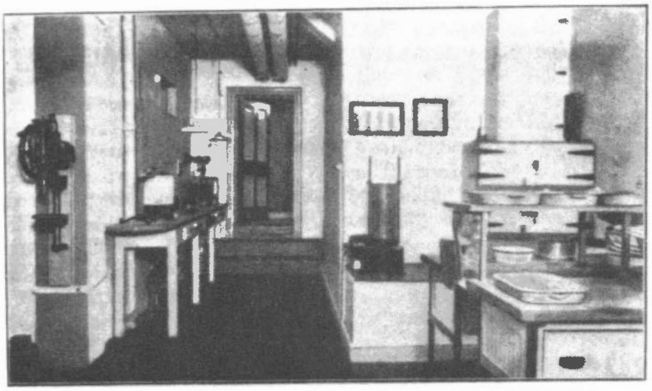
The annual report of the mineral production of Canada was published in preliminary and final editions during this period, with separate reports of the minerals considered of particular interest or importance published in advance. Lists of producers of minerals were included in the earlier annual reports but from 1911, separate lists of mine operators and mineral-related manufacturers were published, the first being: manufacturers of clay products in Canada, lime burners in Canada, and stone quarry operators in Canada.

The annual publication of mineral production was discontinued after 1920 when mineral statistics were taken over by the Dominion Bureau of Statistics in 1921. A periodical review for special occasions (international conferences and exhibitions) of the status of economic minerals continued until becoming an annual review from 1933. The present format of preliminary and final reports and separates published in advance does not differ from the format of former days. It is considered a useful publication by independent publishers who reproduce much of the information.

Mineral Inventory

Another important responsibility of the division was the mineral resource card index or inventory started in 1886. The importance of an inventory was recognized during the war. The Munitions Resources Commission undertook to improve the card index, particularly in those resources that were required for war purposes. The card index was later turned over to the division.

The staff of the division amplified their technical data on mineral commodities from information files and by field visits to properties and related plants. This procedure was encouraged by the director



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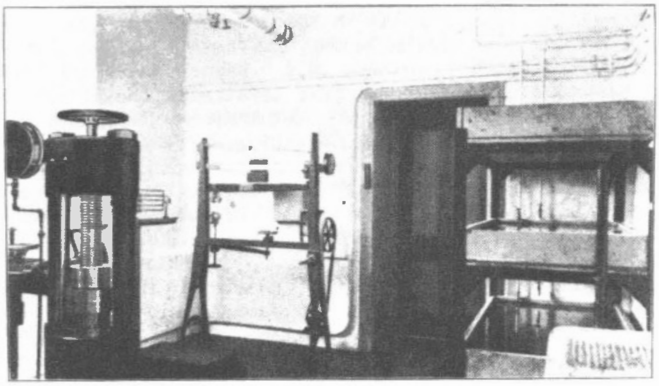

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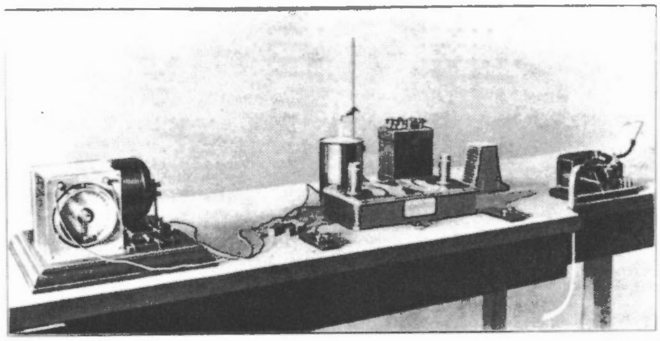
Structural Materials Laboratory: Top - mixing table, sieve agitator, moist closet and asphalt testing apparatus; 2 - compression and tension machines



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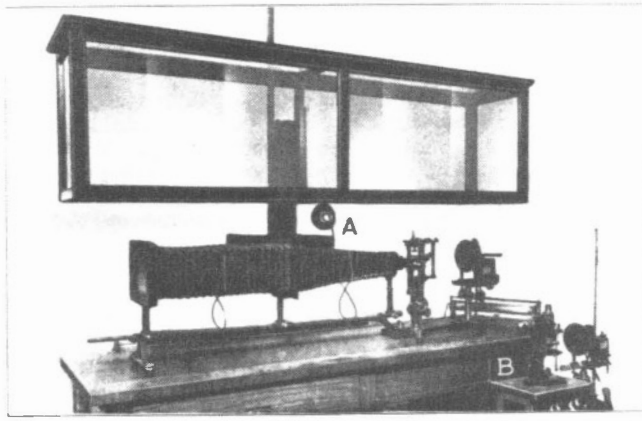

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Metallographic Laboratory: 1 - Scimatco apparatus for transformation point determination; 2 - micro-metallograph and metallographic microscope

and became a tradition which is practised today. This led the division to the role of a central information centre for the department on the mineral industry, later enlarged to include information on mining legislation and taxation. There was perhaps overlap between the division and the Metalliferous and Non-Metalliferous Deposits Divisions, but there is evidence that there was good cooperation and mutual assistance. When the division separated from the Geological Survey in 1907, it moved from the Sussex Street building to the Thistle Chambers, where it stayed until 1912, when it moved back to Sussex Street.

In October 1914, C.D. Cartwright died, which was a severe blow to John McLeish, chief, and to the Mineral Resources and Statistics Division. McLeish described him in his 1914 report as a man of "highest integrity and personal honour", and in regard to Cartwright's capability he says "No matter how capable his successor, it will require considerable experience to render equivalent service". Arthur Buisson and L.L. Bolton, both mining engineers, were appointed to the division on February 6, 1915, and August 1, 1915, respectively. Bolton stayed only a short period though he had time to assist Lindeman on the monograph on iron resources of Canada, published in 1917. Bolton was loaned in March 1916 to the War Purchasing Commission and transferred in September 1916 to the office of the deputy minister. John McLeish, chief of this division, succeeded Haanel on December 16, 1920, as acting director and was confirmed by competition in 1921 as director of the Mines Branch.

Draughting Division

The large number of magnetometric and other maps (both separate and included in the publications of the Mines Branch) together with Haanel's desire to illustrate all reports liberally for the readers' easier comprehension dictated the need to have a group directed to this objective. Moreover, the Geology and Mines Act spelled out this requirement in Section 6 (c) "to prepare and publish such maps, plans, sections, diagrams, drawings and illustrations as are necessary to elucidate the reports issued by the Mines Branch".

Until 1910 the engineers had to prepare most of the maps themselves. In that year, L.H.S. Pereira was appointed and assisted the engineers in finishing or in drawing the maps for reproduction as well as producing engineering drawings for plant requirements. In 1911 the Draughting Division was formed, headed by H.E. Baine, with two assistants, L.H.S. Pereira and A. Pereira. Baine's annual individual reports included in the Mines Branch summary reports indicate the increase in workload with the passing years. By 1913, E. Juneau, draughtsman, and William Campion, mechanical draughtsman, were added. By 1914, a further draughtsman, D. Westwood, was added. As an example of the work load, in 1915, 50 maps were compiled and published together with some 400 mechanical drawings, charts, flowsheets, etc. In 1916, A. Pereira and D. Westwood joined the military for service overseas. In the latter part of the war, the division was preparing diagrams, maps and charts for the Canadian Munitions Resources Commission. As the demand for magnetometric maps waned, branch requirements in diversified maps and mechanical drawings increased. Over 200 numbered maps mostly accompanying reports were issued during this period. The division remained as a distinct entity until 1936.

Publications

Until the appointment of an editor, S. Groves, on March 28, 1908, the editing and preparation of reports for publication was presumably the responsibility of the authors. By Order in Council of May 14, 1908, Groves was appointed editor of the entire department, followed by the appointment by Order in Council of June 23, 1908, of J.J. Bell as assistant editor. The editorial office as well as the departmental accounts office became and remained departmental responsibilities. First they were housed in the Sussex Street building of the Geological Survey, and when the Survey moved to the Victoria Memorial Museum, the editors and accountant were transferred to this location.

During Haanel's period of service from 1901 to 1920, close to 600 reports and maps were prepared (although some of these publicatons were issued after his retirement), nearly 75% of the number published from 1901 to 1946. This is an impressive total if one remembers the state of printing technology of that period compared with the subsequent periods and the modest number of authors compared with the present-day staff. There is no question that the director was imbued from the start with the importance of publicizing the work of Mines Branch but he was also aware of the paucity of precise chemical, metallurgical and mining information available to the interested public. That many of the reports were in demand is demonstrated by the printing of additional editions, usually revised because of rapidly changing developments in the mineral resources of Canada.

Though all reports including catalogues were numbered consecutively, there were in effect three classes of reports - comprehensive reports on mineral commodities were frequently referred to as Monographs, reports on specific investigations were designated Bulletins (they were also numbered in the report series; a total of 33 bulletins were issued), and finally in the third category, all other reports including annual summary reports. After 1921, the bulletins were replaced by mimeographed reports presumably to avoid printing delays. The policy of publishing reports that involved the Province of Quebec or subjects regarded to be of national importance, in both official languages was practised in the Department of the Interior period and continued into the Department of Mines era.

In this regard some 10% of the reports in this period were bilingual and that included all annual summary reports from 1913. The prompt publication of many French texts may be noted by perusing the Catalogue. Translations were the responsibility of the departmental editorial office to 1915 and from 1916 Publications and Translations became the responsibility of the Departmental Publication and Translation Division under Marc Sauvelle, chief.

Right at the start in 1907, Haanel seemed anxious to provide an overall reference tome on the mining and metallurgical industries of Canada and to demonstrate the early implementation of Section 6 (a) of the Geology and Mines Act of 1907 "to collect and publish full statistics of the mineral production and of Mining and Metallurgical Industries of Canada". Realizing that the staff of the division was already overloaded, he looked to consultants to undertake this task. Five regions were covered as follows: Yukon Territory by Dr. D.D. Cairnes of the Geological Survey; the four western provinces by R.R. Hedley; Ontario by F. Cirkel and J.J. Bell; Quebec by J.W. Bell; and Nova Scotia and New Brunswick by W.F. Jennison. The copiously illustrated 972-page "resource inventory" volume was published in 1908 and was sold at one dollar per copy titled "Report on the mining and metallurgical industries of Canada" (MB Rep 24). Haanel observed that "this timely work cannot fail to attract the attention of capitalists and prospective investors in Canada and abroad to the vast mineral resources of the Dominion". It was the director's intention to produce these reviews from time to time. However, no further report was issued during his period of service. A.W.G. Wilson's tome "Development of chemical, metallurgical and allied industries in Canada in relation to the mineral industries", though published in 1924, was worked on during Haanel's time and, could be regarded as a sequel to the earlier volume but in terms of the contribution of the minerals industry by providing source materials for metallurgical, chemical, and other secondary industries that had expanded during World War I.

Special reports and reviews were prepared by the division for particular occasions, for example, a report entitled "Economic minerals and mining industries of Canada" was published in 1913 for distribution in the same year at the International Exhibition in Ghent, Belgium, and at the International Geological Congress in Toronto.

Cooperation with the Geological Survey

Whatever were Haanel's aspirations during his service in the Department of the Interior, he accepted the position of director when the Department of Mines was formed. He served the department well and loyally under three successive deputy ministers, two of whom were past directors of the Geological Survey - Dr. A.P. Low and Dr. R.W. Brock, and R.G. McConnell who was senior officer of the Geological Survey. Their readiness to give Haanel almost complete autonomy helped, of course. Haanel did not hesitate to request the services of men like Dr. D.D. Cairnes and Dr. R.W. Ells, from the Geological Survey. Officers of the Survey assisted Mines Branch officers in collecting samples during their field work and the chemistry laboratories of Mines Branch accepted Survey samples for analysis. The Survey played a helpful part in establishing the Ceramics and Road Materials Divisions, by transferring Joseph Keele to head the Ceramics Division and cooperating with the Branch and the first chief of the Road Materials Division, K.A. Clark.

The outstanding event of this period was the 12th International Geological Congress held in 1913 in which the following officers participated as delegates, participants, or guides in the excursions: Wilson, Cole, de Schmid, Lindeman, McLeish and Cartwright. John McLeish was asked to organize and operate a mining and geological information bureau at Toronto University, the headquarters of the Congress.

It can be said that during this period the Mines Branch and the Geological Survey did not get into "each other's hair", and settled down on the long cavalcade together which has lasted nearly seventy years.

Epilogue: Eugene Haanel

At the formation of the Mines Branch in 1907, Dr. Haanel was 66 years old, but he immersed himself in a task that many men ten or fifteen years his junior would have found demanding, namely the expeditious organization of an R & D establishment in mining, metallurgical and fuels technologies for the optimum production, processing and use of the mineral resources in Canada. Some of the work he had already started, notably in gold, iron, solid fuels, and some non-metallics, but there were no laboratories except one for magnetometric surveying and a small chemistry laboratory. He quickly recognized that the principal problem of the Canadian mineral industry was concerned with selecting the appropriate processing step following the mining step. He decided that as many as possible of the mineral resources should be evaluated quickly and those that showed economic possibilities of treatment should be investigated up to the point of commercial application. He emphasized commodity programs rather than the perfecting of an internal organization which a more bureaucratically inclined person would have done. He used both internal and external manpower to obtain the optimum information on the various resources as rapidly as possible. He encouraged the staff and outside consultants to undertake extensive field work so as to be in touch with the mineral industry and with the manufacturers of appropriate metallurgical or fuel plants whether on this continent or overseas.

The objectives conceived for the Mines Branch are best expressed in his own words that appeared in the first part of the Introductory of the summary report for 1912:

> "The Mines Branch of the Department of Mines was organized primarily for the purpose of assisting, in a practical manner, the development of the mineral industry of Canada. This object is attained:
> - by the gathering and publishing of statistics relative to the mining operations and economic mineral resources of the country generally
> - by initiating and conducting original research work which aims at the commercial utilization of our metallic and non-metallic minerals
> - by mapping out magnetic ore bodies by means of magnetometric surveys
> - by defining the characteristics and, in well-equipped chemical laboratories, determining the properties of specimen ore and rocks.
>
> Results of the work undertaken are given to the public in the form of monographs on the scientific study of the ore deposits of Canada; and by the publication of reports and bulletins dealing with the investigation of certain processes. As examples of this latter branch of the work, may be cited the electric smelting of refractory iron ores; the production of peat fuel; the economic extraction of zinc from refractory zinciferous ores, etc."

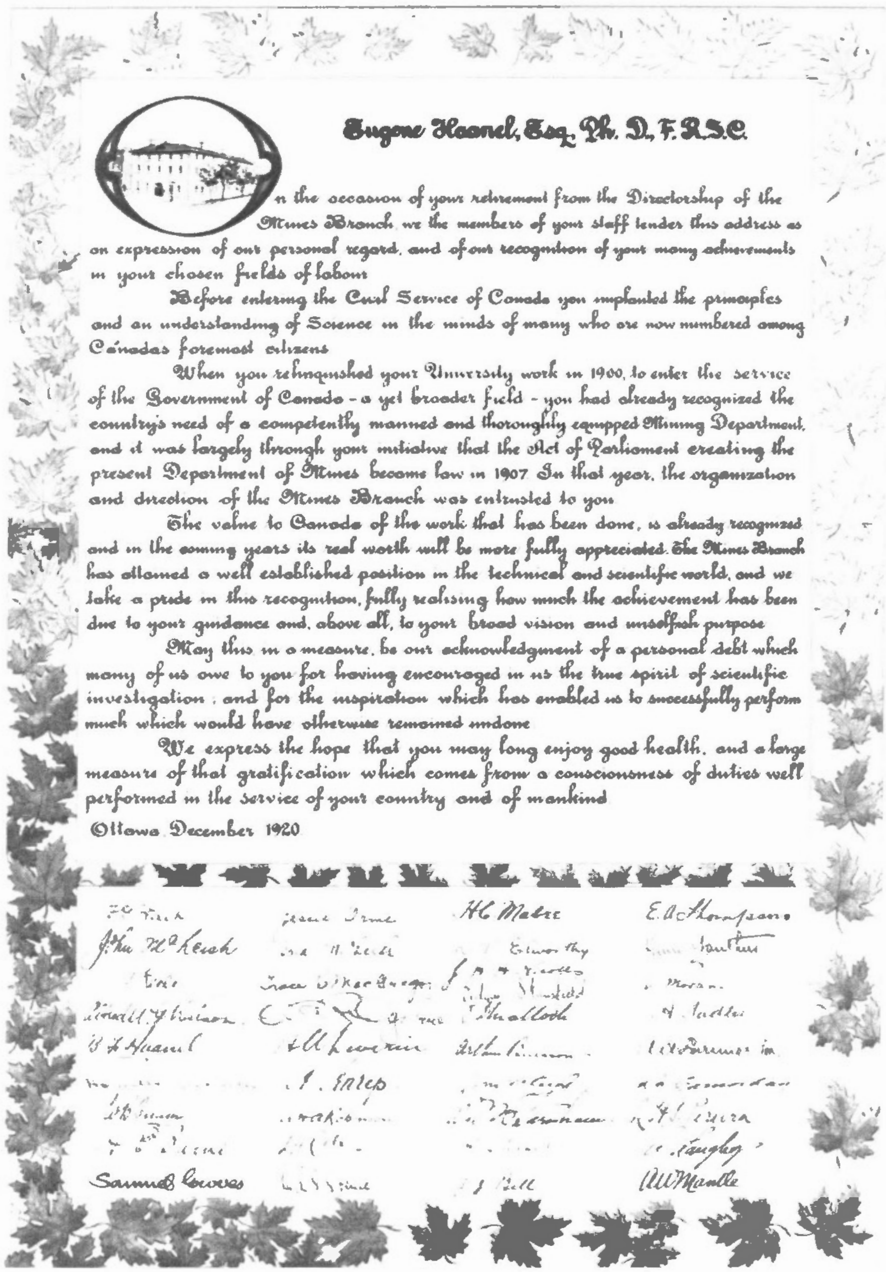
Haanel's initial choice of a professional employee was the engineer; at first these were largely mining. Even with chemistry, which rapidly became dominant in the Branch's activities, he gave preference to chemical engineers, describing them at times as engineering chemists even when performing mostly analytical work. This proved a useful tradition to inherit as many of the Mines Branch chemists are broadly oriented chemists who can give internal and external advice. As the branch developed, so did the disciplines and skills. They provided flexibility and a capability to the branch in responding to requirements of the nation's effort during World War I. When he retired he left an organization of considerable diversification, the core elements of which exist to this day.

Haanel may have been somewhat over-enthusiastic in some of his expectations, such as the program on electrothermic smelting of iron or zinc with technologies in their infancy or not applicable even under present-day conditions. Though his reasoning may have been logical in that period, he did not foresee, for example, the large and productive iron and steel plants close to markets and the bulk shipment of ore by water routes. Haanel's motivation for the iron and most other programs was essentially due to his desire to encourage the domestic production of minerals, many of which were being imported, a fact to which he referred in his annual reports. He was not a narrow nationalist, in fact like many uninhibited Canadians he understood the U.S.A. drive and creativity which he wanted Canadians to adopt in order to better exploit the mineral potential of the land.

Haanel was pointing to the dilemma that Canada has faced throughout its history: how to overcome the national handicap of geography and small population generating a small internal market and living next door to a country, with a large population, a large internal market and possessing many of the resources that Canada had. In short, he was concerned with Canada's competitiveness both in some raw resources and many manufactured goods.

In spite of Haanel's preoccupation with trying to advance the technologies related to the mineral resources of Canada, he found time to devote to the general question of safety in mines and to the manufacture and use of blasting explosives, an expression of his humanism noted early in his career. Another aspect of his attitude to humans was the encouragement given to the chiefs of the divisions and authors of preliminary and final reports to publish their reports under their own names, giving credit for the work done in his "Introductory" in the annual summary reports.

All the evidence points to the conclusion that the Mines Branch was fortunate in having a director of Dr. Haanel's calibre, vision, conscientiousness and determination. He retired at the age of 79 and died in Ottawa in 1927 at the age of 86 years. The senior staff expressed their admiration of Dr. Haanel's important inaugural contribution to Canadian R & D in mineral and metal science technology on the occasion of presenting a testimonial at his retirement.



Eugene Haanel, Esq. Ph. D., F.R.S.C.

On the occasion of your retirement from the Directorship of the Mines Branch, we the members of your staff tender this address as an expression of our personal regard, and of our recognition of your many achievements in your chosen fields of labour.

Before entering the Civil Service of Canada you implanted the principles and an understanding of Science in the minds of many who are now numbered among Canada's foremost citizens.

When you relinquished your University work in 1900, to enter the service of the Government of Canada - a yet broader field - you had already recognized the country's need of a competently manned and thoroughly equipped Mining Department, and it was largely through your initiative that the Act of Parliament creating the present Department of Mines became law in 1907. In that year, the organization and direction of the Mines Branch was entrusted to you.

The value to Canada of the work that has been done, is already recognized and in the coming years its real worth will be more fully appreciated. The Mines Branch has attained a well established position in the technical and scientific world, and we take a pride in this recognition, fully realising how much the achievement has been due to your guidance and, above all, to your broad vision and unselfish purpose.

May this in a measure, be our acknowledgment of a personal debt which many of us owe to you for having encouraged in us the true spirit of scientific investigation; and for the inspiration which has enabled us to successfully perform much which would have otherwise remained undone.

We express the hope that you may long enjoy good health, and a large measure of that gratification which comes from a consciousness of duties well performed in the service of your country and of mankind.

Ottawa, December 1920.

Testimonial of 1920 presented to Eugene Haanel on the occasion of his retirement as director of the Mines Branch

(Courtesy - K.W. Bowles)

CHAPTER 4

PROGRESS AND CONSOLIDATION

DEPARTMENT OF MINES, 1920-1936 - THE GREAT DEPRESSION

JOHN McLEISH: SECOND DIRECTOR OF THE MINES BRANCH

John McLeish was born on November 1, 1874 in Toronto where he received his education. He graduated with an Honours Bachelor of Arts degree in 1896, with specialization in mathematics, physics, chemistry, and mineralogy. He embarked on a career in the federal civil service that lasted nearly 45 years. He first joined the office of the Auditor General on July 6, 1896, transferring to the Department of Finance on February 1, 1897. He joined the Geological Survey Department in the Department of the Interior on July 6, 1897, as an assistant in the Mineral Statistics and Mines Section, where he became responsible for the collection and compilation of annual statistics on mineral and metal production. At the formation of the Mines Department, McLeish with two assistants transferred from the Sussex Street Geological Survey building to the Thistle Chambers on Wellington Street and quietly went to work in cramped quarters. He expanded the scope of statistical and technical information related to the growing mining, metallurgical and fuel industries of Canada.

In a submission in 1912 to Dr. A.P. Low, the then Deputy Minister of Mines, recommending promotion for John McLeish, Haanel speaks of "his executive ability and sound judgment" and that "he has proved himself an exceedingly valuable officer". It should be noted that at that time mining companies were not legally bound to provide information on their operations for the annual mineral production reports that were published by the branch. Haanel referred to the qualities of "courteousness, tact and ability that the officer in charge of the Mineral Resources and Statistics Division had to possess". McLeish indeed possessed these qualities which were no doubt responsible for his later senior appointments. The director showed his confidence in him by leaving him in charge during his absences from Ottawa.

During World War I, McLeish and his division played an important role in supplying war agencies in Canada, the United States, and the United Kingdom with data on mineral resources and metals that contributed to the war effort. In 1917, by Order in Council, McLeish under the Census and Statistics Act was appointed Agent of the Census to provide the official record of mining production for a comprehensive annual census of production and industry undertaken by the Census and Statistics Office of the Department of Trade and Commerce.

McLeish reflected his cooperative attitude in his dealings with various agencies of the federal and provincial governments as well as with organizations abroad.

He succeeded Haanel as acting director on December 15, 1920, and was selected from the heads of the seven technical divisions by the Civil Service Commission as director on October 1, 1921. McLeish had to face his new responsibilities at a difficult time. In 1919, the Civil Service Commission brought in a reclassification system that did not take into account competition for technical skill by the private sector and universities. This resulted in a number of key men resigning from the Mines Branch as well as from the Geological Survey. Following representations to the Commission by the department, the position was rectified in 1922 and a few of the technical men returned.

McLeish continued the branch build-up started by Haanel. Through his work as head of the Mineral Resources and Statistics Division, McLeish became well-known to the industry and the provinces, whose goodwill he gained. This fact together with his knowledge of the department and his general manner was helpful in earning a good reputation for the organization.

McLeish was faced with severe budgetary restraints in 1930 occasioned by the Great Depression. Utmost economy had to be practised, mainly by a reduction of travel, field work, and purchases of equipment and material. He was nevertheless able to retain most of the staff and to maintain the scope of activities of the branch.

McLeish's additional duties were the vice-chairmanship of the Dominion Fuel Board from its formation in 1922, membership in several NRC associate committees, and by invitation from the Government of Alberta,

John McLeish

membership in the Turner Valley Gas Conservation Board from 1932 to 1941.

The director was popular in professional circles in Ottawa. He was elected chairman of the Ottawa Branch of the Canadian Institute of Mining and Metallurgy for two terms from 1925 to 1927, and was also a councillor of the national organization. In 1930, he was chairman of the Ottawa Branch of the Engineering Institute of Canada, followed by serving as councillor of the national organization. In 1933, he was president of the Professional Institute of Canada and in 1937 president of the Royal Astronomical Society. For several years also, he was president of the Laurentian Skating Club and treasurer of the Optimist Club of Ottawa.

McLeish's final contribution to the service of the department and the nation was his appointment to the directorship of the Mines and Geology Branch at the formation of the Department of Mines and Resources in December 1936, serving until May 1, 1941 and completing nearly 45 years with the department and its predecessor. He lived quietly in Ottawa until his death on September 22, 1961, at the age of 87. John McLeish in temperament and style was a contrast to his predecessor. On the other hand he possessed the determination and persistence required to ensure progress and consolidation of the relatively young organization.

Organization of Mines Branch

When appointed as acting director on December 15, 1920, and confirmed as director on October 1, 1921, John McLeish was faced with serious difficulties resulting from the resignations referred to above. Two of the largest divisions were particularly affected, viz the Ore Dressing and Metallurgical, and the Fuels and Fuel Testing Divisions. In the former, the chief for ten years, G.C. Mackenzie, had resigned in February 1919, being preceded by C.S. Parsons in May 1918. W.T. Graham and B.P. Coyne, chemists, had resigned in May and October 1919 respectively. In the latter division, R.E. Gilmore, research chemist, and T.W. Hardy, chemist, had resigned in 1919; J. Blizard, technical engineer, and R.C. Cantelo, assistant chemist, resigned in 1920, and E. Stansfield, chief engineering chemist, in 1921. Other resignations had been K.A. Clark, chief of Road Materials Division in 1920; M. Young, technical assistant in the Ceramics Division, and W. Campion in the Draughting Division in 1921; J. Keele, chief of the Ceramics Division, transferred to the Geological Survey on October 1, 1921.

Most of the resignations in Mines Branch as well as in the Geological Survey were due to general frustration arising from failure of the Civil Service Commission to bring salaries in line with industry and academic levels. A new schedule of technical salaries was applied in May 1922 at a propitious time as the industry, which had suffered a two-year down-turn, started to improve. Two key men, R.E. Gilmore and C.S. Parsons, returned to the branch in 1921 and 1922 respectively; B.P. Coyne also returned in 1921.

A minor reorganization of the branch was carried out in 1922 as may be seen from the organization chart (Chap. 2). The Metalliferous and Non-metalliferous Deposits (Mines) Divisions were merged with the Mineral Resources and Statistical Division, and became Mineral Resources Division. It was made responsible for the investigation of mineral resources and their technology, production, uses, markets, and market conditions. The Statistics Section of the Mineral Resources and Statistical Division was transferred to the Dominion Bureau of Statistics in 1921 because of the government's desire to centralize all statistics in one department. The Ceramics and Road Materials Divisions were merged. Haanel's organization was basically retained in a more consolidated form.

On November 25, 1922, a departmental agency, Dominion Fuel Board, was formed with the deputy minister as chairman and the director of the Mines Branch as vice-chairman. For budgetary reasons, the agency was included with the Mines Branch estimates.

There was a wartime fuel controller from 1917 to 1919, whose principal role was to secure adequate supplies for the chronically fuel-short provinces of Ontario and Quebec. In this sense, the Dominion Fuel Board was the successor to the fuel controller as the shortage in Ontario and western Quebec, the centre of Canadian manufacturing industries, persisted. The board started a system of subventions and incentives for coal producers in the east as well as in the west. Some coal was imported from the United Kingdom to replace U.S.A. anthracite, the reserves of which were being depleted and becoming more costly. The Mines Branch became consultant to the board on the properties of the various coals with which the board was concerned.

The following is a list of the principal officers and departmental officers concerned with the branch during the period from 1920 to 1936; dates are given only when changes occurred. Names are those of the chiefs of divisions except where otherwise stated.

Administration:
Secretary to the Mines Branch - M.M. Farnham
Private secretary - Jessie Orme
Chief librarian - O.P.R. Ogilvie

Draughting Division:
Chief draughtsman - E.H. Baine, retired 1933
- L.H.S. Pereira, from 1934

Dominion Assay Office*:
Chief - G.N. Ford, from 1926 to 1933 (office transferred to the Department of Finance)

Mineral Resources Division:
Chief - A.W.G. Wilson

Ore Dressing and Metallurgical Division:
Chief - W.B. Timm

Fuels and Fuel Testing Division:
Chief - B.F. Haanel

Ceramics and Road Materials Division:
Chief - Howells Fréchette

Chemical Division:
Chief - F.G. Wait, retired 1931
Acting chief - N.A. Thompson, 1932-1936

Headquarters:
Departmental editor - F. Nicholas, retired 1933
Assistant editor - G.C. Monture, 1923-1933
Acting chief editor - G.C. Monture, 1933-1934
Chief editor - G.C. Monture, 1935-1939
Departmental accountant - P.R. Marshall, retired 1930
- E.A. Sawyer, 1931-1936 (representative of the Treasury from 1933)

The Ore Dressing and Metallurgical and Fuels and Fuel Testing Divisions, the two largest laboratory divisions of the Mines Branch were obliged by the scope of their activities which required specialized equipment and disciplines to introduce the organization unit of "section" in the period under review. The necessity for such an infrastructure will be indicated in the description that follows in the metals and fuels sections of the narrative.

An historic event of international importance intervened during the period under review, namely, the "Wall Street crash" followed by a decade of the Great Depression, which affected all of western society and more particularly the North American continent. Hence, it is appropriate to review this period in relation to the funds that the government could make available to R & D establishments like Mines Branch. Normally, research and development are early victims of a depression. Mineral production reached a peak of $311 million in 1929. Funds made available to the Mines Branch for the fiscal year ending March 31, 1930, amounted to $826,610, the largest sum since inception of the branch and in part due to heavy purchases of equipment for the new Fuels and enlarged Ore Dressing Laboratories.

*Note - In 1926 the office was moved to the 2nd floor of the Customs Examining Warehouse at the foot of Howe St., Vancouver following sale of the old Post Office Building at the corner of Pender and Granville Streets, the location of the assay office from 1910.

In the fiscal year ending March 31, 1931, the allocation was only $605,065, dropping still further by 1934-35 to $405,062. However in the following year, the last one for the Department of Mines, it rose again to $439,705.

It may be of interest to analyze the expenditures for fiscal year 1934-35 and to compare these with those of 1920-21 given in Chapter 3, from which will be noted the higher proportion of salary content in the 1935 expenditures.

This financial review of the 1934-35 depression year shows the drastic reduction of 50% in the expenditures compared with the peak year of 1929-30. If retention of human resources in an R & D establishment is the right course in periods of financial restraint, then the director and the department acted correctly.

Mines Branch Expenditures - 1934-1935

Mines Branch Grants	
Civil Government Salaries,	$190,062.00
Investigation of mineral resources, etc.	185,000.00
Publications, etc.	30,000.00
TOTAL	$405,062.00
Mines Branch Expenditures	
Civil Government Salaries	$189,999.52
Salaries and Wages	138,581.87
Mineral Resources Division	13,000.68
Ore Dressing and Metallurgical Division	9,584.70
Fuels and Fuel Testing Division	7,293.69
Ceramics and Road Materials Division	1,636.84
Chemical Division	2,047.77
Mechanical Section	2,882.86
Administrative Division	1,482.60
Dominion Fuel Board	4,047.06
Publications, Equipment, Office Stationery and Miscellaneous	23,095.37
TOTAL:	$393,652.96
Unexpended Balance:	11,409.04
TOTAL	$405,062.00

Certainly, the branch was able to move rapidly forward as soon as the budgetary position improved. Personnel had to accept a 10% cut in salary in 1932, but 5% was restored in 1935 and 5% in 1937.

The following data on the number and allocation of staff indicate the changes between 1920 and 1937. They show the doubling of staff in the decade from 1920 to 1930 and then holding the line in numbers but with some change in distribution. The figures do not include temporary summer employment of engineers or students in the laboratories:

Mines Branch Staff - 1920, 1930 and 1937

Year	Professional	Technical support*	Clerical	Total**
1920	35	41	22	98
1930	62	102	24	188
1937	69	79	32	180

* included laboratories, pilot plants, and workshops
** included temporary which in 1930 numbered 46

In 1931, the total was 197 followed by a small downward trend. In 1937, the first year of Mines & Resources, staff total returned to the level of 1930 with the exception of the 8 employees of the Vancouver Assay Office who were transferred to the Department of Finance in 1933.

Publications

In addition to organizational changes, there were changes with the publications of the Mines Branch. The last annual summary report as a single volume was issued for the calendar year 1922. Already from 1920, separate reports were being published on a calendar year basis for each of the main technical divisions, describing the activities of these divisions as "investigations". Of course the commodity concept was retained in the division but the small organizational changes referred to above and the form of publication tended to favour the disciplinary structure of each division rather than the commodity program of the early days of the branch. This narrative will retain the commodity structure following the sequence of events on a divisional basis given by the director in his annual reports, as it would seem that industrial minerals, metals, and fuels were regarded by the director to rank with equal priority.

The Report and Monograph series were maintained but the Bulletin series was replaced by the Memorandum series which was mimeographed to expedite publication. An annual departmental report commenced with the fiscal year ending March 31, 1921, and terminated with the report for fiscal year ending March 31, 1936; these are not referenced. The activities of the technical branches were briefly reported by the directors, preceded by an overall introductory by the deputy minister.

INDUSTRIAL MINERALS

The Mineral Resources Division was the leading branch unit in field investigations of both metalliferous and industrial minerals, but the latter received more attention because of the diverse and numerically large distribution of occurrences which generally attracted their exploitation by small Canadian firms. Many of the minerals found in Canada were in competition with imports: either the minerals were imported as raw material or as semi-finished or finished products. This was recognized both by Haanel and McLeish who considered that technical aid should be forthcoming from the Mines Branch to the industry for stimulating domestic use of industrial minerals.

Dr. Camsell, the then deputy minister, in his report for the fiscal year ending March 31, 1923, referring to the somewhat adverse effect on Canadian mineral commodities of the application of the Fordney-McComber U.S.A. tariff law, spoke of the importance of foreign markets for the Canadian mineral commodities. H.S. Spence was sent to the United Kingdom in 1922 to survey the potential British requirements for industrial minerals which he reviewed in a report "Investigation of a British market for Canadian non-metallic minerals", Memorandum Series No. 6, 1922. Companion papers to this report were "Directory of Belgian buyers of metals and minerals", Memorandum Series No. 7, 1922, and "Directory of British buyers of metals and minerals", Memorandum Series No. 8, 1922. The interest in the European market was stimulated by Camsell's visit to Belgium in 1922 as delegate to the 13th International Geological Congress and to the United Kingdom. Incidentally, he pointed out in the same 1923 annual report that the growth of mineral production per capita from 1886 to 1921 was from $2.23 to $26.40. He further stated that in 1922 the capital invested in the Canadian mineral industry was derived from Canadian sources to the extent of 54%, from the U.S. sources, 31%, from U.K., 13%, and the remainder of the world, 2%. The deputy minister maintained contact until World War II with Europe and particularly with the U.K. He was a member of the Advisory Council on Minerals of the Imperial Institute which promoted liaison between members of the British Empire. Financial support including Canadian was given the Institute by the Dominions and colonies.

The principal field investigators in industrial minerals were: L.H. Cole, and H.S. Spence; V.L. Eardley-Wilmot from 1921; M.F. Goudge, E.H. Wait, and C.H. Freeman from 1923. A.H.A. Robinson continued in metals and S.C. Ells in studies of the bituminous sands and oil shales. Their work will be reported under metals and fuels respectively. Though the initial work on helium was done by Elworthy, it will be reported under fuels.

Two exhibitions of international significance in which A.W.G. Wilson and Arthur Buisson of the Mineral Resources Division participated on behalf of the department are worthy of record. Arthur Buisson at the request of Senator C.T. Beaubien and the Department of Trade and Commerce was the departmental representative on the Canadian Exhibition Train in France. He spent from July to the end of November 1923 touring the country, speaking authoritatively on Canada's mineral resources.

Wilson was selected as the officer in charge of the Canadian Mineral Resources Exhibit and Information Booth at the British Empire Exhibition at Wembley in London in 1924. He stayed in London from May to October. He availed himself of an opportunity to visit industrial and mining centres in Britain and he also introduced dead burned magnesite to potential British consumers. As the British Empire Exhibition had a second year in 1925, Spence was sent to London to be the officer in charge of the Canadian minerals exhibit.

Incidentally, in 1923 Buisson was placed in general charge of mineral resource records and the compilation of an index of mineral resources. He also prepared the first digest of Dominion-Provincial laws for the British Empire Exhibition in 1924 (MB Rep 627). A revised edition was published in 1931 (MB Rep 713), a new edition in 1939 (MB Rep 795), and a fourth edition in 1950 (MB Rep 828) just before Arthur Buisson retired. At this period John Casey was placed in charge of the collection, compilation and filing of statistical records and the preparation of data required by officers of the branch and to meet a growing number of inquiries from the public. These two officers gave unstinted service to the Mines Branch, Casey serving it from 1909 to 1946 and Buisson from 1915 to 1950. John Casey's son, Leo, followed his father in devotion and modesty, serving the branch from 1940 to 1975.

Mineral Pigments

The mineral pigment project was undertaken by Howells Fréchette, prior to his appointment as chief of the Ceramics and Road Materials Division, in the knowledge that the large proportion of colouring material used by the Canadian paint manufacturers was imported. For four seasons, 1919 to 1922 inclusive, occurrences of oxides, mainly iron (ochre) were examined in Ontario, Quebec, New Brunswick, and Nova Scotia. The main deposits were located north of the St. Lawrence River, principally in the Trois Rivières district. Canada Paint Company operated at Red Mill, an extensive plant to the east of Trois Rivières for calcining, washing and grinding pigments, producing a variety of shades of red, amber, and sienna. The Champlain Oxide Company adjoined the Red Mill operation. The Paint Products Company of Canada had just erected a large plant in Lynch Township near Annonciation in Labelle County. Deposits and prospects were also examined in the Portneuf, Montmorency, Drummond, and Saguenay Counties. Some previous mining had taken place but on the whole these deposits did not compare with those north of the St. Lawrence River.

In Ontario, occurrences in several counties, mostly in the southern portion of the province, and one near Cochrane were inspected. However, with the exception of those of Halton County where the mineral paint works of Campbellville mined variegated clay and shale deposits, grinding the product for sale to paint manufacturers, no other prospects or operations existed. The Cochrane oxide deposits were adjudged to be suitable only for gas purification.

A deposit of bog manganese in Albert County, New Brunswick, could yield satisfactory pigment material, and three areas in Nova Scotia appeared promising for pigment source material from manganiferous iron oxide deposits - Hants, Kings, and Lunenburg Counties - the latter a source of umber. The red clays so prominent in New Brunswick and Nova Scotia were considered suitable only as fillers in the manufacture of linoleum.

There is no further reference in the Mines Branch literature to mineral pigments other than Robinson's report on titanium, referred to in the metals section, and in the Canadian Minerals Yearbook under mineral pigments and fillers, now a publication of the Mineral Policy Sector.

It should be noted that Fréchette carried out systematic field work from 1908 to 1922 through the years that he was chief of the Non-Metalliferous Deposits, but the administrative demands of the later years allowed him only occasional field work.

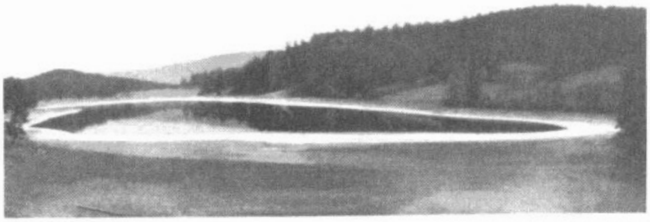
Alkali Salts

This program was undertaken to evaluate the naturally occurring sodium sulphate and to a smaller extent, carbonate as well as magnesium sulphate in the arid regions of Western Canada, principally in Saskatchewan. The main reason for this program as for the previous one was the importation of these commodities, particularly large in the case of sodium sulphate. The importation in 1921 of anhydrous sodium sulphate or salt cake amounted to about 27,000 tons valued at $680,000, and of the hydrous sodium sulphate or Glauber's salt, 290 tons valued at $4,500. Canadian production in 1921 was 2400 tons valued at $55,000 and 1240 tons valued at $42,700 respectively. The pulp and paper industry used substantial quantities of salt cake; other uses were in the glass and metallurgical industries. Glauber's salt was used in medicine and in the tanning and textile industries.

Magnesium sulphate or Epsom salts was in less demand, its use being mainly in medicine, agriculture, and dyeing. In 1921 there was an export valued at approximately $4,500 as against imports valued at $30,000.

These salts were principally found in bedded deposits or brines, the former providing the larger tonnages. The main program was carried on for four years and involved surveys, drilling, sampling, and field assaying. Initially Cole was helped by an assistant, F.M. MacNiven, but in 1923 he was joined by H.A. Leverin and M.F. Goudge, who carried out a two-party drilling campaign. The surveying was done by assistants under Cole's direction.

This work increased the estimated quantity of natural sodium sulphate in Western Canada to be in excess of 50 million tons. Field work was continued by Goudge during the 1924 season in Saskatchewan and British Columbia where there were several magnesium sulphate and sodium carbonate deposits. In 1926, Cole investigated a sodium carbonate deposit at Soap Lake south of Spences Bridge, B.C. Preliminary reports were published in the reports of investigations of mineral resources and technology for 1920 to 1926 - MB Rep 575, 588, 607, 616, 642 and 687. A monograph on sodium sulphate was published in 1926 (53). Canada is now an exporter of sodium sulphate, disposing of 117,000 tons in 1977, almost entirely to the U.S.A.



Soap Lake, B.C.

Fluorspar

A review of the position of fluorspar in Canada was made by Eardley-Wilmot in 1922 (MB Rep 607, pp 32-35). It will be recalled that in 1914 Spence reported only 40 tons of Canadian-produced ore used by Canadian firms. In 1922 the position had improved. Domestic production was approximately 4500 tons, having fallen from 11,200 tons in 1921; of this, 2940 tons were exported against 6900 tons in 1920, and 4780 tons were imported as against 6810 tons in 1920.

In 1922 there were two areas where fluorspar was produced in Canada - the Kettle Valley of B.C. and the Madoc area of Ontario. Practically all the Canadian production in 1922 came from the Rock Candy mine owned by Cominco, yet in 1918 some 30 mines in Madoc were producing most of the Canadian output. At the time of Eardley-Wilmot's visit to the Madoc area, there were only two producing mines - Wallbridge and McIllroy - and the Perry mine was shipping from stock but not working.

The Mines Branch Ore Dressing Laboratory devoted considerable attention to the concentration of Madoc fluorspar, good results being obtained after some experimentation by calcining the ore before tabling. The Madoc mines flourished again during World War II when they were assisted by government loans. No further reports were issued on this commodity until 1961 when "Fluorspar" by C.M. Bartley was published (MB IC 127).

Silica

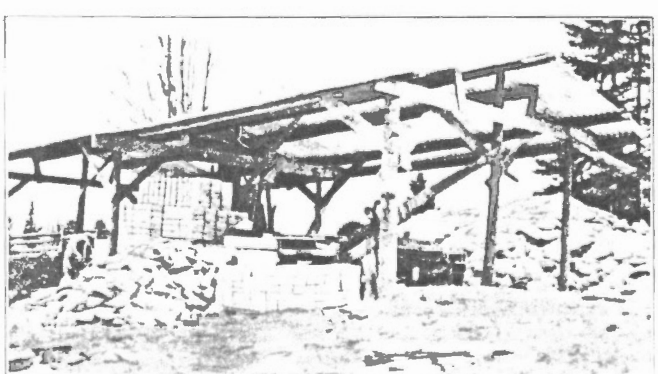
The 1918 summary report contains two reports on pages 52-68 by Cole titled "Preliminary report on the silica deposits of Eastern Canada" and "Preliminary notes on the moulding sand deposits of Eastern Canada". Cole's work on silica was interrupted by the joint survey with Keele of structural materials in the St. Lawrence Valley and by the alkali salt program in Western Canada. Cole found time between these tasks to complete the silica report for Eastern Canada, which was published in 1923. He spent the field seasons of 1925 and 1926 in Western Canada collecting data for the companion report which was published in 1928 (54).

Bentonite

Consequent upon inquiries by the Imperial Mineral Resources Bureau of London, England regarding bentonite in Canada, Spence in 1920 visited the known occurrences in Alberta and B.C. Samples were taken and the Chemical Laboratory carried out tests for chemical and physical properties of this commodity which was at the threshhold of its wider use, particularly in the petroleum industry. A report titled "Bentonite" by H.S. Spence, MB Rep 626, was published in 1924.

Talc and Soapstone

During the 1921 season, Spence examined prospects of talc and soapstone in the Kenora area and in Lanark County of Ontario as well as in the Megantic County of Quebec. The latter area indicated the more promising prospects. In 1922, Eardley-Wilmot reported on the two operating mines in the Madoc area - the Henderson mine in Huntington Township producing three quarters of the 14,500 tons of Canadian production for 1922, and the Connolly mine of the Asbestos Pulp Company on an adjacent lot east of the Henderson mine located on the continuation of the same orebody. The latter mine accounted for the greater part of the remainder of the Canadian talc output. There was a considerable spread in prices from $9 to $22 per ton, the best grade being used for talcum powder and other grades for fillers in the paper and rubber industries.



Portable sawing equipment employed by Robertsonville Soapstone Company, Leeds and Thetford Townships, Que.

There was some mining and prospecting activity in western Ontario at Mine Centre in the Rainy River district and in Zealand Township of the Kenora district where Wabigoon Soapstone Company, which Spence had visited the previous year, had opened up a deposit. In British Columbia, two companies were mining and shipping a few hundred tons of talc - the Canadian Talc and Silver Company were erecting a mill at Keefers, and the Eagle Talc and Mining Company at Wolf Creek in the Victoria mining district. Spence's general report on talc and soapstone was issued in 1932 (55).

Beneficiation tests on Madoc talc were carried out in 1932 by R.K. Carnochan and R.A. Rogers, who improved quality by separation of the contained dolomite (Report of investigations in ore dressing and metallurgy, MB Rep 736, pp 231-234, 1932).

Feldspar

Eardley-Wilmot investigated the feldspar mines and prospects in Canada in 1922 and reported in some detail on the developments since 1911-12 when Spence made his first studies (1922 Summ Rep, pp 21-31). Ontario production shifted from mines in the Kingston area to the Perth area, where Rock Products Company shipped about 4500 tons in 1922 and was the second largest producer in Canada. The prior mining activity in Frontenac County north of Kingston had subsided but there was some prospecting activity in the Bancroft area.

The largest Canadian output in 1922 was derived from the Derry mine owned by O'Brien and Fowler Company, Buckingham, Quebec, which shipped about 7500 tons. Output from Quebec was previously much smaller than from Ontario. In 1920, Ontario produced a peak output of over 37,000 tons, whereas Quebec only produced 650 tons. However, in 1921 the Ontario tonnage dropped to 20,000, whereas the Quebec tonnage rose to 9700. Some field work on feldspar was done by Spence in the Sudbury area in 1923 and in 1926. In 1932, a new edition of a general report on feldspar in Canada was published (56).

Abrasives

V.L. Eardley-Wilmot joined the Mineral Resources Division in 1921. His first task was to prepare the monograph on molybdenum referred to in Chapter 3 of this narrative. The following year he visited active non-metallic properties in Ontario and Quebec. In 1923, he commenced an investigation of naturally occurring abrasive materials and their use. These included sands and sandstones, silts, volcanic ash, garnet and diatomite. He inspected 88 localities in the Maritimes and 32 in British Columbia. He secured numerous samples for examination and testing. This program continued until 1935. In addition to field work, he visited firms making artificial abrasives in Canada and the U.S.A. This program resulted in a number of reports (57,58).

In 1935, Eardley-Wilmot commenced an investigation of industries producing sands for blasting, mineral grits for shingles and stuccos, roofing slates, and mineral fillers, and this work was carried on into the Mines and Resources period.

Graphite

It will be recalled that in Haanel's time Spence followed up Cirkel's original report on graphite (MB Rep 18, 1907) by publishing a monograph on graphite in 1920 (MB Rep 511). In 1926, he returned to this commodity with a view to stimulating the use of flake graphite for the manufacture of crucibles. After preliminary research on a small scale which resulted in the report "The concentration of flake graphite ores" by C.C. Parsons [MB Memorandum Series 25, (1926)] two carloads of graphite from western Quebec were treated in the ore dressing laboratories and a sample was despatched for tests to the Morgan Crucible Co. in England. This was described in "Investigations of mineral resources and the mining industry, 1926", (MB Rep 687, 1928) under "Graphite in Ontario and Quebec" by H.S. Spence, 1926. It may be noteworthy that the Black Donald mine, Renfrew County, Ontario, was the sole producer in Canada in the depression years and operated until 1954. In 1916, Canadian production amounted to 3955 tons and in 1932 to 345 tons. Graphite is presently not produced in Canada.

Mica

This mineral was also one of the early commodities studied by Cirkel in 1905 (MB Rep 10). De Schmid published a comprehensive monograph of 418 pages in 1912 (MB Rep 118). He continued to review the state of the industry which was essentially based in western Quebec and Eastern Canada. Lesley mine, Frontenac County, Ontario, was reputed to be the largest amber mica mine in the world before its closure after World War I. In western Quebec, the Gatineau and Lièvre Rivers district was the principal producing area. Canadian production in 1924 reached a maximum of 4091 tons, falling to 310 tons in 1932. A third edition on mica was produced in 1929 by Spence (de Schmid) (59).

Asbestos

In 1910, Canadian production which was entirely from mines in Quebec was 102,215 tons; it reached 306,055 tons in 1929 to fall below 200,000 tons for about four years. However the output started to recover in 1935, rising to 411,026 tons in 1937.

This was another of the industrial minerals reviewed by Cirkel (MB Rep 11, 1905, and MB Rep 69, 1910). The third edition was commissioned to Capt. J.G. Ross of Asbestos Corporation and was published in 1931 "Chrysotile asbestos in Canada" (60).

Limestone and Dolomite

Goudge commenced a comprehensive field study of limestones and dolomites in 1925, first in Ontario and Quebec, then the Maritimes, then all Western Canada, and this work continued into the Department of Mines and Resources period. By 1930 he completed the areal surveys of the potential resources. A preliminary report was prepared in 1927 on limestones in Ontario and Quebec (MB Rep 682, 1927, English text; 683, 1929, French text). A very large assortment of samples was collected. L.C. O'Brien, who joined the Central Chemical Laboratories on Sussex Street in 1926, was engaged largely on the analysis of field samples. In 1930, Goudge turned to the quarrying of limestone and marble for building and ornamental stone and also to the production of whiting. A black marble was discovered at St. Albert, Ontario. In 1931, Goudge discovered that certain deposits of argillaceous limestone in the Niagara Peninsula were suitable for the manufacture of rock wool, a useful insulation product. Some experiments were carried out that proved promising, and the results were published in 1931 in MB Rep 727, pages 93-106. By 1936, up to three rock wool plants were established in Ontario based on Goudge's research work.

A series of reports published over a period of more than 20 years attests to Goudge's thorough coverage of these resource commodities. The report on Quebec, first published in 1935, required reprinting in 1962 (61).

Gypsum and Salt

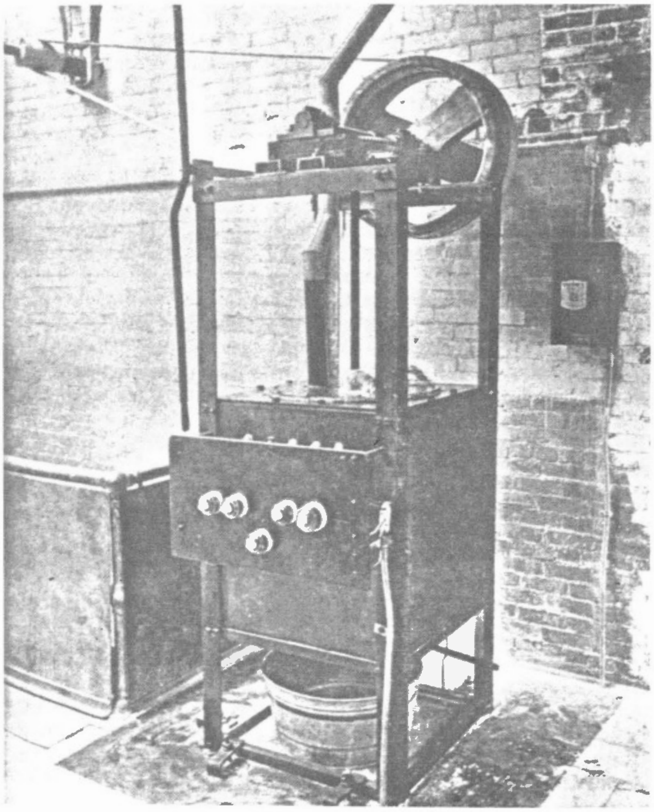
Cole recommenced field and process studies of gypsum and salt industries in 1926. In that year he inspected gypsum deposits at Cranbrook and Falkland, B.C. In 1927, he conducted field work in the Maritimes, calling at Malagash mine which he first visited as a discovery in 1918. Large samples of gypsum for research purposes and samples of rock salt and of salt springs were secured. The presence of potash salts in the well of the Maritimes Oil and Gas Company in the valley of the Petitcodiac River, New Brunswick, was detected (MB Rep 710, 1930, pp 19-27). In 1929, Cole was invited to sample 980 ft of rock salt in another well belonging to the same company; analyses were made for potassium, bromine and iodine.

Incidentally, in 1927 the Second Empire Mining and Metallurgical Congress was an event of some importance and Cole was appointed as representative to accompany the congress to Western Canada, returning to Quebec and Thetford Mines.

The work of up-dating his monograph on gypsum and salt was completed by Cole in 1929. The production of gypsum in Canada, though varying from year to year, indicated an expanding market: in 1910 the production was 525,246 tons, by 1927 it was 1,063,177 tons. However in the period 1931-1936 it fell below a million tons, dropping to 382,736 tons in 1933, but in 1937 it was again over a million tons.

Canadian salt production, from less than 100,000 tons in 1910, was over 300,000 tons in 1929, dropping slightly for two years. It regained the lost ground by 1934 and attained 450,000 tons in 1937. Recent advances in the technology of gypsum and its production and of salt in Canada and U.S.A. were included in these reports (62,63).

It may be pertinent to recount the following vignette relating to the monograph on salt: "While Dr. Camsell, the Deputy Minister, was waiting in the office of the Director of the Mellon Institute in Pittsburgh, he glanced at the Director's desk and saw three books between book rests - a bible, the rules of the Institute and a volume strangely familiar to him.



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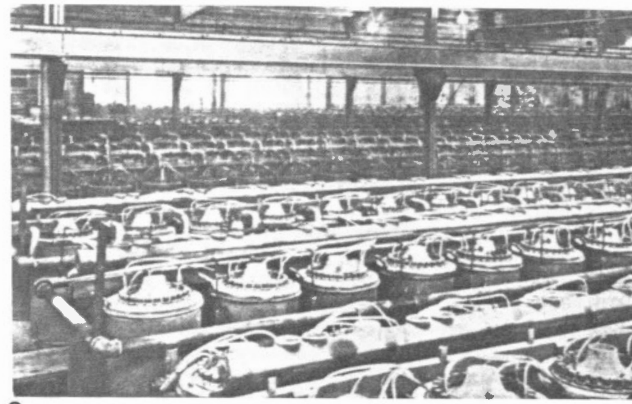

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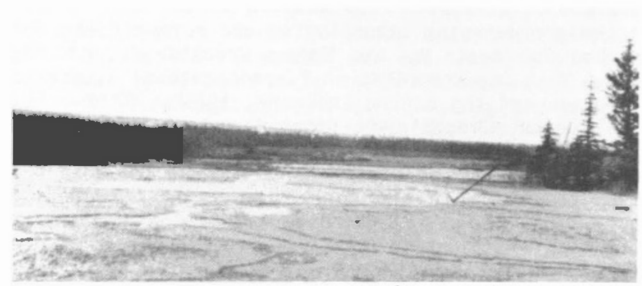

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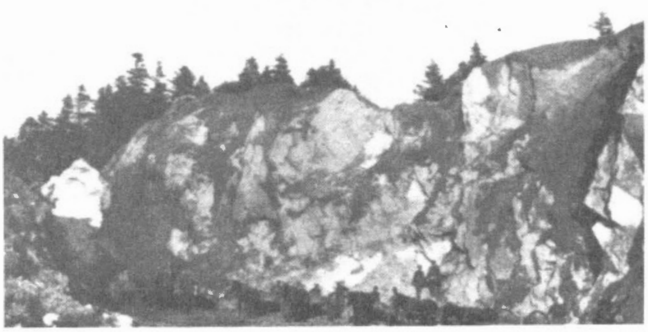

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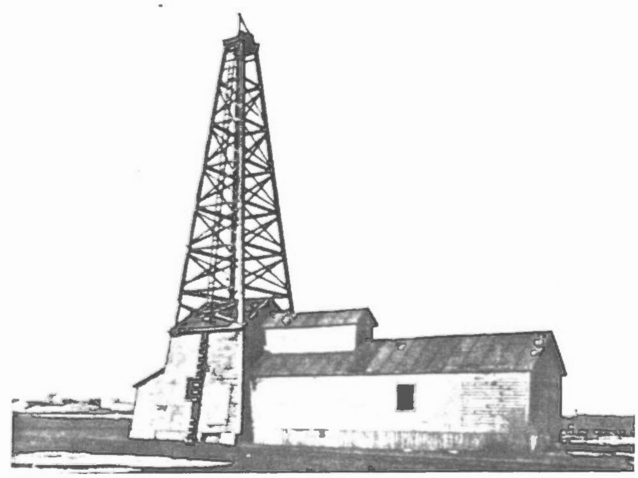

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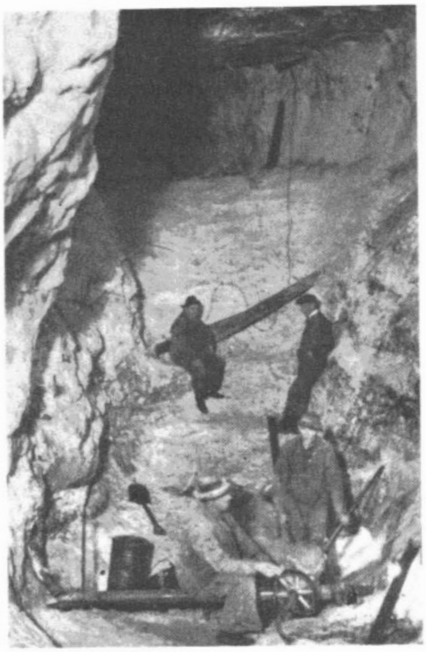
1. Electrically heated gypsum calcining kettle, designed by L.H. Cole and built in the mechanical shops of the Fuels and Fuel Testing Division, Mines Branch, Booth St., Ottawa

2. Working face in the quarry of the Nova Scotia Coal and Gypsum Company, Mabou, Inverness County, Nova Scotia

3. Electrolytic cell room for the decomposition of brine, Canadian Industries Limited, Sandwich, Ontario

4. La Saline flats, Alberta

5. Typical brine-well building and derrick, Canadian Industries Limited, Sandwich, Ontario



Stope in salt mine, Malagash, N.S.

When the Director walked in to greet Camsell, who had in his hand a copy of 'Salt in Canada' by Cole, he said: 'I keep that book there to show the students and research men here just how a proper report should be written as I think it a perfect example for them to follow'."

In 1929, Cole, later joined by R.A. Rogers, carried out a field and laboratory study on anhydrite (anhydrous calcium sulphate) and anhydrite cement. A report titled "Anhydrite in Canada: occurrence, properties and utilization" by L.H. Cole and R.A. Rogers was published in 1933, (MB Rep 732).

Granite

The first study on granite to be done by Mines Branch exclusive of Professor Parks' prior work on building and ornamental stones was by C.H. Freeman on granite paving stones in 1926 (MB Rep 687, pp 64-68, 1928). In 1930, Cole commenced a program on granite and related rocks for building and ornamental use and it was carried into the Mines and Resources period. However, it was not until 1955 that a monograph on granite was published. This was a handsome volume with coloured illustrations by F.G. Carr, who was in the Mines Branch from 1948 to 1956. At $4.50 it was the most expensive publication in Mines Branch history to that date (64).

Sand for Special Use

There was some interchange of staff dealing with sand. It will be recalled that Cole was the first officer concerned with the major study of silica, sandstone, and sand from 1914 to 1918. J.F. McMahon, an officer of Ceramics and Road Materials from 1925 to 1936, studied the refractory character of moulding sand as reported in "Investigations of ceramics and road materials, 1926" (MB Rep 690, pp 9-24). Cole and McMahon were co-authors of a report on kaolin and associated clays of Punk Island in Manitoba in the same report (pp 25-35). Cole, Carnochan, and W.E. Brissenden of the Development Department of Canadian Pacific Railways co-authored a report on the suitability of certain Canadian sands for sandblasting, contained in "Investigations of mineral resources and the mining industry for 1931" (MB Rep 727, and separately in MB Rep 727-1).

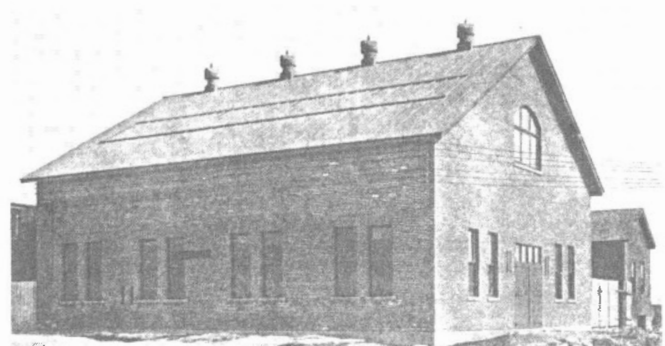
C.H. Freeman, who in 1923 was first assigned to the Records Section of the Mineral Resources Division, commenced a study of sands and gravels of Eastern Canada in 1928, but this study turned into a specialization on moulding sands. A preliminary report "Moulding sands in Eastern Canada" was published in "Investigations of mineral resources and the mining industry for 1928" (MB Rep 710, pp 47-52). Freeman continued this work into the Department of Mines and Resources period. However, in the last year of the Department of Mines, a report entitled "Natural bonded moulding sands of Canada" by C.H. Freeman (MB Rep 767, English text, and 768 French text) was issued in 1936.

Industrial Minerals Laboratory

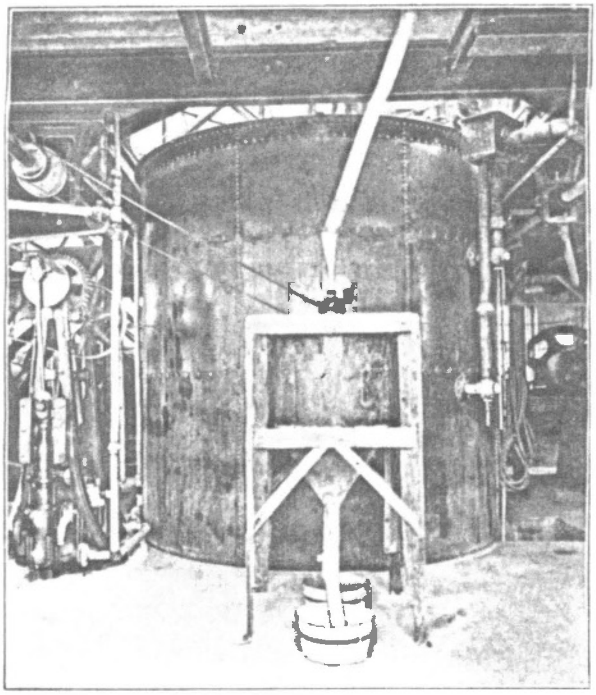
Following a year's preparation, a "non-metallic" laboratory was opened in 1926 as part of the reconstructed Ore Dressing and Metallurgy Laboratory following a fire in 1920. Carnochan was placed in charge and Rogers was transferred from the Chemical Laboratories on Sussex Street, to assist him.

The first investigations undertaken in 1926 were: (1) fine grinding of graphite ore from a deposit near Perth, Ontario with elimination of calcite impurities; (2) concentration of low-grade fine graphite flake from Buckingham, Quebec; and (3) preparation of bentonite to meet market requirements.

The establishment of a separate non-metallics laboratory after some fifteen years' experience with mixed processing of both metals and non-metals was a significant decision, particularly as it was taken by men of McLeish's and Timm's background. This decision must have come about by realizing the differences between metallics and industrial minerals. Comminution and preparatory steps are generally different though



The non-metallic laboratory, part of Ore Dressing and Metallurgy Laboratory



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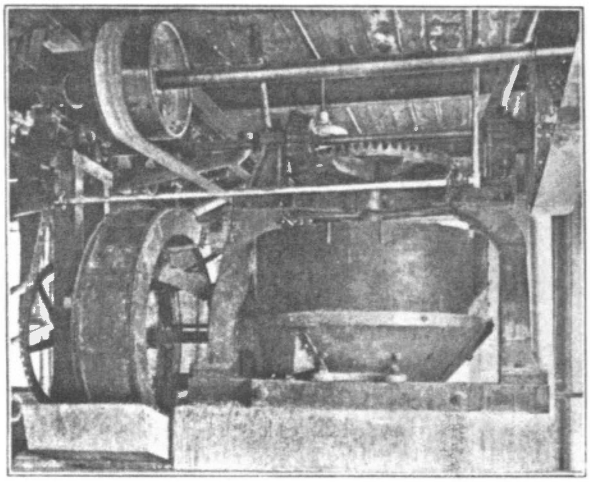

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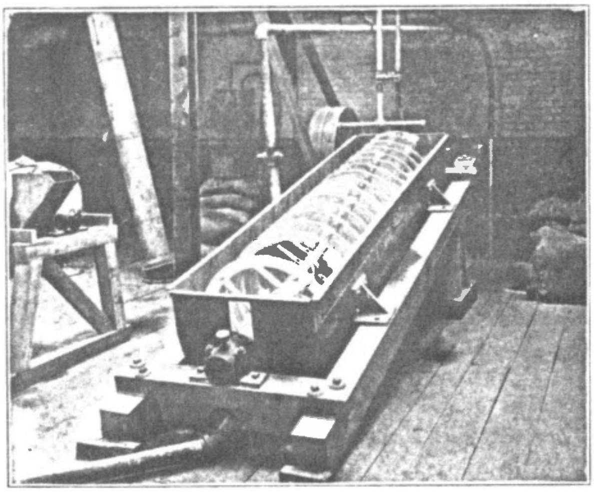

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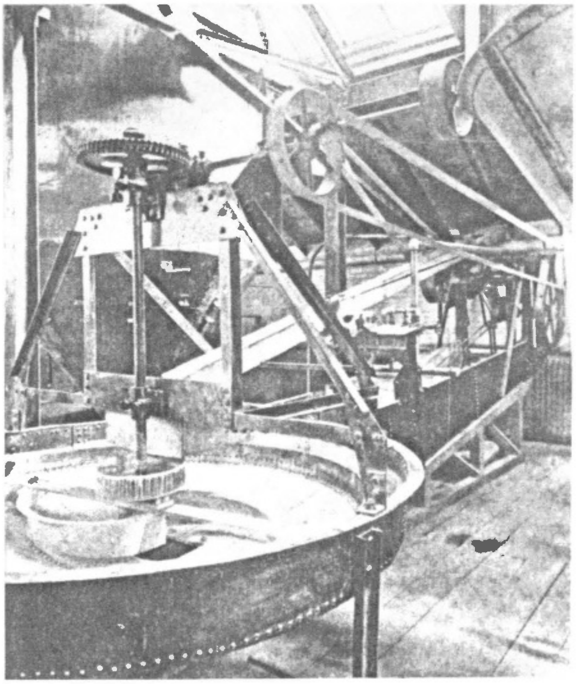


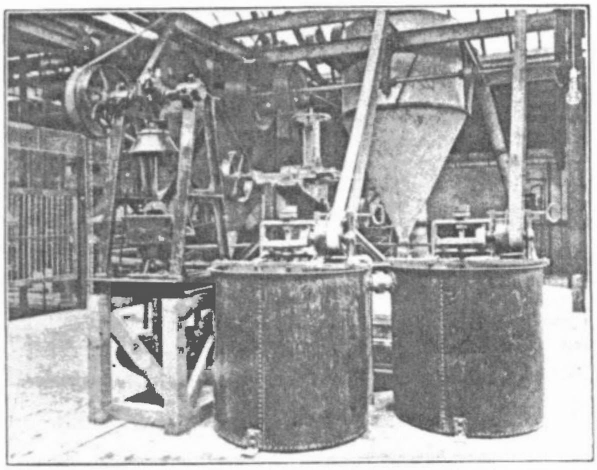
4

Equipment in non-metallic laboratory; 1 - 12-ft x 12-ft Dorr thickener and 30-in. Gayco air separator in foreground; 2 - 4-ft Chilean chaser mill for silica grinding; 3 - 24-in. Akins classifier; 4 - Dorr bowl classifier and 8½-ft Sturtevant air separator; bowl for fine water-floated product and separator for fine air-floated product (cont'd next page)

some pieces of apparatus may be similar. Industrial minerals must be prepared for distinct end uses where size, colour, moisture, etc., play important roles in meeting market requirements. Processing has to remove small amounts of impurities at the lowest possible cost as most industrial minerals are relatively low-priced commodities.

Appellation of Industrial Minerals

It may be of interest to the reader to learn why and when the expression "industrial minerals" was first applied to non-metallics. L.H. Cole recounted that until the 34th Annual General Meeting of the Canadian Institute of Mining and Metallurgy in 1933 in Toronto there were no sectional meetings, only plenary. Papers on non-metallics were accepted by the Institute but were relegated usually to the end of a session, when the attendance tended to diminish. For example, at the Annual General Meeting in 1929 in Winnipeg, the first one to be held west of the Great Lakes, Cole was presenting a paper titled "The place of non-metallics in the mining industry". This was the last paper scheduled for that session. There was a general exodus of participants following presentation of a paper on a



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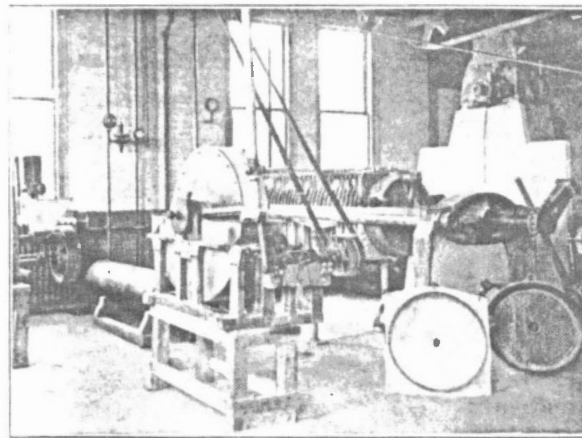


6

5 - Dorrco pump, Dorr thickener, and two mixing tanks; 6 - Oliver 3-ft x 6-ft filter and 28-in. Patterson filter press

metallic mineral and there were left in the meeting hall four persons - Cole, two members, and chairman Gordon Hutt of the C.P.R. Cole asked for the paper to be taken as read and the session was terminated.

The new secretary of the Institute, E.J. Carlyle, appointed in 1931, consulted Cole on this episode and after discussions suggested the preparation of a brief to Council of the Institute. In the preparation of this brief by a group of mining people, Mines Branch staff like Cole, Fréchette, etc., were undoubtedly to the fore. The "hard rock" fraternity considered non-metallics as prosaic minerals and their recovery, moreover, to be a manufacturing process. Howells Fréchette is credited with suggesting the new term "industrial minerals" to replace the negative term "non-metallic".

On October 15, 1932, Council accepted the formation of the Industrial Minerals Section, the first section of the Institute, and appointed a General Committee of the section for the first year under the chairmanship of L.H. Cole and N.B. Davis as secretary. Both of them served the two terms, 1932-33 and 1933-34.

This committee organized three sessions of the Industrial Minerals Section simultaneously with the plenary sessions of the Institute at the 33rd Annual General Meeting in Toronto.

The term "industrial mineral" was adopted by the American Institute of Mining, Metallurgical and Petroleum Engineers in March 1935. The Industrial Minerals Section of the Canadian Institute of Mining and Metallurgy was elevated to divisional status in 1941.

METALS

Organization of Ore Dressing and Metallurgical Division

Following the resignation of G.C. Mackenzie, chief of the Ore Dressing and Metallurgical Division, in February 1919, W.B. Timm, who had been virtually superintendent of the division's laboratories for several years, was appointed acting chief. Timm was confirmed chief of the division on April 1, 1920, some eight months before Haanel's official retirement, and remained in charge until the end of the Department of Mines period.

He immediately had to face the post war resignations and a fire in February 1920 which destroyed a portion of the laboratories, offices, and workshops on Booth Street. For a time the chemical analytical work had to be transferred to Sussex Street. At that time he had only three professional staff members - R.K. Carnochan, assistant mining engineer, who joined the division in 1920, and H.C. Mabee and R.J. Traill, chemists.

He applied himself vigorously to building up an organization which by the end of the decade could fairly claim to be one of the world's leading R & D institutions in process metallurgy. Considerable construction and modifications were carried out in several stages as demands on space grew because of expanded programs. In the initial period, additions were made on the original site, thus, the following laboratories were developed during this period - in 1924, a hydrometallurgical laboratory, in 1926, a non-metallics laboratory, and in 1928-30, a pyrometallurgical/metallographic laboratory. A new building at 552 Booth Street was put up in 1930 for housing laboratories and technical staff on the site of the original Fuels Building - the first on Booth St. known at that time as the Peat Building.

In spite of these changes and the extension of scope of activities, Timm ensured that the core program of ore and mineral processing would not be affected by the wider scope of the R & D. He maintained the ore dressing laboratories up to date both in bench and pilot-scale equipment. During his term of 16 years as chief of the division, some 500 published investigations were carried out, a high proportion of which were on a large scale. They contributed to the development of a number of mill flowsheets. In addition, a considerable number of investigations were made for companies requesting nondisclosure of results, or confidentiality.

In 1928 Timm introduced the following organizational structure in the Ore Dressing and Metallurgical Division:

Ore Dressing Section for Metallic Ores:

Engineer in charge - C.S. Parsons (1914 - 1918), (1921 - 1951)
Assistants - A.K. Anderson (1916 - 1953)
- J.S. Godard (1922 - 1931)
Mill superintendent - B.M. Derry (1914 - 1930)
- A. Davie (1917 - 1938)

Ore Dressing Section for Non-metallics:

Engineer in charge - R.K. Carnochan (1920 - 1940)
Assistant - R.A. Rogers (1924 - 1956)

Hydrometallurgical and Electrochemical Section:

Officer in charge - R.J. Traill (1916 - 1955)
Assistant - W.R. McClelland (1924 - 1956)
- J.P. Johnston (1925 - 1960), Fuels (1925 - 1927)

Chemical Section:

Officer in charge - H.C. Mabee (1914 - 1937)
Assistants - B.P. Coyne (1917 - 1919) and (1921 - 1950)
- H.L. Beer (1927 - 1954)
- L. Lutes (1916 - 1966)
- W.F. White (1927 - 1953)

Iron and Steel Section:

Officer in charge - T.W. Hardy, Fuels (1914 - 1919), Metallurgy (1928 - 1934)
- A.E. Larochelle (1927 - 1966)
- W.S. Jenkins (1930 - 1964)
- H.H. Bleakney (1931 - 1935) and Physical Metallurgy (1952 - 1963).

Mineragraphic Laboratory:

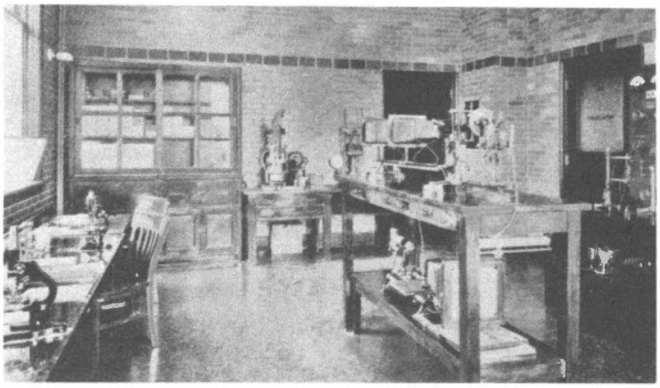
Officer in charge - M.H. Haycock (1931 - 1965)

The Mineragraphic Laboratory, inaugurated in 1932, provided useful facilities for microscopic examination and spectroscopic analysis in treating metallic ores and industrial minerals, mill products, etc.

Dates in the above list indicate the total years of service in the Mines Branch. Three of the laboratory groups: Ore Testing and Research, Pyrometallurgical and Mineragraphic have been described in the Memorandum Series (65).

The staff showed flexibility across the sections. If the workload of any section appeared excessive, the staff from other sections came to its assistance. This list is not inclusive, particularly in regards to the mill staff and persons employed for short periods.

The workload carried by a relatively small staff is worthy of note, an example being that in the fiscal year ending March 31, 1936, the last under the Department of Mines, 137 reports of investigations were prepared of which 51 were published and the remainder sent to interested parties in industry and government. They included studies of metallic and radioactive ores, non-metallic minerals, and metallurgical products. In the mineragraphic laboratory, 104 mineralogical determinations and 38 spectroscopic analyses were made. For the mineralogical work, 1166 polished sections from



Mineragraphic laboratory

ores and mill products were prepared and 27 thin sections were prepared from non-metallic minerals. The chemical laboratories received 4935 samples requiring 14,644 chemical determinations. Minor investigations are not included in this count. It must be remembered that the state of knowledge in metallurgical processing was not as advanced as it is today; hence many of the investigations were not routine and required preliminary research to resolve particular problems.

It was fortunate that all the facilities outlined above were developed and most of them in place before the depression of the 30's started, in the light of the severe reduction of budgets that occurred.

It was Timm's practice to keep in touch with industry by regular field visits to mining camps and metallurgical works when new processes were being developed; even many of the laboratory staff spent time at mills and plants to obtain first-hand information on problems of the industry and innovations in metallurgy. In 1930 Timm attended the Third Empire Mining and Metallurgical Congress in South Africa as a departmental representative. During the depression there was a reduction in travel but essential field work and attendance at conferences were not cancelled.

The respect in which the work of the division was held may be gauged from the cooperative agreements made in 1927 with the Base Metals Extraction Company of the United Kingdom and the Cassel Cyanide Company of Canada. In 1929, the same type of agreement was made with the American Cyanamid Company. The Base Metals Extraction Company built and equipped a laboratory for testing and demonstrating a hydrometallurgical process for treating complex lead-zinc and zinc-copper ores. The Cassel Company placed a research fellow in the Mines Branch to study the use of cyanide for selective flotation of base metal sulphide ores, particularly copper-zinc. In 1929, at the request of Dr. J.N. Greenwood, Professor of Metallurgy at the University of Melbourne, Australia, C.B. O'Maley, the then recently appointed lecturer in ore dressing at that university, spent a five-month training period in the Mines Branch laboratories to become acquainted with Canadian and U.S. milling practices. Furthermore, advantage of the laboratory facilities was taken by investigators from industry and equipment firms to carry out tests in connection with ore treatment problems. However, following onset of the depression, these cooperative studies were discontinued.

The thrust of the research and investigative work of this division during the 1920 to 1936 period until the depression was in base metals and after 1930 in gold and precious metals. Timm did not overlook ferrous metallurgy, in fact he devoted some of the division's efforts in promoting research in pyro and physical metallurgy. Industrial minerals received more in-house attention than in Haanel's period.

BASE METALS

As prospecting and mining activities increased in Canada there was growing realization of the abundance of base metals which occurred mostly in mixed sulphide ores such as lead-zinc, zinc-copper, etc., almost always in association with iron sulphides. Often these ores contained precious metals and those posed special difficulties in obtaining adequate recoveries, for example, the gold and silver from telluride ores. The older separation and concentration techniques such as magnetic, electrostatic, and wet methods - jigging, tabling, etc. - were inadequate for these ores. Impure concentrates were thus being smelted with attendant loss of metals and penalties were exacted by smelters. It will be recalled from Chapter 3 that this was the case with the lead-zinc ores of British Columbia.

Haanel and the Mines Branch staff were cognizant of most developments on flotation from Ingall's first experiments in 1905, and kept in touch with continental and international technology. When enlarging the Ore Dressing Laboratories in 1912, provision had been made for an oil flotation apparatus which was installed in 1914 (1914 Summ Rep, p 76).

Molybdenum

In spite of an imperfect understanding of the flotation process, Mackenzie, Timm, and a small group of associates in the Ore Dressing Laboratories had to face the challenge for war purposes in 1915 of devising an effective separation and concentration method for molybdenite. As mentioned previously, their research was successful. The treatment of molybdenite ores on a custom basis was discontinued after August 1, 1918, principally because the urgent demand for this mineral by the British Government had ceased and because of interference with other testing work of the laboratories caused by such commercial work. As the years passed after the war, the demand for molybdenum ore dwindled. The peak demand was in 1917 when saleable ore and concentrates totalled 1554 tons and this figure was not exceeded in World War II. The main producer in World War I was the Quyon Molybdenite Company in Pontiac County, Quebec. It closed in 1929, and reopened at the end of the depression just prior to World War II. The only production recorded by the Dominion Bureau of Statistics in the early to middle 30's was the 1222 pounds of concentrate made at the Mines Branch laboratories in 1932 from ore mined in Bagot Twp., Ontario.

Differential Flotation and Studies of Flotation Reagents

Following the successful application of flotation to molybdenum ore, this process was used increasingly in solving recovery problems when water gravity concentration methods were inadequate in treating metallic ores such as mixed sulphides and low-grade ores, or non-metallic ores such as graphite.

Concurrently, flotation reagents were being studied, leading the way to mastering differential or selective flotation, meaning the successive separation of minerals in order of their "floatabilities". Actually, the study of reagents started in 1916 when the cobalt-silver producers appealed to the government for assistance in treating low-grade ores.

Prior to joining the Branch in 1917, R.E. Gilmore was employed at the Forest Products of Canada Laboratories in Montreal. As imported pine oil was in short supply, the object of a test program was to find a Canadian substitute. Extensive distillation of Canadian woods carried out by Gilmore developed a satisfactory substitute for pine oil using Canadian hardwoods as the yield from Canadian pines was considered to be too low.

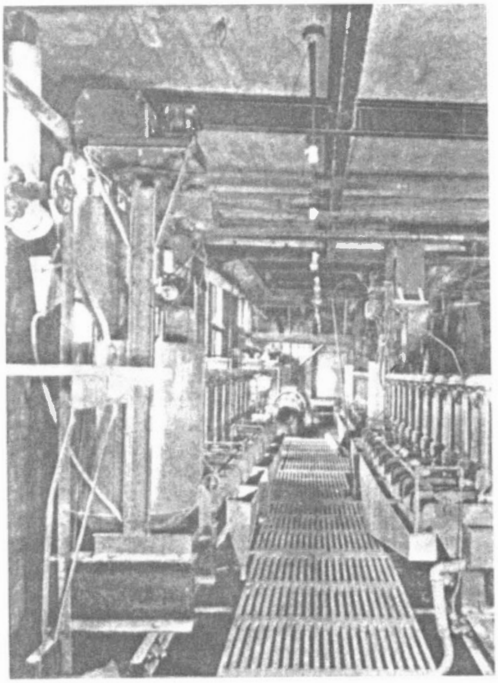
The oils were tested in flotation runs in Ottawa by Parsons, and full-scale tests were made at Cobalt. A paper was presented by both authors to the annual meeting of the Canadian Mining Institute in March 1917 in Montreal ("Canadian wood oils for ore flotation" by C.S. Parsons and R.E. Gilmore, and Trans Can Min Inst, Montreal Vol XX, pp 38-92).

The flotation reagent program was interrupted by the work on war minerals but it was restarted in 1921 and was widened in scope to include mineral oils and other reagents manufactured in Canada. A questionnaire was circulated to the mining industry requesting their cooperation in stimulating the use of Canadian-made products and to provide data with respect to the amount of oils and reagents used, costs, etc. A report by Parsons was published in 1928 ("Investigations of mineral resources and the mining industry for 1926", MB Rep 687). The Mines Branch studies on reagents were largely carried out by Parsons with laboratory and mill assistants. They were enlarged in 1927 by cooperative agreement with the Cassel Cyanide Company and in 1929 with the American Cyanamid Company, as mentioned previously. Timm deemed the presence of outside research associates beneficial to the R & D activity of the Ore Dressing Laboratories as well as to the Chemical Laboratory where Mabee was studying recoveries of iron, sulphur, precious metals, and base metals from metal sulphides.

R & D on Treatment of Base Metal Ores

It is difficult to give a precise list within the confines of this narrative except to record that between 1920 and 1936, when the Department of Mines ceased, about 510 investigations were carried out at the Mines Branch Ore Dressing Laboratories. Very complete accounts of the ores investigated during this period were published in "Investigations in ore dressing and metallurgy" on an annual basis from 1920 to 1932 and on a semi-annual basis from 1933 to 1939, the last 3 years under the Department of Mines and Resources. Of the 510 published reports, no less than 200 or so referred to base metals, particularly in the period up to the depression. Probably at least an equal number of investigations were carried out but were not published.

From 1922, after Parsons' return in 1921, an ever-increasing program of testing complex sulphide ores and other ores including industrial minerals,



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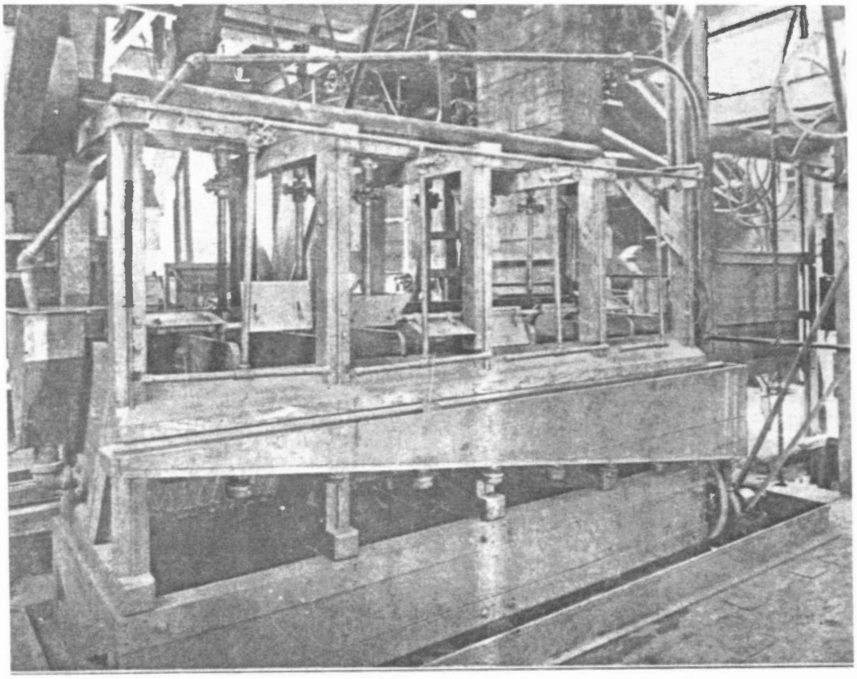


2

Some of the equipment used in flotation research, 1 - flotation unit with capacity of 500 pounds of feed an hour; 2 - Greenawalt mechanical agitation flotation machine (cont'd p 73)

arising from requests of the industry or at the instigation of the staff, was conducted using the new technique of selective flotation (66). Many of the mining companies sent staff to participate and assist in the test program, and Timm encouraged this policy. Bench-scale tests were carried out before proceeding with pilot plant-scale testing. When flowsheets resulted from these investigations, the Mines Branch invariably kept in touch with the operations after the mills had gone on-stream and its advice was sought when problems arose. From all reports, the Mines Branch ore dressing and metallurgical staff had far more contact and interchange of ideas with the metallurgists and mill personnel of the industry than would have been possible at professional or formal meetings.

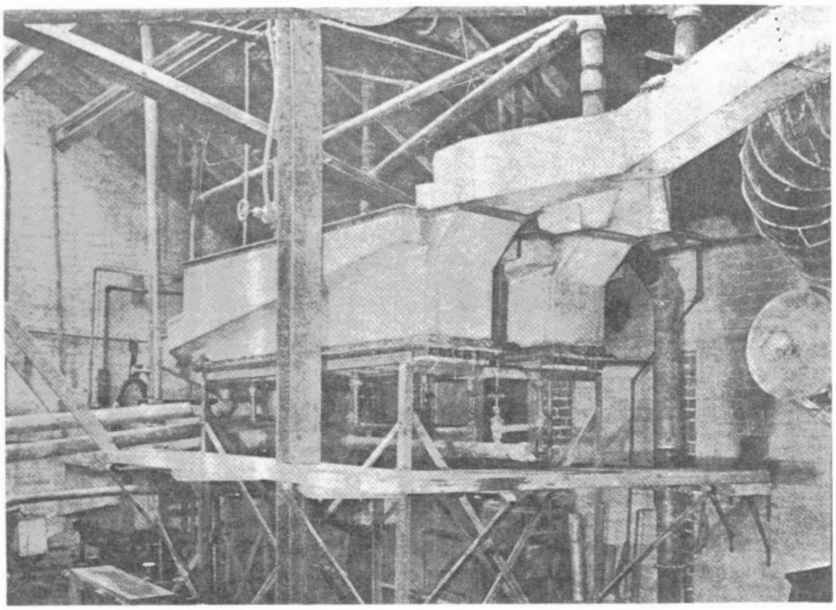
Most of the companies presently operating or their predecessors such as Cominco, Noranda, Sherritt Gordon, Hudson Bay Mining, Inco, and Falconbridge had investigations carried out at the Mines Branch laboratories at this period. It should be noted that the selective flotation process was applied in Canada first at the Sullivan mine of Cominco; the concept is credited to being tried first at Broken Hill in New South Wales, Australia, in 1913.

It is appropriate to quote from the annual report of the Mines Branch director (Report of the Department of Mines for the fiscal year ending March 31, 1934, p 24) that indicates the impact of the foregoing R & D on the industry: "During the past three years, 170 or more investigations of the ore treatment type have been made. During the same period, 28 plants have been erected; substantial changes effecting greater efficiency in operation have been made in 6 established plants; 9 plants are now under construction (April, 1934) and 29 plants are being planned and their construction contemplated, all for the treatment of ores on which preliminary tests have been made in the Ore Dressing Laboratories."

Hydrometallurgical and Electrochemical Research

It is noteworthy to record the start of research into hydrometallurgy and electrochemistry at the Mines Branch. In 1921, a roasting and a water and acid leaching test was conducted on a very small scale on the complex sulphide ore from Flin Flon but it was claimed to be inconclusive. In 1922, R.J. Traill started a program of hydrometallurgical and electrochemical research, first on a small laboratory scale, increasing the scale towards the end of the decade when better facilities became available.

This program seemingly originated from Traill's alertness for spotting and studying innovation and possibly because of his intuition as a chemist that the chemical route would avoid losses to the atmosphere as well as in slags that usually occur with the smelting route. Furthermore, he reasoned that the hydrometallurgical process could yield better recoveries of all the constituents of complex ores which are abundant in Canada. In effect, Traill built up the various segments of extraction metallurgy and electrochemistry - leaching with or without roasting, electrodeposition, and chemical precipitation of metals. It is clear that chemists like Traill and Mabee and their young associates like McClelland and Johnston were competent and flexible, and were the kind that the branch had looked for from Haanel's period in the creative role of a chemist. Most of the research work was directed to the production of electrolytic iron from iron sulphides and of titanium oxide from titaniferous ores with recovery



3

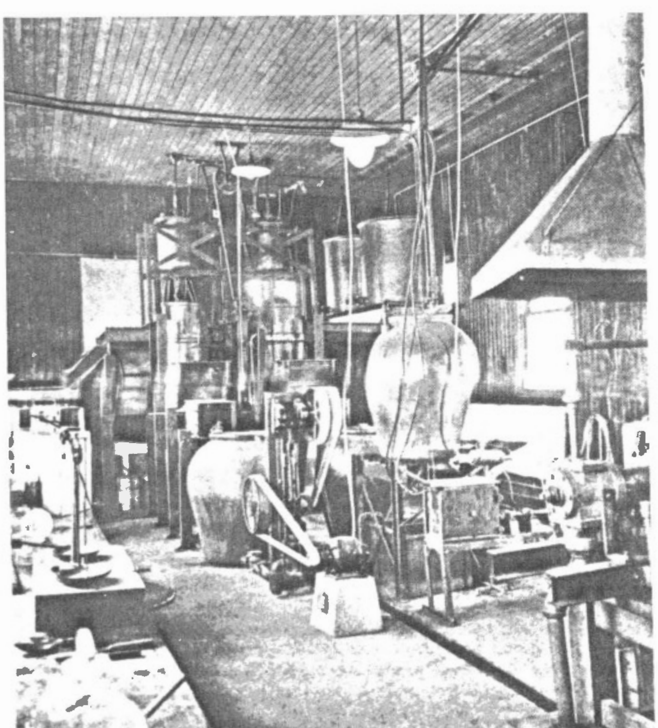
3 - The Callow pneumatic flotation unit consisted of two rougher and two cleaner cells for large-scale comparative tests with mechanically agitated cells. The two types of flotation units each had a capacity of 1,000 pounds per hour

of sulphur and co-occurring metals. However, some of the investigations were directed primarily to base metal and precious metal recovery. Examples of three such studies were:

(1) hydrometallurgical treatment of pyrrhotite with low gold and copper content from Noranda, 1925

(2) hydrometallurgical and electrochemical processes for the recovery of zinc from Canadian ores, concentrates, and residues, 1929

(3) Traill and Mabee worked in cooperation with the Base Metals Extraction Company mentioned earlier; a laboratory was equipped to conduct tests and demonstrations of the company's hydrometallurgical process for treating bulk concentrates from mixed base metal sulphide ores. This study was carried out in 1929 but because of the depression, the company terminated the project in 1931.



Equipment in electrochemical laboratory for electrolytic iron investigations

These researches were reported in "Investigations in ore dressing and metallurgy" (MB Rep 617, pp 107-114), and [MB Rep 643, 670, 688, 695, 711, and 720 (1924 to 1929 inclusive)].

Following the historical discovery in 1930 of pitchblende at Great Bear Lake, NWT, Traill's group became involved with hydrometallurgical research on radioactive ores.

GOLD AND SILVER

It may be interesting to recall the history of gold and silver production in Canada. After producing over a million ounces of gold per annum for four successive years from 1899 to 1902 and peaking at 1.35 million ounces - mostly from the Klondike placers in the Yukon - Canada's output, which was mostly from underground mines in Ontario and British Columbia, was below a million ounces per annum for the next 20 years. In 1922 it was 1.26 million ounces, with Ontario's contribution being approximately one million. Production then increased to 2.1 million ounces by 1930, reaching a peak of 5.35 million ounces in 1941. It then started to decline but picked up at the end of the war, reaching another peak in 1960 of 4.63 million ounces. It then declined again to the present rate of about two million ounces per annum. The story of silver has been different. The peak of nearly 33 million ounces a year was first attained in 1910, largely from Cobalt. Production varied up and down for the next 35 years between the latter peak and a low of about 12-1/2 million ounces in 1946. It has however risen again over the years and in 1975 was about 41 million ounces. Silver is largely a byproduct from treating mixed ores and smelting and refining of base metals and crude gold. Up to 1920 only nine auriferous ores were reported on by the Mines Branch Ore Dressing Laboratories for gold recovery. Gold and silver assays of ore samples were of course made periodically from the early period of the Department of Mines. In the next nine years to 1929, some 40 samples were submitted for treatment. By 1936 in the final period of the existence of the Department of Mines, some 220 samples were reported on. Very few gold quartz ores were investigated, most being associated with sulphides of iron, copper, arsenic, etc.

The decade of the 30's and part of the 40's was the gold boom period of Canada, which from 1929 to 1933 placed her second in world production after South Africa and third in 1934 after the Soviet Union. An important reason for this was the higher price of gold after the U.K. and U.S. went off the gold standard in 1931 and 1933 respectively. Base metals and most other minerals fared poorly during this period; however, the diversified mineral resources of Canada have helped to even out fluctuations of the Canadian economy; thus gold was the "saving grace" in the 30's as energy minerals are in the 1970's.

A.H.A. Robinson, metal specialist in the Mineral Resources Division, produced the commodity report on gold in 1932 entitled "Gold in Canada" (MB Rep 730). The edition was sold out quickly. An updated report was published in 1933 entitled "Gold in Canada, 1933", (MB Rep 734), and this also went out of print rapidly. A third report with revisions up to and including 1934 entitled "Gold in Canada, 1935" (MB Rep 769) was published in that year. In the latter edition some 70 properties were described. There have been no further reports of this nature published since that date.

It is interesting to recall that in 1934 Ontario produced 70% of Canada's gold. Of the Ontario total of 2.1 million ounces, over 90% came from the famous Porcupine and Kirkland Lake camps, two relatively small areas in northeastern Ontario about 65 miles apart. The combined daily mill capacity in 1934 of the three largest mines in the Porcupine belt - Dome, Hollinger, and McIntyre Porcupine - was 8750 tons, and of the three largest mines in the Kirkland Lake belt - Wright-Hargreaves, Lakeshore, and Teck Hughes - 4650 tons. The discovery and early development of these camps started in the second decade of the century. By the 1930's, the mines mentioned were rivalled in output and depth of mining only by the South African mines and by one in Brazil.

In 1934, next to Ontario, Quebec was Canada's second largest gold producer with an output of 390,000 ounces representing about 13% of the total output of the country. The famous Horne copper mine at Noranda accounted for 64% of the province's total gold output in 1934. In the same year, British Columbia produced 296,000 ounces or nearly 10% of the total production of the country.

FERROUS METALS

Following organization of the Mines Branch in 1921 and formation of the Mineral Resources Division under Wilson as chief, the only officer assigned to metallics was A.H.A. Robinson. He continued for the first three years to devote his time to iron and titanium. A report on titanium by Robinson was published in 1922 (MB Rep 579). During the 1924 season he surveyed a group of deposits of titaniferous iron in Bourget Township, Lac St. Jean, Quebec. This group was considered to be possibly the largest of its kind in Canada and contained 40-50% iron and 15% titanium. The last survey carried out by the Mines Branch using a magnetometer was in this area, as described in "Investigations of mineral resources and the mining industry, 1924", under "Report on titaniferous magnetic deposits of Bourget Township, Chicoutimi District, Quebec", by A.H.A. Robinson (MB Rep 642, 1926).

Timm must have shared Haanel's concern about not using domestic ores in the Canadian iron and steel industry and the importation of low-cost ores mostly from the United States. He republished in summary form the beneficiation tests on Canadian iron ores largely from Ontario and Quebec carried out in the Ore Dressing Laboratories prior to World War I. Most of these ores were less than 50% in iron content and some were below 40%. The publication of these data was probably to draw attention to the possibility of using beneficiated ore of acceptable grade for domestic blast furnaces: "Investigations in ore dressing and metallurgy, 1923" (MB Rep 617, 1925). It was believed at the time there were no large iron ore deposits such as the Minnesota taconites in the then accessible parts of Canada and it was not until the 1950's that Canada actually became a large exporter following the impressive developments in Labrador and New Quebec. However, in the period under review after 1921, Canadian blast furnaces depended entirely on foreign ore - in 1929 imports reached nearly 2.5 million tons but in 1931 they fell to just over 800,000 tons, demonstrating the severe effect of the depression on the ferrous industry.

It should be recalled that during the previous two decades, the Mines Branch, aided by prior and contemporary work of the Geological Survey of Canada, made a substantial effort by magnetometric surveys and other studies to evaluate promising areas, particularly in Ontario and Quebec. Deposits of respectable sizes were identified and the following types of ore occurrences were recognized: high and low sulphur magnetite, mixed magnetite-hematite, carbonate, and titaniferous.

As mentioned earlier, in 1922 Traill commenced projects to produce electrolytic iron and titanium oxide - for the pigment industry - using Canadian pyrite, pyrrhotite, and ilmenite ores.

A decision was reached to proceed with a semi-industrial-scale pyrometallurgical laboratory constructed at the back of the original Fuels building. It was started in 1928 and completed in 1930. The laboratory was equipped for both pyro- and physical metallurgy investigations. The equipment included a continuous sintering unit, briquetting machine, a roasting furnace, a metallizing (direct reduction) furnace, and high frequency induction and arc-type melting furnaces; also heat treatment furnaces and a cupola. Furthermore, there was apparatus for metallographic analysis and physical and mechanical testing.

An iron and steel section was formed in 1928 and T.W. Hardy who was with the Fuels Division from 1914 to 1919, returned in 1928 and was placed in charge of the section and the laboratory. The objective of the

Part of the pyrometallurgical laboratory

program was to explore ways and means of utilizing iron ores by improved beneficiation and to investigate their adaptability to direct reduction or sponge iron processing. The physical metallurgy activity was an extension of the metallographic work that was started more than 10 years previously in the Sussex Street Structural Materials Laboratory.

One of the first projects in 1930 was a cooperative program with the Rogers Playfair group from Montreal, which was granted permission to demonstrate on a pilot plant-scale the "Musso semi-direct steel process" for the production of steel from iron ores. A four- to six-ton capacity pilot plant was installed which the Mines Branch staff assisted in operating, but through plant inadequacies the tests carried out failed to show commercial results. Independent Mines Branch tests showed that iron and coal mixtures could produce a sponge iron by the Musso method. The project was discontinued, however, because of disagreement between the Rogers Playfair group and the inventor.

T.W. Hardy (CMJ, 1930)

Other investigations carried out in 1931 by Hardy, aided by Traill, McClelland, and Jenkins were:

(a) beneficiation and metallization tests on Wabana, Newfoundland hematite from Sydney, N.S.; Bell hematite from Sault Ste. Marie; siderite ore from Helen Mine, Michipicoten; and pyrite sinter from the Freeman flash roasting process, Trois Rivières, Quebec
(b) physical metallurgy tests were made on a fractured aircraft exhaust valve, on chilled shot for cutting marble, and on a sample of nickel cast iron.

At the conclusion of this work, Traill, McClelland, and their group switched to working on pitchblende from Great Bear Lake, NWT.

In 1931 Hardy, assisted by H.H. Bleakney who joined the branch in 1930 and Jenkins, carried out the following investigations:

(a) production of low-sulphur sponge iron from coal-ore mixtures
(b) laboratory concentration of Texada Island and Bathurst, N.B. iron ores
(c) semi-direct reduction of nickel steel from Sudbury copper-nickel ores
(d) mechanical properties of samples of Monel metal.

They also carried out cooperative work with Canadian steel companies including:

(a) production by the basic electric furnace of a steel similar to an imported steel used in Canada
(b) production of a modified austenitic manganese steel for special applications
(c) production of cast alloy ring dies, and
(d) annealing of large, high-carbon chromium molybdenum steel castings.

They also investigated a failed wedge bar from a ball mill and carried out a number of metallographic studies and mechanical tests in the physical metallurgy section.

In 1932, Hardy and Bleakney carried out the following investigations:

(a) production of sponge iron from Texada Island, B.C. iron ores, and Moose Mountain, Ont. concentrates, and
(b) concentration and sintering of a high-sulphur magnetite ore from Texada Island.

In addition they carried out special physical metallurgy investigations for the Aeronautical Division of the Department of National Defence and three steel companies.

In 1933, Hardy and Bleakney investigated the sintering and metallization of Moose Mountain magnetite concentrates and the sintering, briquetting and metallization of Texada magnetite. A total of five physical metallurgy investigations were also made - two for Canadian Pacific Railway, one for Algoma Steel Corporation, one for Dominion Engineering Company, Montreal, and one for the Aeronautical Division of the Department of National Defence.

In 1934, Hardy resigned and joined Canadian Atlas Steels Ltd. Bleakney carried on this section with the aid of A.E. Larochelle as senior technician. They investigated:

A.E. Larochelle

(a) metallization of high-grade concentrates from Texada Island
(b) relative value of sponge iron and scrap iron as a base for steelmaking
(c) production of four ingots of nickel-molybdenum iron to develop improved stay-bolt material for the CPR and Canadian Atlas Steels.

Furthermore, they carried out eight physical metallurgy investigations for the Departments of Defence and Public Works, Canadian National Railway, Dominion Engineering, and Atlas Steels.

Bleakney resigned in 1935 and the work was carried on by A.E. Larochelle. He continued the projects on the metallization of Texada magnetite concentrates and on the sponge iron and scrap. He investigated the suitability of Quebec chromites for production of ferrochrome and he carried out nine investigations that included tensile strength, impact, and hardness tests for Dominion Bridge, Departments of National Defence, Marine, and Public Works, and two Ottawa engineering firms.

The work of the iron and steel section continued into the Mines and Resources period until the physical metallurgy activities were separated into a laboratory of their own in 1943. A Physical Metallurgy Division was formed in 1950. The pyrometallurgical activity continued with the Ore Dressing and Metallurgy Division. Research and investigations in this section were reported in MB Rep 711, 720, 724, 728 and 736, from 1928 to 1932 inclusive. No further reports were published after 1932.

RADIOACTIVE ORES

In 1929 work was started to develop an occurrence of uraninite in a pegmatite dyke near Wilberforce, Haliburton County, Ontario. A carload of the ore was sent to the Mines Branch Ore Dressing Laboratories for testing. It yielded the equivalent of 2.56 pounds of uranium oxide, U_3O_8, or the equivalent of one gram of radium from 3422 tons of ore. The Mineral Resources Division was involved with this investigation, particularly Spence who eventually became the resource specialist for radioactive ores. "The Wilberforce radium occurrence" by H.S. Spence and R.K. Carnochan appeared in "Investigations of mineral resources and the mining industry, 1929", (MB Rep 719).

Important deposits of pitchblende in association with rich silver ore were discovered in 1930 at Echo Bay, Great Bear Lake, NWT, by G. Labine. This was described in "The pitchblende and silver discoveries of Great Bear Lake, NWT" by H.S. Spence (MB Rep 727-3, 1932), reprinted from "Investigations of mineral resources and the mining industry, 1931" (MB Rep 727, 1932).

A year later in 1931, 20 tons of high-grade material was sent to the Mines Branch laboratories for hydrometallurgical treatment. The first commercial shipment of this ore was made in 1932 to Trail for smelting.

The two tests mentioned above inaugurated the long involvement that Mines Branch has had with radioactive ores. It should be remembered that at the time public interest was centred on radium, mainly for medicinal use. Demand for uranium was also small, the principal use was for ferro-uranium for hardening and toughening steel and in the glass and ceramic industries as a colouring material.

Eldorado Gold Mines commenced treatment of its radium-bearing ores in a new plant at Port Hope, Ontario, in 1932. It may be said that Mines Branch was

Uraninite vein near Wilberforce, Ontario; ore shipped to the Mines Branch came from pit in foreground; Nov. 1929.

Labine Point and Labine Bay, Great Bear Lake, North West Territories. Approximate course of pitchblende vein shown by dotted line, discovery point marked X

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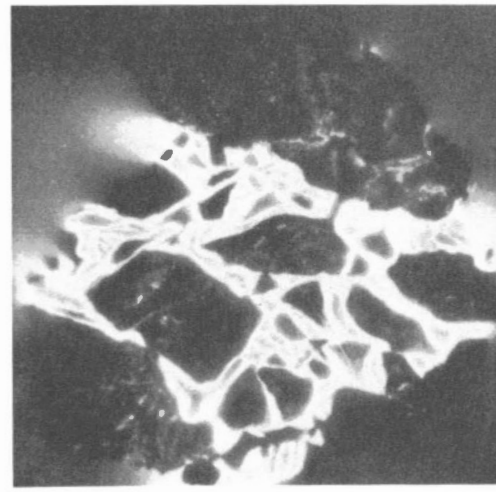

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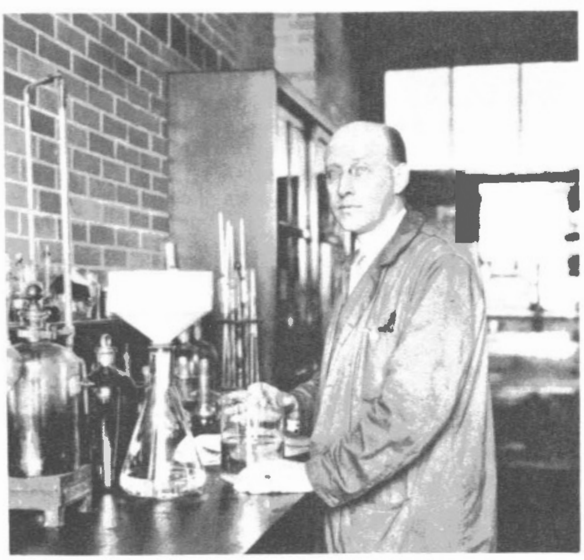
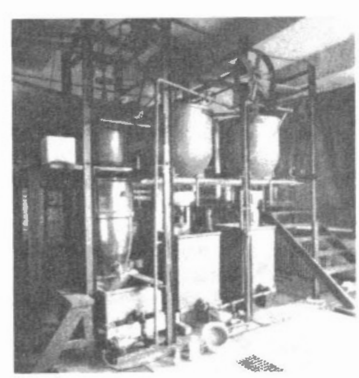
Pitchblende ore from No. 3 vein of Labine discovery showing 1 - polished section of pitchblende in veinlets; 2 - radiograph of same specimen.



R.J. Traill analyzing radioactive ores, 1932

Visit of Mines Branch staff to Port Hope Refinery; (left to right: F.D. Reid, W.B. Timm, G. Labine; back to camera, J.A. Faulkner, Sir F. Banting. (Public Archives, Canada)

associated from the grass roots with all metallurgical developments relating to radioactive ores. A study was made of the treatment of radioactive ores and minerals, on the methods of determining radium by electroscopic means, and the hazards involved and precautions to be taken. The investigations of the treatment processes were assigned to Traill and the electroscopic determination to McClelland. Their work was reported in "Investigations in ore dressing and metallurgy for 1931 and 1932" respectively (MB Rep 728 and 736). A paper was prepared by Traill for the 1933 CIM Annual Meeting entitled "Extraction of radium from Great Bear Lake pitchblende" (Transactions of the Canadian Institute of Mining and Metallurgy, 1933, Vol XXXVI, pp 448-467). This was probably the first public article in Canada on the treatment of radioactive ores.



Pilot plant for investigating extraction of radium from Great Bear Lake pitchblende ores (Public Archives, Canada)

Gilbert Labine of Eldorado Gold Mines, W.B. Timm and R.J. Traill (left to right) with lead-lined safe containing radium-barium sulphate concentrate. (Canadian Nuclear Technology, Spring 1962)

In 1932 and the following year, Traill was advised on medical grounds to take periodic leaves and abstain from further contact with radioactive ores as electroscopic tests of his exhaled air showed high levels of radiation. Traill continued to be consultant at the Port Hope refinery, but towards the end of the period he returned to assist in the iron and steel section after Hardy's and Bleakney's resignations.

FUELS

Exclusive of radioactive ores where the national impact is not yet clearly known, the energy minerals of Canada by their distribution and characteristics in relation to the growing needs of population and industry posed from the early days a national problem which still eludes a satisfactory solution. The R & D effort of the Fuels group in the Mines Branch in its long history of constructive work from 1910, has been and is directed to the identification of basic properties of Canadian fossil fuels as known or discovered and the determination of their marketability in raw or converted form.

Like other groups in the Mines Branch and the Geological Survey at the end of World War I, the Fuels Division suffered the loss of key staff like Gilmore, Stansfield, Blizard, and Hardy. This slowed the research and investigational work of the laboratories but the earlier position was restored by the end of 1921.

For the entire period to 1936, coal received the largest emphasis in this division, as the commodity was the principal fossil fuel in use as an energy source, though more than half of the national requirements were imported, principally to supply Ontario and Quebec. Formation of the Dominion Fuel Board in 1922, of which B.F. Haanel, chief of the division, was a member, provided another reason for this emphasis as several of the branch officers acted as consultants to the board. The work on hydrocarbons reflected the national concern of the day: depletion of the small resources in Ontario and a small western production. It was not until 1924 when Turner Valley Royalite No. 4 well "came in" with a large flow that the outlook was improved somewhat for Canadian crude oil.

The Fuels Division continued studies in shale oil and started some preliminary work on extraction of the heavy bitumen from the Alberta oil sands. The analytical facilities for oil and gas analysis were considerably expanded. After 1930, the emphasis shifted to research on production of synthetic liquid fuels from coal when Dr. T.E. Warren came to the division. Investigations by S.C. Ells, "the lone pioneer" of the oil sands, continued throughout this period. It will be recalled that Ells, when he first started in 1913, was assigned to the Non-Metalliferous Deposits group; in 1916 for a short period he was with the Ceramics Division, presumably in relation to his work on shales. He then transferred to the Mineral Resources Division for the period 1920 to 1936; from 1937 until his retirement in 1945 he was on the staff of the Fuels Division.

Arising from a British interest during World War I in the possibility of using helium as a substitute for hydrogen in airships and balloons, a research project was carried out by Elworthy of the Chemical Division on helium. After Elworthy's resignation in 1927, helium determinations were made the responsibility of the Fuels Division as this gas is normally associated with the occurrence of natural gas. P.V. Rosewarne, who joined the Fuels Division in 1921, became head of the Oil and Gas Laboratories. He undertook another duty in 1931 on the retirement of Dr. A.E. McIntyre, the chief explosives chemist, by being responsible for

B.F. Haanel - Winner of the Gzowski Medal in 1918 the chemical work of the Explosives Division in his laboratory until 1940.

As mentioned in Chapter 3, B.F. Haanel in 1918 became secretary of the Federal-Ontario Peat Committee, set up to design an improved production machine; this was achieved largely by the contribution of E.V. Moore. The committee was disbanded in 1922 and the Alfred bog enterprise was taken over by Peat Fuels Limited. Haanel kept in touch with developments in this period and must have been quite disappointed with the inability of the company to get the project "off the ground". Accordingly, it was decided to make one more try by managing the project from 1927 to 1930 and placing Moore in charge at the Alfred bog with a view to demonstrating commercial viability. However, the project did not succeed, partly because of the uncompetitive delivered cost of peat compared with coal and partly because of onset of the depression.

1. Fuel testing station known as Peat Building, and Ore Dressing and Metallurgical Laboratories before demolition and replacement by 552 Booth St., Ottawa

2. Ore Dressing and Metallurgical Laboratories at 552 Booth St. (on the site of the former Peat Building)

3. Department of Mines Fuel Research Laboratories at 562 Booth St. before addition of third floor

The growing space requirements of the Ore Dressing and Metallurgy Laboratories as well as the Fuels group decided the department to erect a building for fuels, well separated from the original 1910 site. Building started in 1927 and the staff started to move in in 1929. The building had overall dimensions of 156 ft long by 56 ft wide and consisted of two storeys and a basement with a front section for laboratories and offices and a back section for pilot plant operation. The building was located at the present 562 Booth Street, some 250 ft south of the original site now occupied by 552 Booth Street. Sufficient headroom was provided in the pilot plant section and thus there was only a mezzanine in lieu of a full second floor. A third floor for the laboratory and offices section at the front was added in 1938.

Organization of Fuels and Fuel Testing Division

When R.E. Gilmore returned to the Mines Branch in 1922 he was named superintendent of the Fuel Testing Laboratories, later renamed Fuel Research Laboratories as designated above the main door on the new building at 562 Booth Street. E.S. Malloch was promoted technical engineer of the division. The distinction of these positions was based on a discipline orientation - chemical or mechanical - of the processing and utilization steps of fossil fuels respectively, in the primary role of supplying heat energy. The testing work was grouped under Gilmore in four sections: (1) solid fuel analyses and related investigations; (2) carbonization of coals and other solid fuels; (3) liquid fuel analyses and investigations of petroleum products; and (4) oil shale and bituminous sands laboratory investigations. The officers in charge of these groups were: J.H.H. Nicolls, R.A. Strong, P.V. Rosewarne and A.A. Swinnerton respectively. The technical engineer, E.S. Malloch, was equivalent to mechanical engineer as equipment played an important role in the efficiency of energy delivery from heaters, boilers, etc. In later years the term mechanical was equated with combustion engineering.

When the group moved to 562 Booth Street in 1929, the organization was described by Haanel as follows (67):

"Mechanical Engineering:
large-scale testing; technical tests on boilers, heaters, gas producers and engines, staffed by the mechanical engineers and laboratory assistants. Head: E.S. Malloch (1914 - 1947), assisted by C.E. Baltzer (1923 - 1965), and J.R. Kirkconnell (1930 - 1937), thence to Mines and Geology Branch administration.

"Coal Carbonization, etc.:
technical-scale tests on Canadian coals, peat, and other solid fuels in standard and experimental washing, carbonizing, and briquetting installations for the production of coke, char, gas, and oils, conducted by chemical engineers and laboratory assistants. Head: R.A. Strong (1924 - 1945) and assisted by E.J. Burrough (1927 - 1963).

"Oil Shales, etc.:
heat treatment of oil shales and bituminous sands for the production of oil with special reference to yield and quality of crude oil as a substitute for natural crude petroleum, staffed by chemical engineers, Head: A.A. Swinnerton (1919 - 1958), assisted by G.P. Connell, (1923 - 1936).

"Oils and Natural Gas:
technical-scale tests and analyses of petroleum and substitute oils in their natural state and as derived from Sections 2 and 3, and the synthesis of liquid fuels from natural and manufactured gas, conducted by engineering chemists and laboratory assistants. Head: P.V. Rosewarne (1921 - 1954), assisted by R.J. Offord (1921 - 1958), H. McD. Chantler (1924 - 1958), and W.P. Campbell (1928 - 1937), (1937 - 1955, Explosives).

"Solid Fuels:
physical, proximate and ultimate analyses of coals, coke, peat, etc. derived from Sections 1, 2 and 3; coal classification and research and methods of solid fuels analyses conducted by engineering chemists and laboratory assistants, Head J.H.H. Nicolls (1914 - 1949), assisted by C.B. Mohr (1923 -1937), (1937 - 1950 Explosives), E. Swartzman (1928 - 1960), and R.J. Young (1929 - 1957)."

Note: Dates denote total service in the Mines Branch.

The emphasis on designation of the professional staff as engineers or engineering chemists is quite evident.

In addition to laboratory work - there was considerable interchange between sections when faced with periods of heavy workloads in any particular section - many of the staff undertook field work related to sampling, visiting plants, etc.

Haanel, in addition to the above five sections, had a sixth which he designated as Special Investigations and the professionals working in the section as research engineers. This group was probably formed by Haanel largely because he wanted to investigate on a sound scientific basis current German researches on the production of synthetic fuels from coal (Bergius and Fischer-Tropsch), the motivation being the accelerating demands in Canada for gasoline and other oil products subsequent to World War I. Dr. T.E. Warren who was appointed in 1929 was the first chemical engineer with a doctoral degree. During the first two or three years he was associated with Professors E.A. Smith and G.B. Frost from Ontario and Nova Scotia respectively. These were summer engagements and, had they lasted, would possibly have been of assistance to Warren in his researches on hydrogenation of coal initiated by him. Actually, Smith was interested in heat treatment of Ontario lignite and peat, and Frost studied the fusibility of the Nova Scotia coal ashes. K.W. Bowles, who had been working as a summer student in the fuels laboratories, joined Warren as an assistant in 1933 after graduation from Queen's University.

Tom Warren in his office, 1938

Ken Bowles in his office, 1945

The Oil Shales Section and the Special Investigations Section were the forerunners of the chemical engineering group specializing in treatment by high pressure hydrogenation of low-grade oils including oil sands, residues, etc.; Warren was to become its first head.

B.F. Haanel continued to be responsible for the Mechanical Section headed by A.W. Mantle, who served the increasing needs of the whole branch in maintenance of equipment and in providing fabricated articles required by the various laboratories. In 1931, responsibility for the Maintenance Section was transferred to the director's office.

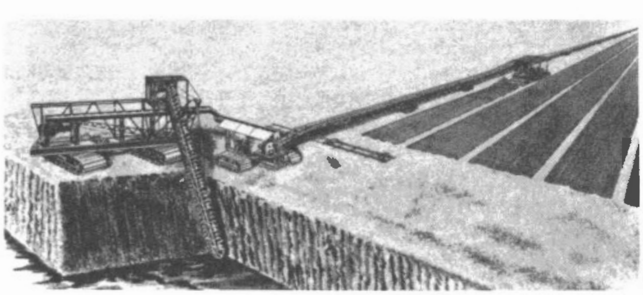
Peat

The Peat Committee formed in 1918 was dissolved early in 1923 after completing the task of redesigning the former Anrep plant. The machinery was disposed of to Peat Fuels Limited. The company made an effort to carry on but without success. The expenditures for fiscal years 1920-21 and 1921-22 less receipts amounted to about $71,000. A final report of the Peat Committee was published in 1926 (68).

The interest of the chief of the Fuels Division in peat fuel continued for most of the decade of the twenties. Research was largely in the areas of combustion and carbonization in an attempt to find an economic application of peat as a fuel. A carload of air-dried peat from the Alfred bog was carbonized in 1922 in hardwood carbonization ovens of the Standard Chemical Co. at Longford, Ont. The technical feasibility of the low-temperature process was evaluated for peat; however, the economic feasibility remained in doubt.

The Fuels Division Mechanical Engineering (Combustion) Section carried out several tests on the application of peat in domestic heating, with the same economic implications. Considerable publicity was engendered in this period on peat fuel for household use. A three-page pamphlet entitled "Directions for domestic use of peat fuel" was published in 5000 copies in 1928 and reprinted in 10,000 copies in 1929; furthermore, a peat fuel folder in 5000 copies and a peat fuel poster in 1000 copies were published in 1929.

A decision was made to take over the plant that included all the improvements recommended by the Peat Committee from Peat Fuels Ltd. and to operate it as a demonstration plant under E.V. Moore who improved the original Anrep machine under Haanel's supervision. The plant operated during the 1928 summer for an effective time of about 1200 hours during which some 10,000 tons were produced in the field. Towards the end of the season the operations had to be stopped because of very wet weather. Some several hundreds of tons of peat fuel and humus were sold. Possibly due to the onset of the depression the plant closed down indefinitely in the autumn of 1929. According to the 1927-30 accounts, the second Alfred bog project cost about $133,000 with a revenue from sales of about $7500.



Perfected Plant No. 4 as recommended by the Peat Committee

Peat fuel continued to be sold for some years from Ontario and Quebec points; according to the Dominion Bureau of Statistics, the production declined to 145 tons in 1946. On the other hand, production of unhumified peat for horticultural purposes, or peat moss, attained nearly 28,000 tons in 1941 when it was first reported under the Canadian mineral production data and not under manufactures as previously; by 1946 production was nearly 97,000 tons. Today's production of peat moss amounts to about 400,000 short tons.

Peat moss is still the technical responsibility of CANMET, being a nonrenewable resource. T.E. Tibbetts of the Energy Research Laboratories is the present officer responsible for evaluating the properties of this commodity. The shortage of energy and reductants may result in humified peat becoming one of the sources for energy and metallurgical use.

Coal

The R & D work on coal described in Chapter 3 was concerned with the systematic development of basic chemical and physical data on the types of coal in various regions of Canada. Some small-scale carbonization and large-scale gas producer and boiler tests were carried out during that period.

World War I and the general growth of the country demonstrated the dependence of the eastern section of the country and particularly the densely settled and industrialized area of Ontario and Quebec on the importation of coal from the U.S.A.

It should be borne in mind that, other than hydroelectric energy and growing amounts of Western natural gas, coal was the dominant energy source in the country until the end of World War II. The rapidly increasing use of the internal combustion engine and growing use of oil heating caused the large importation of crude petroleum and products faced with a limited domestic supply.

Potential coal resources, geologically considered, are large but scattered and possess negative characteristics as far as their utilization is concerned such as medium to high sulphur content in the Maritimes' coals, poor storage properties of low-rank Prairie coals and friability increasing with depth and a relatively high ash content of Mountain coals. The coal programs throughout their history in the Mines Branch reflected concern for these problems.

Administratively, it required the intervention of specific government agencies like the Coal Controller in World War I, followed by the Dominion Fuel Board from 1922 to 1941, a Coal Administrator during World War II, and a Dominion Coal Board from 1946 to 1970, to ensure the equitable distribution of coal throughout the land and to assist financially in moving the coal across the long distances involved. With formation of the energy-oriented present Department of Energy, Mines and Resources, presumably the reason for special agencies to deal with coal disappeared.

The Fuels Division was always consulted in technical matters by these agencies in the past and it undertook special projects at their request.

Resource Evaluation

The main R & D emphasis of the division during the period under review was on coal, essentially to encourage greater use of Canadian coal resources. During the initial period following the war, Nicolls was placed in charge of the Coal Laboratory and he was helped by laboratory assistants and a few temporary professionals. In addition to doing ordinary analytical work, Nicolls continued with evaluation of the laboratory-scale carbonization of low-rank Alberta coals. In this work he was helped by H. Kohl, who was appointed in 1921 but died in 1924. In 1923, Nicolls spent the summer in Nova Scotia and New Brunswick collecting samples from coal seams and screening plants or tipples.

This work really started the survey of the physical and chemical properties of Canadian coal (P & C survey) which provided a quality assessment of coal resources. The activity was interrupted until 1928 because of shortage of staff, but in that year Strong and Burrough carried out a P & C survey of the Phalen seam on Cape Breton Island. The project continued intensively and systematically for some 25 years until all the mine seams in Canada had been analyzed for their physical and chemical properties. In a considerable number of cases this would mean not only a chemical analysis but a whole range of beneficiating tests - cleaning, carbonization, briquetting. Some of the early results were reported in Reports of Investigations and the Fuel Testing annual series, but as much of the information was considered confidential by the industry, a special series known as "Report of Investigations of the Carbonization Section (RICS)", totalling 199, was introduced. Reports were issued to authorized inquirers. This activity represented an important part of the coal group's work over the years and is of considerable archival importance. Periodic surveys of commercial or tipple samples were also made and this practice has continued to this day.

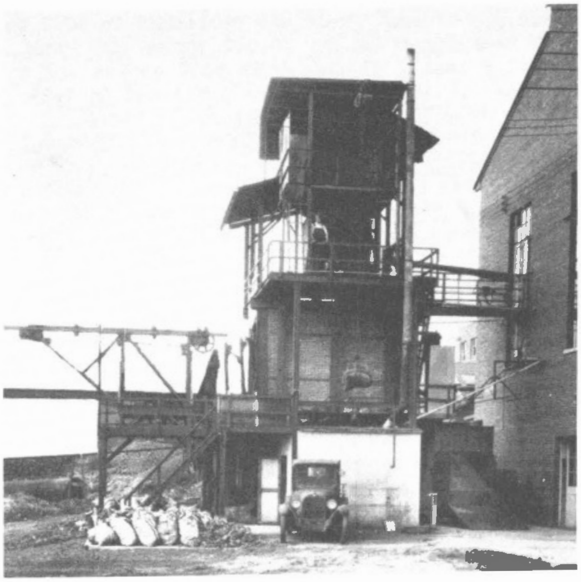
This resource R & D became the responsibility of Section 2, as mentioned earlier, and it was headed by R.A. Strong. The two officers with the longest experience in this work were E.J. Burrough, specializing in carbonization or coking, and E.S. Swartzman, specializing in sampling, cleaning, and briquetting, with interchange of duties as the workload dictated. Though the section was called "Carbonization" it was of course much broader in scope and included all phases of beneficiation or preparation that the various kinds of Canadian coals required before they could be marketed.

Coal, being a heterogeneous and chemically complex substance in association with mineral constituents and extraneous mine rock, required the development of analytical procedures which would provide the basis of a classification system for typifying them. The analytical procedures, both chemical and physical, had to be standardized, and this required a considerable amount of experimentation. Gilmore and Nicolls in particular spent a considerable part of their careers in this important work. Various classification systems in the U.S.A. and Europe were examined. Considerable contact was maintained with the U.S. Bureau of Mines, and several staff members participated in the work of the Coal Classification Committee D-5 and its subcommittees of the American Society for Testing and Materials. Eventually the ASTM D-388 1938 classification by rank was adopted by Mines Branch with additional tests that better identified coking and semi-coking coals, namely the Gray (U.K.) caking index, F.R.L. swelling index (MB Rep 737-2, 1933), and F.R.L. specific volatile index (MB Rep 725-2, 1933). The work of this section and of the analytical laboratory, Section 5, was considerably expanded when the Fuels laboratories moved to its new quarters in 1929. The group was represented on the Associate Committee of Coal Classification and Analysis of the NRC formed in 1927.

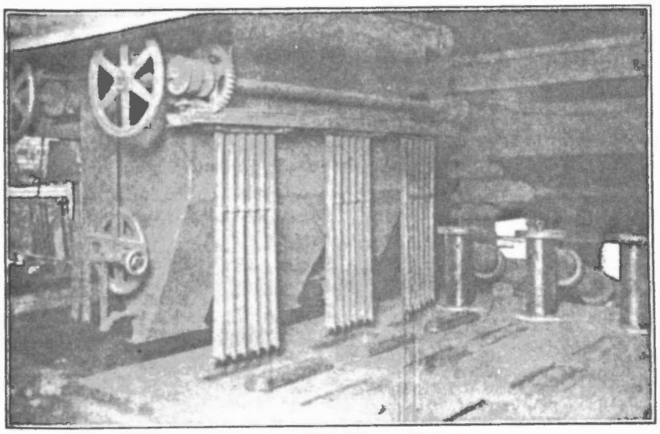
Carbonization

A two-ton byproduct coke oven that represented a semi-industrial scale was constructed at the northwestern end of the pilot plant section. Two 500-lb experimental ovens, one 16 in. wide operating at 2200°F and the other 12 in. wide at 1400°F, were added later. In the pilot plant hall, a briquetting roll press was installed together with some coal cleaning or washing equipment as a back-up to the bench heavy liquid separation work. A Lehmann mill for separating "bright" - usually the coking - and "dull" - non-coking - constituents of bituminous coal, particularly related to carbonization, was also acquired.

An extensive testing campaign was undertaken for the majority of the coking coals of Canada over the next few years, a large proportion in connection with the physical and chemical survey of Canadian coal seams as mentioned earlier. Briquetting tests on raw or carbonized coal of various ranks were also carried out (69).



2-ton byproduct coke oven plant, Fuel Research Laboratories, Ottawa, Nov. 1931



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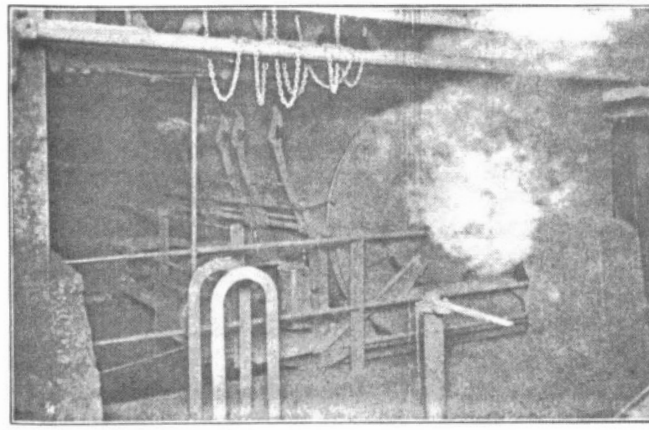

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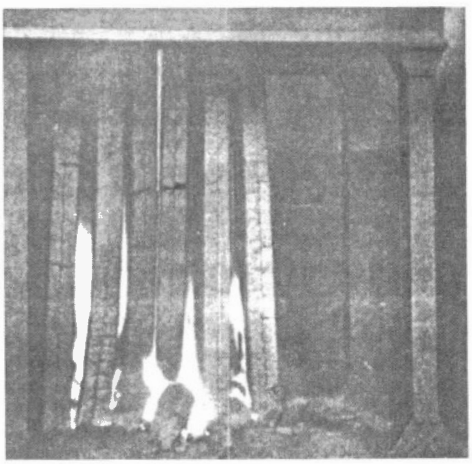

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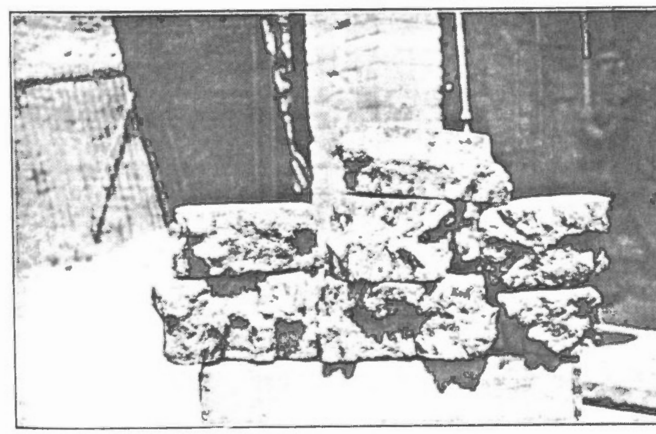

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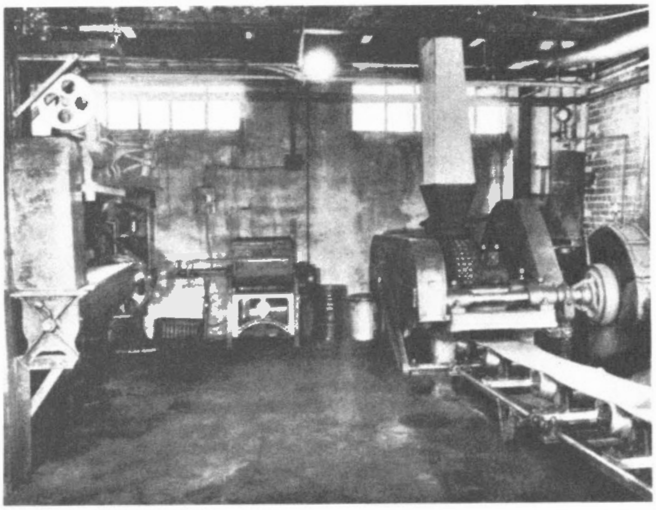
Illingworth Low Temperature Carbonization Company, South Wales: 1 - Charging floor of carbonization retort; 2 - Coke being discharged from retort; 3 - Revolving drum for cooling coke; 4 - Coke prepared from Sydney coal by Illingworth process

The aim of the coking program was to cater for both metallurgical as well as for the household coke markets with considerable emphasis on the latter because of a desire to find a substitute for anthracite, the smokeless fuel of the period. An extensive program on a laboratory scale was conducted by Strong and Burrough on low-temperature carbonization of Canadian coals and this was followed up with monitoring of a 20-ton lot of Nova Scotia coal at the experimental plant of the Illingworth Low Temperature Carbonization Company at Pontypridd in South Wales in 1929. The object of this large-scale test was to determine the application of Nova Scotia low-temperature coke for household use. In 1930, 10,000 tons of Nova Scotia coal was monitored at the Lasalle carbonization plant of the Montreal Coke and Manufacturing Company, and a 1000-ton lot of Crowsnest Pass coal at the coke ovens of the Winnipeg Electric Company to obtain first-hand information of the performance of Canadian coals carbonized in byproduct slot-type ovens with coke destined largely for household and commercial use.

Innovations in coking processes and plants both in the U.S.A. and in Europe were closely followed by the chief of the division and the staff of the carbonization section. It is appropriate to mention that Haanel continued the practice of the early days in personally visiting laboratories and plants where new processes and equipment were being developed. In this connection it may be useful to note in view of the present interest in oil agglomeration as a promising method of separating the extraneous impurity from coal "fines", his inspection of the Trent process in 1920. This was an oil coal agglomeration process but the design was inadequate as the consumption of oil was quite high. He had samples of high-ash coal and lignite sent to the Trent operation, Washington, D.C. from Nova Scotia, Alberta, B.C., and Saskatchewan. The lowest "ash" results were obtained from the Nova Scotia coal and Saskatchewan lignite (MB Rep 577, pp 45-54, 1922).

The coal analytical laboratory (Section 5) worked very closely with the carbonization section in view of the large number of primary and plant samples involved with the research work. These activities could be made possible only by a substantial increase in staff during the decade 1920-30. Personnel had to be trained, as coal science and technology courses for the engineer or technologist had never been established in Canada. It may be appropriate to name the technicians who were recruited in 1920-30 and who became key



Briquetting equipment at Fuel Research Laboratories: roll press and conveyer

personnel because of their knowledge of coal acquired "on the job" C.J. Coleman (1927 - 1967), C.H. Glaude (1929 - 1972), J.W. Custeau (1929 - 1965) and P.B. Seely (1929 - 1964). The latter was transferred early in the 1930's to the oil laboratory.

This section, like the other two coal sections, participated in the development of standards leading to the accepted classification of coal; e.g., fairly lengthy studies were carried out on how to measure coal friability. (MB Rep 762 by Gilmore, Nicolls, and Connell, 1935).

Combustion

The mechanical engineering section, was the large-scale group before advent of the carbonization scale-up. After phase-out of the producer gas work, this section in reality became the Combustion R & D group. E.S. Malloch was left to carry on after Blizard's resignation in 1920. He completed the latter's review on pulverized coal firing of boilers (70).

In 1921, Malloch joined by Baltzer in 1923, started a program of combustion tests in a small water heater adapted for lignite burning. Then followed an extensive program with various solid fuels, i.e., U.S.A. and Welsh anthracite, coke, bituminous coals, and peat in a domestic hot water furnace. This work had the sponsorship of the Dominion Fuel Board. Occasionally the Fuel Board used the Mines Branch series for its technical reports, for example Dominion Fuel Board, Report No. 3, "Central and district heating" by F.A. Combe [MB Rep 628 (Engl), 1924, MB Rep 629 (Fr), 1925]; Dominion Fuel Board Report No. 5, "Coke as a household fuel in Central Canada" by J.L. Landt [MB Rep 630 (Engl), 1925 and MB Rep 631 (Fr), 1926].

Another project comprising data on fuel use and performance requested by the Dominion Fuel Board was a fuel power survey of electric power generation, heating, and steam processing plants. This project was conceived by the division some years earlier but through staff shortage was not carried out. The original intention was to conduct the survey, province by province, evaluating the data for each before proceeding with the next. The survey for Ontario with particular reference to the Peterborough district was carried out in 1926 and a report issued to the Dominion Fuel Board at the end of the year. It was published in 1928 as MB Rep 698, "Industrial fuel and power statistics for Ontario, calendar year 1925" by E.S. Malloch and C.E. Baltzer. There is no record of similar surveys being done in other provinces.

Carbonization Group, 1934; back l-r: R.A. Strong, section head, Carbonization and Mining; T.H. York Sr., carpenter; Robinson, plumber; Hickson, Lacroix, Hobbs, G. Hinton, labourers; T.H. York Jr., secretary; L. Labelle, machinist; Moodie, labourer. Front l-r: E. Burrough, engineer in charge of coke plant; J.W. Custeau, observer; Baker, A. Lacroix, labourers; T. Burstone, foreman; R.E. Gilmore, superintendent of FRL; C.H. Glaude, Physical Testing; Robinson, labourer; E. Swartzman in charge of Physical Testing; A. Kritsch, in charge of coal shed. Seated: Boot, R.E. Gilmore's constant companion; Cousineau, labourer; W. Kritsch, in charge of preparation and crushing coal samples

The R & D program on the use of fuels for domestic hot-water heating was reported in MB Rep 705, published in 1929 and titled "Combustion tests of various fuels when burned in a domestic hot-water boiler" by E.S. Malloch and C.E. Baltzer. A useful report by Malloch was published in 1929 in the Dominion Fuel Board series, Report No. 14, "A comparison of the cost and convenience of house heating with various fuels" (MB Rep 706).

A pulverized fuel boiler was installed in the new building in 1929. A comprehensive program of combustion tests on Canadian coals started with 10 coking coals from British Columbia. These coals were also tested for high-temperature coking in the two-ton by-product coke oven. One of the aims of the coking trials was to demonstrate that Michel, B.C. coal could replace U.S. coal imported for coking at the Winnipeg Electric Company's plant.

An important aspect of this combustion-carbonization fuel program was that it provided important data for alternate tonnage use of coking coals, particularly for Western Canada where industrial uses were limited at that time.

In 1930, the combustion and carbonization programs were enlarged to include burning and carbonizing lignite from Onakawana, Ontario. For the combustion tests, a reference or "operating" coal was used for comparing results between various fuels. The domestic fuel program was continued simultaneously when J.R. Kirkconnell was appointed in 1930. H.P. Hudson was appointed in 1921 and became the principal technical officer in the combustion section. Before Custeau and Seely were transferred to the coal and oil laboratories respectively, they were used in the combustion program to sustain the tempo of the tests which represented the most intensive period in the division's history of R & D in coal.

In 1932, Baltzer assisted by Hudson developed a new method for measuring the grindability of coals and the results were reported in a jointly published report titled "A method for rating the grindability or pulverizability of coal, developed by the Fuel Research Laboratories (FRL) Department of Mines, Canada (correlated with the 'Cross' and 'Hardgrove' methods" (MB Rep 737-1, 1933).

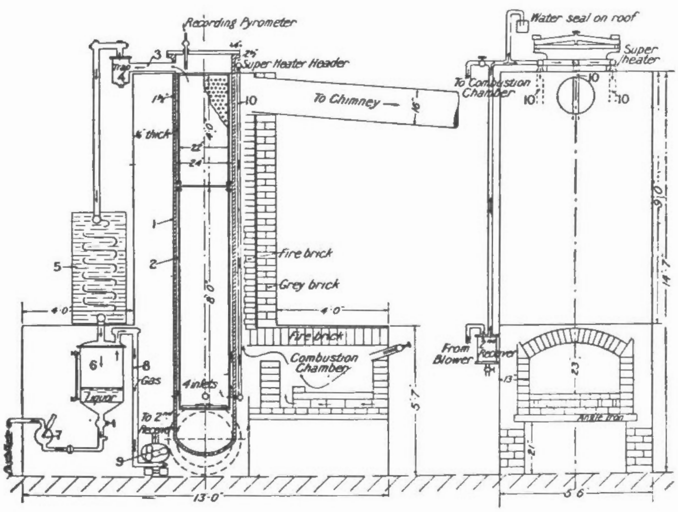
Combustion problems in government buildings and industrial plants started to come in as the work of this group became known; as the years went by this became an important part of the section's work. This group, as did the Coal Carbonization Section, played an important role in the "Canadian Government Purchasing Committee" formed towards the end of the twenties.

Oil Shales

In the face of growing demand for oil in the period following World War I, the oil shales program was continued into the 1920's. In 1921, Ells carried out a sampling survey in the Pasquia Hills (Carrot River area) of Saskatchewan and in the Swan-Pine Rivers area of Manitoba east of Lake Winnipegosis on the outcrops of Cretaceous shales that were reported to be oil-bearing. Twenty-two samples were taken in Saskatchewan and 19 in Manitoba, with 21 sent to Ottawa. Some samples were retort-tested in the field and only showed traces of hydrocarbons. The Ottawa analyses indicated a maximum content in one sample of 12.8 gallons of dehydrated crude oil per ton of shale. This was reported in "Investigations in 1921: Mineral resources and technology and Chemical Laboratory research" published in 1923 (MB Rep 588). Also in 1921, Ells prepared a general review of the economic prospects for oil from oil shales in Canada, published in the same report.

Swinnerton resumed distillation tests in 1921 on oil shales in the apparatus first used in lignite carbonization but with an iron retort having a section shaped like a cross and a charge of about 3500 grams of shale. The samples included some of the Albert, New Brunswick shale obtained from the 1919 tests, samples collected by W.J. Wright of the Geological Survey, and later acquisitions from Ells in Saskatchewan and Manitoba. Following these laboratory tests, attention on oil shale was directed to the evaluation of treatment processes. Thus, after being examined by Haanel in 1921, the Ryan oil digestion process was tried by Swinnerton in 1922 on a bench-scale in Ottawa. The results were not as good as the destructive distillation tests. In 1923 Swinnerton witnessed a test with the Hartman retort at St. John, New Brunswick. This retort was similar to the roasting furnace with a multi-deck arrangement of trays for the shale around a central rotating shaft on which were mounted agitators. Swinnerton witnessed several runs with a pilot plant but was not impressed with the results as described in "Investigations of fuels and fuel testing, 1923" (MB Rep 618, 1924). A car-lot of oil shale from Rosevale, N.B. was sent to Ottawa in 1925 and a part of this supply was crushed for treatment in Toronto in a Pritchard retort. The feature of this process was circulation of the uncondensed gases through the charge, thus assisting the better distribution of heat through the system. Gilmore and Swinnerton who monitored the test did not consider there was any advantage in this method compared with straight distillation practice, as shown in "Investigations of fuels and fuel testing, 1926, Part II: Liquid fuels" (MB Rep 689-2, 1928).

In 1923 when in Europe to attend the World Power Conference with Haanel, Camsell visited the depleted oil fields of Alsace in France and Hannover in Germany



Diagrammatic sketch of Pritchard retort and accessory equipment which had developed a mining method for final recovery of the oil. Buisson who was in France with the Canadian exposition train joined the deputy minister for these visits, which were made because of the concern about exhaustion of the oil fields of southern Ontario. On return to Canada, a report was issued by the deputy and A. Buisson entitled "Recovery of petroleum by shafts and galleries at Techelbronn, Alsace, France and Wietze, Hannover, Germany" (Memorandum Series No. 10, 1924). In 1924 Swinnerton made a comparison of oil sands from Techelbronn with the Alberta bituminous sands, but there is no record of the results.

Swinnerton increasingly worked on the chemical aspects of bituminous sands from 1926, though he spent a part of most summer seasons in sampling oil shale occurrences in New Brunswick, Nova Scotia (Pictou County), and Quebec (Port Daniel). In 1929, he visited the U.S. Bureau of Mines oil shale plant at Rulison, Colorado.

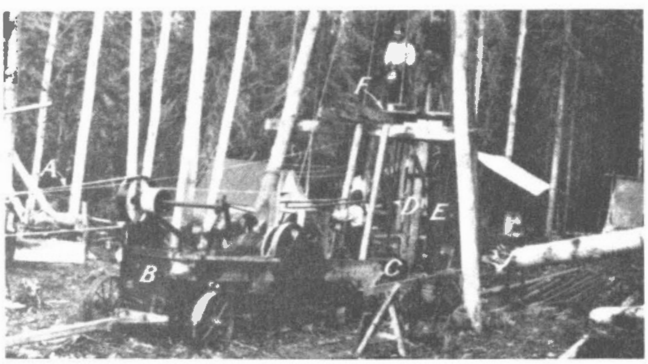
Swinnerton spent considerable time in developing analytical methods as well as assaying oil shales and bituminous sands, and in this work he was assisted by G.P. Connell.

The oil shale program was constrained by inability to scale up because of space requirements for more urgent work in the Fuel Research Laboratories. However, the general view of the fuels group, and that included Ells, was that the oil shales which required relatively costly mining, were too lean to compete with well oil even if imported.

Oil Sands

Ells continued as principal field officer in this resource throughout the period to the end of the Dept. of Mines in 1936. The topographical survey of an area of some 1160 square miles was completed in 1923; although about seven field seasons were involved, this was quite an achievement as the resources were limited and there were a number of interruptions. He compiled a comprehensive report of the investigations to the end of 1924 which is considered today as the best overall reference for the evaluation of this resource (71). In 1934 some shaft sinking was undertaken into the unaltered oil sands to procure an unweathered sample for the laboratory research work being done in Ottawa.

In 1925, Ells commenced a study on core drilling of the bituminous sands for systematic sampling. In the next season he opened a quarry on the north bank of the Clearwater River within a mile of the "end of steel" at Waterways, Alberta. Thirteen carloads or about 375 tons of sand were excavated and shipped to Jasper, Alberta for road paving tests for the Parks



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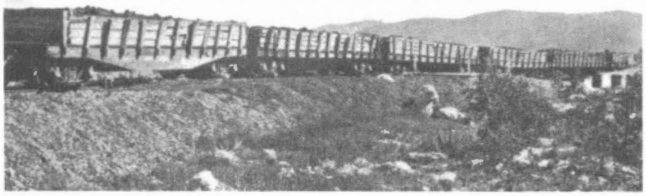
Early work by Mines Branch on Alberta bituminous sands: 1 - equipment adapted for core-drilling: A. belt to tractor, B. portable well drilling rig, C. rotary table, D. drill rock, E. drill rods not in use, F. working platform; 2 - bituminous sand quarry on Clearwater River, McMurray, Alberta; 3 - newly opened quarry and separation plant building; 4 - Franklin Ave., the main street of McMurray (cont'd next page)

Branch of the Department of the Interior. Next, Ells supervised the construction of an internally heated mixing plant at Edmonton, and in this work he used the city workshop through the courtesy of the mayor and city engineer. When finished, the plant was shipped to a Canadian National siding at Jasper Station. Though the paving work started in October with interruptions due to inclement weather, 2700 feet of a roadway 15 feet wide were laid in 16-1/2 days. Connell of the Fuels Division assisted Ells with analyses of the mixes. In 1927, a further 12,100 feet of motor highway was paved together with 3200 square yards of garage, drives, and parking space, and 2100 square yards of walks in the Jasper Lodge grounds. Altogether in 1926 and 1927, upwards of 35,000 square yards of wearing surface were laid at Jasper (MB Rep 694, 1927).

In the same season of 1927, three further holes were drilled but Ells thought that the most efficient type of drill had not yet been developed. In 1928 Ells selected sites for two additional quarries and experimented further on the development of a suitable drilling technique for sampling. Two problems were encountered: incomplete core recovery and difficulty in separating bitumen from the sand. Tentative plans for an improved portable heating and mixing plant were made and some of the components purchased. Ells spent some time in 1928 in Europe studying rock asphalt occurrences and the preparation of material for use. In 1929, Ells prepared a quarry adjoining the experimental plant designed by K.A. Clark, former head of the Mines Branch Road Materials Division whose work over many years on oil sands was widely acclaimed. This plant was to separate the bitumen from the sand by the "hot water" technique. The plant started operations in 1930, feed being supplied from the quarry that Ells had prepared. About 15,000 gallons of separated bitumen were produced in the first season and the bitumen was used mostly for paving by the Alberta Highways Department. The mixing machine was completed during 1930. It was constructed to use the bituminous sand either directly as a paving material or to use separated asphalt blends with aggregate material.

The easterly and northeasterly extensions of the oil sand area were explored by Ells in 1931. The area involved was about 6000 square miles and, additionally about 60 miles of previously unmapped rivers were surveyed. During the season, representative samples of sands were secured in the extreme northeast and extreme southwest sections to determine possible variations in the character of the bitumens associated with the sand. For the next four years Ells was concerned in evaluating the uses to which the McMurray bitumen could be



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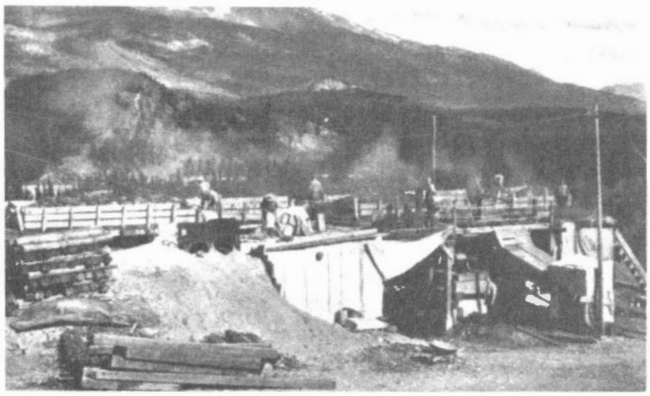

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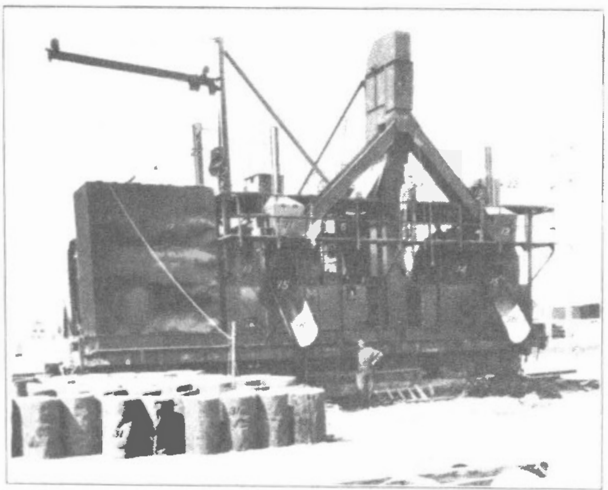

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Early work by Mines Branch on Alberta bituminous sands (cont'd): 5 - first shipment of bituminous sand for Jasper, Alberta highway shipped by S.C. Ells, 1926; 6 - plant for manipulation of bituminous sand at Jasper, Alberta; gravel drier at left; 7 - portable, internally heated, drum-type mixing plant built by Mines Branch at Edmonton, Alberta, 1930; 8 - typical example of bituminous sand road surfacing, Jasper, 1927 applied in comparison with natural and refinery asphalts. During the period under review he was attached to the Mineral Resources Division but he worked closely with the Fuels Division supplying samples for the chemical treatment program that was developing.

In this program, Rosewarne participated with Swinnerton, Connell and others. The first study related to bituminous sands was a laboratory method evolved for dehydrating wet bitumen after separating from sand, (MB Rep 689-2 by P.V. Rosewarne and G.P. Connell, 1928). Samples of dehydrated bitumen and of oil from oil shales were sent to laboratories equipped with pressure cracking facilities for the production of gasoline and fuel oil; the bitumen was sent to Kansas City Testing Laboratory where it was cracked according to the Cross process, and the shale oil to the laboratory of Universal Oil Products Company of Chicago where it was treated according to the Dubbs process, (MB Rep 696-2 by R.E. Gilmore, A.A. Swinnerton, and G.P. Connell, 1929).

Warren carried out experiments in 1930 on hydrogenating and pressure cracking of Alberta bitumen. Some experimental work was done in 1931 on the influence of pressure on the rate of formation of hydrogen and unsaturated hydrocarbons from the pyrolysis of methane. These experiments were extended to low temperature coal tar from Nova Scotia. In 1933 a 4-litre reactor was constructed for experiments at 3,000 psi on Alberta bitumen, low temperature tar and a suspension of powdered coal in the tar. The early research was conducted by T.E. Warren and A.R. Williams and the 1933 series by T.E. Warren and K.W. Bowles. Both series are reported in MB Rep 727-3. This work was reported in Part 1 of "Investigations of fuels and fuel testing for the years 1930 and 1931" (MB Rep 725-1).

Petroleum and Natural Gas

This section, which Haanel termed Section 4 - Oil and Natural Gas - provided not only analytical services but research and investigations on its own initiative or in cooperation with Section 2, Oil Shales, etc. The section worked in close cooperation with Warren in his hydrogenation research.

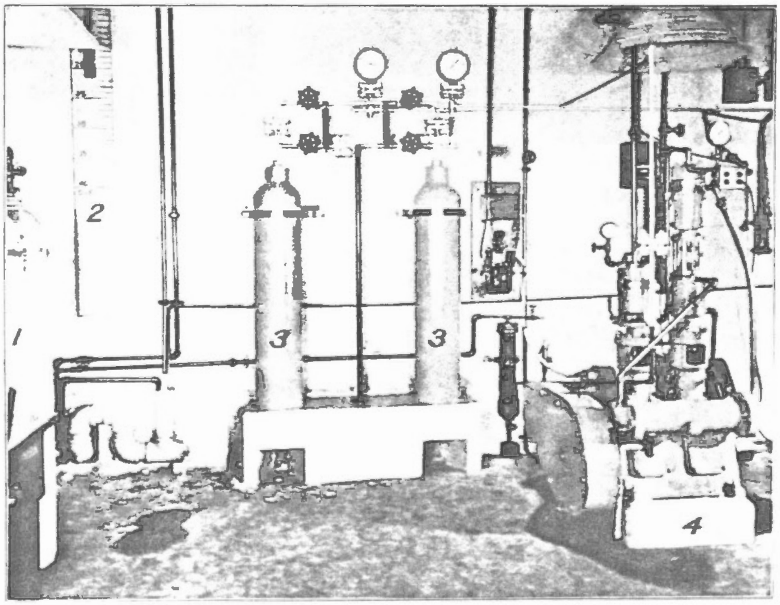
The Oil Laboratory was almost at a standstill for about two years until P.V. Rosewarne's appointment in 1921. In addition to doing analyses of hydrocarbons, the first projects to which he addressed himself were:

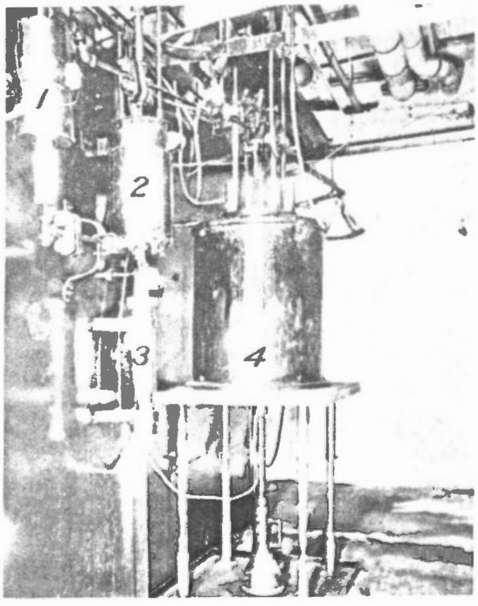
(a) at the request of the Department of Naval Service, the investigation of burning qualities of kerosene for illuminating purposes and determining which brand would produce less smoke in a lamp
(b) at the request of the Air Board of Canada, the determination of lubricating value of cod liver oil compared with that of castor oil; results showed that cod liver oil was superior to castor oil except for gumming.

In the period 1921 to 1925, Rosewarne undertook studies of lubricating oils in Canada and of waste lubricants from automobile engine crankcases.

At this time there were complaints about variations in the quality of gasoline; thus in 1922 Rosewarne started a gasoline survey in Ottawa and in the following year the survey was extended to 10 different Canadian cities. This survey became a regular undertaking for some 30 years until the 1950's when the constancy of gasoline grades in Canada became assured.

Over the next years Rosewarne increasingly parti-





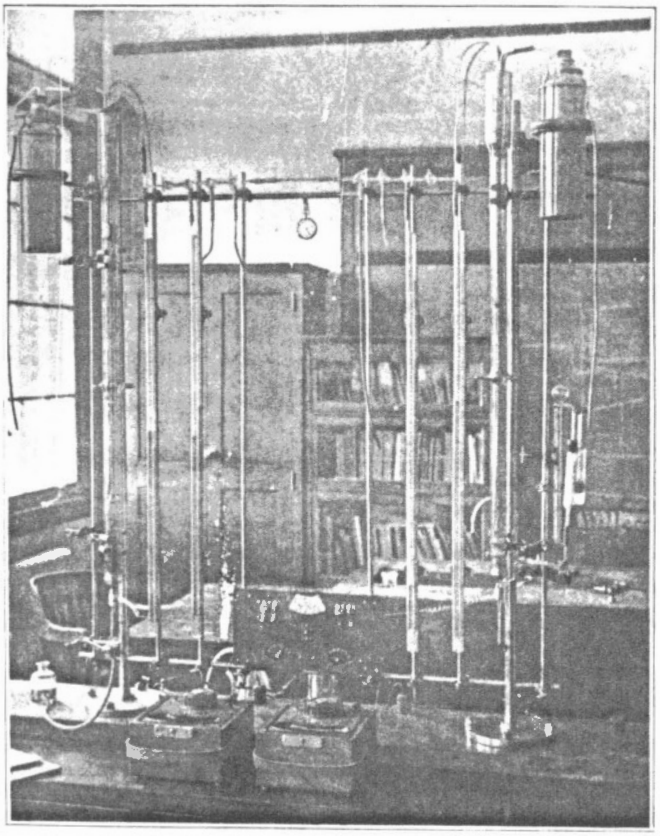
Continuous liquid phase hydrogenation pilot plant of 4-litre capacity, 562 Booth St.; at left: hydrogen compression system; at right: 1 - magnetic pump, 2 - condenser, 3 - high pressure receiver, 4 - reaction chamber cipated in a program of treating the crude oil from oil shales and oil sands.

In 1928 he visited Turner Valley and other Canadian gas fields. Samples of natural gas and naphtha were taken by Rosewarne and Offord. They received full cooperation from the industry, and the Institute of Technology at Calgary provided them with facilities for their analytical work. The natural gas was also investigated for helium content.

A crude oil survey was also started. In this, Chantler and Offord assisted Rosewarne. A cooperative arrangement was entered into by the Mines Branch with the Alberta Government Committee on "Inquiring into fuels and lubricating oils" whose chairman was Major H.G.L. Strange.

In 1929 Rosewarne and Chantler visited refineries in Ontario and Oklahoma as well as the United States Bureau of Mines Experiment Station at Bartlesville and the Bureau's helium plant at Amarillo, Texas.

In 1931, a knock-testing engine was installed in the laboratory at Booth Street and octane ratings of gasolines could henceforth be compared. In the same year, testing of explosives became an added responsibility for Rosewarne, Campbell, and some other associates in the laboratory.



Podbielniak apparatus for hydrocarbon analysis by distillation set up at laboratory of the Provincial Institute of Technology at Calgary, Alberta

The resource work of that period on crude oils, naphtha, associated with natural gas, shale oil, and bitumen presented in the form of analyses was reported in 1936 (72). Connected with this program, Rosewarne and his associates developed or improved analytical techniques, becoming leading consultants to many agencies on the quality of petroleum and products. In this connection the laboratory worked closely with the National Research Council which was responsible for standards. The Council formed associate committees on natural gas and helium with which this Mines Branch group cooperated. It may be of interest to note that in 1929 Canada passed its first one million barrels per annum of petroleum production. On the other hand, the importations in that year amounted to about 30 million barrels of crude oil for refining in Canada valued at about $46 million and products valued at nearly $32 million.

As in the case of other divisions, the R & D of the Division of Fuels and Fuel Testing was published mostly annually in the Investigations of Fuel and Fuel Testing Report series from 1920 to 1932 as follows: MB Rep 577, 590, 607, 618, 644, 671, 689 and 696, the latter two were also issued as separates for solid and liquid fuels: 689-1 and 2 for 1926 and 696-1 and 2 for 1927; 712, 721, 725 (for 1928, 1929 and 1930-31) and 737 (1932). Reports of tests and research after 1932 were issued in mimeograph form at the division or branch level (Memorandum series) except those complete reports that were included in the original Mines Branch Report series.

Helium

Early in 1915 the British Admiralty, through the Board of Invention and Research, approached Professor J.C. McLennan, head of the Department of Physics, University of Toronto, to investigate the helium content of natural gases with which helium is normally associated, occurring in the British Empire. The need was to substitute the somewhat lighter but much more hazardous hydrogen gas in airships by the inert helium.

McLennan assembled a group in his department which included Professor John Satterly and R.T. Elworthy of the Mines Branch. It may be recalled from Chapter 3 that Satterly and Elworthy were connected in a Mines Branch sponsored investigation of Canadian mineral waters. McLennan was requested to make a survey of the British Empire countries for their helium potential and to develop techniques for the separation and concentration of helium. The survey in Canada showed that the richest natural gas contained 0.36% by volume of helium.

An experimental station was first established in Hamilton and later moved to Calgary under John Patterson of the Meteorological Office, Toronto. Through the entry of the United States into the war, the urgency for this project was considerably reduced. Supplies of helium were much greater in the U.S.A. than they were in Canada. However, the project was written up and a report published in 1920 (73). The report included the first maps of oil and gas fields to be published by the Mines Branch. An interesting notation reflecting his dedication to developing secondary industries from the mineral wealth of Canada was made by Dr. A.W.G. Wilson in his formal transmittal letter to Dr. Haanel, giving the reasons for the publication of the report; he describes himself as engineer in charge of investigations of chemical industries. More than

40 years later, John Satterly offered to recount his reminiscenses of the work and this was published by the Mines Branch in 1959 (74).

At the end of the war Elworthy, who was a staff member of the Chemical Division, made natural gas and helium a special R & D project, reporting his work in the "Investigations of mineral resources and the mining industry, 1923" (MB Rep 616 and separate 616A). Before leaving the Mines Branch in 1927, Elworthy prepared a separate resource report on helium (75).

The analysis of natural gas and its helium content became the responsibility of the Fuels and Fuel Testing Division. Rosewarne prepared a report of analysis of helium and natural gas for the years 1926-31 and this was published in the Mineral Resources Investigations for 1931 and as a separate (MB Rep 727-2, 1931).

L.P. Collin

Ceramics and Road Materials Division

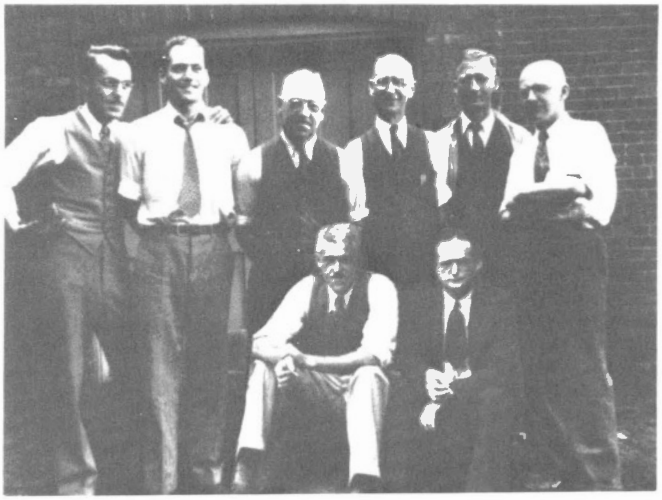
This combined group involved with closely related, widely occurring industrial minerals continued the work initiated by Haanel who was convinced that the Mines Branch had the responsibility of stimulating optimum utilization of domestically produced minerals in all sectors of the Canadian economy. The group pursued pioneering R & D on building materials and ceramic ware when there was no other research facility in Canada. It also completed the evaluation of gravel and stone along some of the principal highways that had to bear increased motor vehicle traffic.

The division was formed from the informal merging of the Ceramic Division with the Road Materials Division following the retransfer of J. Keele to the Geological Survey in October 1921 (he died in 1923). Howells Fréchette was appointed acting chief on that date. The official status of the division was confirmed in the reorganization of 1922, Fréchette becoming chief on January 1, 1923. The work of this division as well as that of the Chemical Division and the resource statistics and records of the Mineral Resources Division is chronicled under their descriptive names as it does not lend itself to reporting by commodity. The ceramics group was largely concerned with utilization of Canadian clays, shales and refractories, and the road materials group with gravels and stone for roads.

On the ceramics side of the division, L.P. Collin was appointed in August 1923 and Miss F.M. Campbell, a senior laboratory assistant, in September 1923. She was replaced on her resignation in December 1924 by Miss R.L. McLeish, the director's sister who joined the Mines Branch in 1908 and who retired in 1950. J.M. McMahon was appointed in October 1925 and J.G. Phillips joined in July 1928. The division had the services of E. Lester, a dedicated technician, who joined it at the start in 1915, retiring in 1944.

The small staff achieved a considerable amount of work in the resource and application aspects of these materials and within a few years attained a standing as the most ceramics-knowledgeable group in Canada. They were engaged in some resource surveys but not to the extent of the early period when extensive surveys were made by Keele and others in delineating shale and clay deposits. The Geological Survey continued its resource work, particularly by F.M. McLearn, and supplied samples for testing properties. Industry began to consult on problems such as scum prevention on bricks, glazing of ceramic ware, etc. In this connection, clay works, brick and tile plants, ceramic works, etc. were widely visited by the staff. Rapport was established in 1925 with the National Research Council on a joint project for producing high-grade refractory magnesite brick. The NRC officer was R.T. Watkins.

The laboratory became very well equipped (76) and drew the attention of various agencies, e.g., facilities were provided to the Air Board and the Department of Marine and Fisheries for special tests. Similarly, the laboratory was placed at the disposal of G.M. Hutt of the CPR, who conducted tests on clays from the company's lands in southern Saskatchewan. The staff was increasingly consulted by various government agencies. It may be interesting to record that during the depres-



Ceramics and Road Materials Group, Sussex Street, Ottawa; left to right: H. Mercier, R.M. Lake, W. Reid, E. Lester, R.W. Toll, C.M. Freeman; seated: J.G. Phillips and John McMahon

Canadian Ceramic Exhibit at British Empire Exhibition, London, 1924

sion when a brick plant was established at the Rockcliffe Relief Camp by the Department of National Defence, advice was sought from this group on details about the plant, equipment, and operation, and tests were carried out on the clays from which bricks would be manufactured.

Aside from problem-solving, the division undertook a considerable amount of R & D work on its own initiative such as performing studies on the physical properties of Canadian bricks, colour and density control of bricks, ceramic bodies for electric heating, production of shapes from soapstone dust with sodium silicate as bonding agent, treatment of clays to overcome drying defects, etc. Ceramic shapes were produced for other divisions and for exhibitions such as the British Empire Exhibition in 1924-25 in London and the National Museum of Canada in 1936.

The expertise that this group acquired brought Fréchette and his associates to undertake an active role on committees such as the Associate Committee on Magnesian Products of the NRC, Canadian Engineering Standards Association, Panel on Standard Brick Sizes (chairmanship), the Canadian Government Purchasing Standards Committee, Subcommittee on Refractories (chairmanship), and other subcommittees. Fréchette and his associates participated extensively in affairs of the Canadian Ceramic Society. He was president for a term, Collin a vice-president, and other members served on the committees of the society. A special project was undertaken with departmental approval on a request from the society, the Canadian Brick Manufacturers Association, and the Structural Clay Tile Association to carry out tests on structural assemblies that involved brick-mortar and tile-concrete.

In regard to road materials, after Clark's resignation in 1920 there remained H. Gauthier as officer in charge and R.H. Picher, the two engineers that carried on with the investigation on road materials. Following World War I, the hard-surfacing of motor roads accelerated, thus the Parks Branch of the Department of the Interior started on a program of hard-surfacing roads in the Rocky Mountains Park, and the division was consulted on road building materials. The first two highways that were thoroughly surveyed by Gauthier were from Banff to Lake Louise, and from Castle Mountain (now Mount Eisenhower) intersection to Windermere. The field work was greatly facilitated by the cooperation of J.M. Wardle, chief highway engineer, and R.S. Stronach, superintendent of Rocky Mountain Park.

In 1920, Picher started a systematic survey of road construction materials along some of the main Nova Scotian highways such as Halifax-Windsor-New Glasgow-Sydney, Windsor-Middleton-Bridgewater, Halifax-Shag Harbour, etc. The work continued for the next three or four years and Picher then transferred to New Brunswick at the request of the provincial highways department. The gravel deposits along the main highways such as Moncton-St. John to Fredericton, Woodstock, and Edmundston were examined for suitability.

A survey was started in 1927 on the materials for paving the highways of Prince Edward Island. This continued for about two years.

Gauthier resigned in 1924, leaving Picher on his own to continue the road materials work. During this period he made surveys in eastern Ontario and western Quebec and included the use of crushed stone. A survey of gravel resources was made in the Eastern Townships of Quebec on a line east of Lévis to Waterloo.

In the period from 1920 to 1931 the work of this division was reported in "Investigations in ceramics and road materials" published in MB Rep 578, 591, 610, 619, 645, 672, 690, 697, 722 for 1928-1929 and 726 for 1930-1931 and additionally as a separate report "Road gravels in Quebec" by R.H. Picher, [MB Rep 751 (Engl) and MB Rep 752 (Fr), 1935].

Chemistry Division

This division demonstrated, during this period, the versatility that was its hallmark from 1907. As the analytical and other chemical workload was handled in the other two laboratory divisions - Ore Dressing and Fuels - the Chemistry Division was able to handle the chemical requirements of the Mineral Resources Division and of the Ceramics and Road Materials Division, and at the same time undertake research projects of its own on behalf of the other divisions of the branch. Because of a fire in February 1921 that affected the Ore Dressing and Chemistry Lab, space had to be found for the analytical work of that division in the Sussex Street laboratory. In June 1920, Moran was transferred with the mine air analysis work to Sussex Street because of the chemical workload in Fuels Division; he returned to Fuels on Booth Street in 1937. M.F. Connor, who transferred from the Geological Survey in 1907, returned to the Survey in 1918; Turner also left. They were replaced by N.A. Thompson and A. Sadler in 1918 and 1919 respectively.

The British Department of Scientific and Industrial Research showed an interest in two mineral commodities for chemical uses - bentonite and natural gas - the latter as a source of such products as methanol, formaldehyde, and formic acid in demand in the U.K. for chemical uses. This coincided with the interest of the Mines Branch in augmenting the use of mineral resources in Canadian chemical and allied industries in which Wilson of the Mineral Resources Division was particularly concerned. Elworthy undertook a project on the oxidation of natural gas (MB Rep 588, 1923). Thompson, aided by Sadler, studied bentonite. They prepared the "Chemical and physical characters of bentonite" in the same report and a sample of Canadian bentonite was sent to the U.K. Elworthy continued with a variety of projects; thus in 1922 he investigated samples of fossil resins from Coalmont, B.C. and Cedar Lake, Saskatchewan. Elworthy's opinion was that these resins were only suitable for varnish manufacture but they would have difficulty in competing with resins from the tropical regions of the world because of the darker colour and low solubility in petroleum ether of the Canadian product. At the request of the Department of the Interior, Elworthy designed a field method and apparatus to determine by electrical conductivity measurements, the character of water leaking into oil and gas wells to protect producing horizons from saline water encroachment. Both studies were reported in MB Rep 607, 1924. In 1923, Elworthy worked in cooperation with the Geological Survey and Professor A.E. Flynn of the Nova Scotia Technical College on the kerogen content of Nova Scotia oil shales and torbanites. In 1925, Elworthy reported on "Hot springs in Western Canada - their radioactive and chemical properties" (MB Rep 669, 1926). In September 1926 he went to Europe on special leave and in 1927 joined the Industrial Process Development Company of Kingston.

Until the appointment of Haycock as head of the Mineragraphic Laboratory in 1930 and the iron and steel group undertaking physical metallurgy investigations, Thompson carried on the mineralogical studies of ores and metallographic examinations of metallic components; this was in addition to his responsibility for analyses and assays of more complicated character such as gold tellurides. On the average, some 1200 samples and specimens were dealt with annually in this division.

There was assistance given to projects outside the division, thus Leverin assisted Cole in field work on alkali salts in 1924, and he was also involved with the Alfred bog project in 1928. Specialization in a commodity was of course made use of; thus in Leverin's case, as he had worked on peat since the early period, he continued to do so until his retirement in 1944.

In 1926, L.C. O'Brien joined the division at the time that Goudge was starting his limestone program. A large number of analyses was required and O'Brien was largely responsible for the analytical work involved in this program but he also undertook analyses of a variety of commodities such as mine air, silver-lead ore, radioactive ores, etc. O'Brien stayed until 1935 when he transferred to the Dominion Fuel Board, serving its successors and completing his career as chairman of the Dominion Coal Board from 1961 to 1965.

Wait, the chief of the division, retired in July 1931 and he was succeeded by Thompson who remained acting chief to the end of the Department of Mines in 1936. He died suddenly in 1937.

A systematic survey of industrial waters of Canada was started by Leverin in 1934. In the initial period, the municipal water supplies were sampled and analyzed. The survey was continued by the Mines Branch until the Department of Energy, Mines and Resources was formed in 1966, when it was transferred to the Inland Waters Branch of the Department of Environment. The first reports on industrial waters were published in the Memorandum series and later in a consolidated form (77).

The Chemistry Division ceased to exist in 1936 with the Mines Branch becoming the Bureau of Mines of the Department of Mines and Resources.

Mineral Resources Division

Prior to the appointment in October 1921 of John McLeish to the directorship of the Mines Branch, the transfer of the statutory statistical work of the old Mineral Resources Division to the Dominion Bureau of Statistics in the same year and the reorganization of the Mines Branch in 1922, the division found itself in limbo. The previous division, without the statistical responsibility, was combined with the Metalliferous and Non-Metalliferous Divisions to form the new Mineral Resources Division with A.W.G. Wilson as chief or chief engineer. The Civil Service Commission procrastinated in granting Wilson a reclassification appropriate to his position and this naturally caused him considerable irritation.

From 1923, the mineral resources records and index were placed formally under Buisson and all the statistical material under Casey. These men were not purely office men but travelled to mining and manufacturing centres to obtain first-hand information on mineral resources and their utilization as well as on plant and technology changes. Buisson in particular dealt with the latter. For example he reviewed the use of zinc dust in gold mines in the precipitation of gold from cyanide solutions: "Zinc dust consumption at Canadian gold mines, 1931-1932-1933" by A. Buisson (Memorandum Series 61, 1934). The joint report by C. Camsell and A. Buisson on the recovery by mining methods of residual oil in France and Germany will be recalled. Articles for the technical press were also prepared by Buisson on various mineral resource subjects and they were listed in the deputy minister's annual lists of "Papers Issued".

In 1930 at the request of the Dominion Fuel Board, Casey started a series entitled "Petroleum fuels in Canada - deliveries for consumption" which continued to 1944 (MB Rep 745, 759, 772, 780, 789, 808, and 814).

As mentioned in Chapter 3, reports on annual mineral production ceased in 1920; however, for the British Empire Exhibition in 1924 and 1925 "The Canadian mineral industries" was published in two editions for the two years. Commencing in 1933, this review became an annual publication until the war. "Operators lists" comprising "Metallurgical works", "Milling plants", "Metal and industrial mineral mines", "Coal mines", "Petroleum and natural gas"*, "Sand-lime brick plants"**, and "Sands and gravel pits"** continued to be published.

Other office staff like Freeman and E.G. Wait, who joined the Mineral Resources Division in 1923, were encouraged to undertake field work in support of the mineral specialists, but sometimes on their own. In 1926 Miss D.M. Stewart, who had been with the division from 1913 "while on a trip to the lower Gulf of the St. Lawrence was instructed to visit points on the Island of Newfoundland to obtain information with respect to occurrences of diatomite"; the samples she procured were transferred to Eardley-Wilmot for examination and comparison with the material collected by him in the Maritimes.

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* discontinued in 1930 and replaced by "Petroleum refineries in Canada";

** discontinued in 1924 and replaced by "Cement mills in Canada, 1949" and "Stone quarry operators in Canada, 1948".

The division was responsible for the preparation of documents and exhibits for expositions, publication of special reviews for international meetings and exhibitions, etc. It was much involved with the Imperial Economic Conference held in Ottawa in 1932; Wilson, the division chief, acted as advisor to the conference. A series of statistical statements believed to be the most complete studies yet made of the Canadian mining industry at the time was prepared by John Casey for the conference under the following general titles:

(1) "Ore and mineral production, calendar years 1913/1930"
(2) "Summary of Canadian metals, production, imports, exports, supply, and recorded (local) consumption, 1927/1930"
(3) "Inter-trade in minerals, metals, and their products; United States - Canada, calendar years 1927/1930"
(4) "Inter-trade in metals, minerals, and their products; United States - United Kingdom (except Irish Free State) calendar years 1927/1930"
(5) "Inter-trade in metals, minerals, and their products; United States - British Empire units, calendar years 1927/1930".

As mentioned previously, most of the mineral specialists in this division were engaged on industrial minerals, not the least reason being that metals and fuels had their own officers who also undertook a fair amount of field work.

Wilson participated actively in the programs of the division, visiting the various officers in their field investigations when this was necessary. He increasingly became the resource consultant of the Mines Branch and the liaison officer with the chemical and allied industries who were large users of mineral products, following the publication in 1924 of his report "Development of chemical, metallurgical and allied industries in Canada in relation to the mineral industry" (37).

Library

Mrs. Ogilvie continued to be the chief librarian during this period, and the library was located on the upper floor of the Sussex Street building. The accommodation first used had to be enlarged, shelving was added, and stacking resorted to as accessions were growing at an average of about 4000 per annum, inclusive of documents and pamphlets, etc. Considerable attention was paid to acquiring library material on international developments in mineral technology, and translations were made. Following Haanel's retirement in 1920, the library received part of his valuable scientific collection. In 1929, when J.G.S. Hudson died, he also bequeathed part of his collection of books and documents.

It is interesting to note that during the fiscal year ending March 31, 1928, the largest number of copies of Mines Branch publications was issued - 137,498 - which presumably has never been duplicated.

Draughting Division

The head of this group since its inception in 1911 was H.E. Baine. He retired in 1933 and was succeeded by L.H.S. Pereira as acting chief.

It was customary for Baine in his annual report to give a list of numbered maps that formed part of the sequential numbering with the reports of the Mines Branch that were instituted by Haanel from the outset. Some of the numbered magnetometric maps were not part of the reports and many report maps could be obtained as separates. The listing of these numbered reports was discontinued following publication of the annual report for the fiscal year 1929-1930. The last of the numbered maps in the Mines Branch catalogue are 812 and 813, issued with Part V, "Limestones of Canada" by M.F. Goudge in 1946. The division ceased to exist after 1936 and became a section of the Economics Division. In the later years there were draughting groups in the Mines Branch but they were limited mostly to preparing mechanical drawings.

National Research Council

In the light of the emphasis on mineral resources by the NRC in its early years, a mutually promoted cooperation existed between it and the Mines Branch.

The NRC was formed in 1916. Until 1924 when the Research Council Act was promulgated, it was known as the Honorary Advisory Council for Scientific and Industrial Research of Canada. In 1923, Dr. T.H. Tory was appointed president, continuing his presidency of the University of Alberta to 1928 when he resigned to take full time charge of building the Council's own laboratories. He reported, as did the rotating administrative chairman, to the chairman (Minister of Trade and Commerce) of the Privy Council on Scientific and Industrial Research.

Promoting utilization of natural resources was the stated objective of the Council. In the early period, it had an industrial orientation and concerned itself in a large measure with problems that beset industry. One of the first projects that the Council addressed itself to at the first meeting on December 4, 1916 was replacement of the importation of U.S. anthracite used in Manitoba and Saskatchewan by a carbonized briquette from lignite. A.R. Ross, a Montreal consultant engineer, and a member of the Council became the first chairman of the Lignite Utilization Board founded in 1918. He was also author of Report No. 1 published by NRC "The briquetting of lignite" by A.R. Ross, 1918.

The associate committee on mining and metallurgy was organized in the fall of 1917, holding its first meeting on March 5, 1918 in Montreal. This was an advisory committee. The lignite project came under its purview. In 1920 J.G. Morrow, inspecting engineer of the Steel Company of Canada and member of the Mining & Metallurgy Committee, was made chairman of a sub-committee on iron ores. Report 14 was published in 1924, titled "On the utilization of the low-grade iron ores in Canada" by J.G. Morrow. Other mineral resource and processing projects undertaken mostly by the academic world were supported by the NRC, as they are at present. The problem of beneficiating iron ores was discussed at a joint Department of Mines/NRC/U.S. Bureau of Mines Conference in March 1927, indicating not only the cooperative spirit of the times but also the foresight of the U.S.A. group in regard to depletion of shipping grade taconite ores which were then still relatively abundant. An Advisory Associate Committee was formed in 1933 with Morrow as chairman; Timm joined the committee in 1937.

Camsell was a member of the Mining & Metallurgy Committee from 1926 until it ceased in 1932. He was member of the NRC from 1924 to the dissolution of the Department of Mines in 1936.

Other associate committees dealing with mineral resources, some being research, others advisory, on which Mines Branch staff served, were:

Magnesite 1925, name changed to Magnesium Products in 1931:
Camsell, member; later Fréchette; initial work done jointly with Mines Branch.

Helium 1924-35:
McLeish and Elworthy, later Rosewarne. Camsell chairman after 1931.

Heating and Insulation of Buildings 1926-33:
Camsell, chairman representing Dominion Fuel Board.

Coal Classification and Analysis 1927:
Camsell, joint chairman; McLeish and Gilmore, members; later Nicolls.

Gas (Natural) 1929:
Camsell and Rosewarne.

Trail Smelter Smoke 1929:
Camsell, member.

Asbestos 1930:
Camsell, member; later Wilson

Metallic Magnesite 1937:
G.S. Farnham, Goudge, Wilson.

The foregoing indicates the degree of participation, and, in the case of magnesium, of joint work that the Mines Branch staff was involved in with the NRC. The spirit of cooperation engendered by Tory and Camsell has continued to the present, particularly in chemistry, with considerable contact between officers of both organizations.

General

The period from 1920 to 1936 could be described as a productive one for the Mines Branch, possibly the most productive in terms of available resources. In the 16 years the staff doubled to about 200 and it produced a great deal of data and information which the mineral industries used. There were no disappointments of importance in the projects undertaken, with perhaps the exception of the peat and oil shale programs. The extra effort in these programs was made in the light of the serious fuel shortage in the most populated parts of Canada. The R & D work of the Ore Dressing and Metallurgical Division was probably adjudged to be the most successful of those undertaken as the Mines Branch came up with answers to many of the problems of treating complex metal ores for the industry, which of course appreciated this effort. This is not to imply that the other groups in the Mines Branch made less effort, but in the industrial minerals and fuels areas with few exceptions, profits were lower than for metals, possibly causing operators to be more conservative about expenditures for research and development.

The mineral production of Canada grew rapidly for ten years up to the depression following World War I. However, with the exception of base metals and gold, the demand of the nation for iron, steel, energy, and many of the industrial minerals at competitive prices, particularly with the U.S.A., outstripped supply, resulting in a negative balance of trade in the mineral products sector.

It seems clear from reading the deputy minister's reports that the considerable departmental support for expanding Mines Branch activities was motivated by the desire to assist the mineral industries in their effort to increase mineral production for export. Thus during this period, which included the depression years, the department carried out what for the times was an extensive building program in the Booth Street area with updating of equipment. All of this and a responsive staff caused Camsell to state in his departmental report for the fiscal year ending March 31, 1933, "...During the past ten years in particular, most of the milling and metallurgical plants placed in operation are using treatment methods or slight modification of such methods that have been devised in the department's ore dressing and metallurgical laboratories... It is doubtful if there are anywhere on the American continent or perhaps in the world such facilities for experimental and test work as are provided by the laboratories of the Ore Dressing Division of the Mines Branch."

These sentiments were echoed by independent observers; thus it is appropriate to quote the independent views of two participants in the second Empire Mining & Metallurgical Congress in 1927, relating to the work of the Mines Branch Ore Dressing & Metallurgical Laboratories.

First, from R. Hon. Sir Robert Horne, Hon. President, Empire Council of Mining & Metallurgical Institutions, in his inaugural address to Congress on Aug 22, 1927 he stated in part "...The assistance which is given by the Canadian Government to the cause of research shows that its importance is fully realised here. The Ore Dressing & Metallurgical Laboratories at Ottawa, which are maintained by the Government cannot but be of great service to the development of the mineral wealth of Canada ..."

Second, from Bernard W. Holman, Professor of Ore Dressing at the Royal School of Mines, London, "...Government testing. - The most notable single factor contributing to the increased use of the flotation process in Canada appears to be the extremely well staffed and well equipped Government 'Experimental Ore-Testing and Research Laboratories' near Ottawa. The testing staff of these flotation laboratories consists of a number of keen research workers all of whom have had considerable experience in flotation work, and have had actual experience in mills using the principles on which they are engaged to research.... Inquiry elicited from one or two Canadian members of the Congress who were consulting engineers that they regarded with favour this apparently wholesale gratuitous consulting work undertaken by the Department of Mines. This explanation of their attitude, like the explanation of so many well-known paradoxes, was simple. They considered the laboratory only undertook work that required far more extensive staff and equipment than any consulting engineer had, or was ever likely to have, and that in many cases, which were named, properties had been opened up which would have otherwise remained dormant because of the complex nature of their ores. The starting up of these properties was said to have yielded more in taxation than had been spent on the laboratories altogether, and to have provided a considerable amount of employment to consultants and assayers apart from the technical staffs they supported to the general benefit of the profession." (78).

The second part of the last quotation may be of interest in the light of the considerable discussion in later years about the merit of test and research work done for industry without charge.

The important factor in the success of the Mines Branch in this period was the cooperative attitude of the industry. Most of the companies were relatively small by today's standards and because of the department's "open door" policy based on Clause 6 (d) of the Department of Mines Act relating to aid to industry, company personnel and consultants freely conferred with officers of the various divisions, a tradition that was started by Haanel.

It was a period of stability for and cooperation by the department as a whole. There were only two ministerial changes in the 15 years from 1921 to 1935 - Charles Stewart (1921-1930) and W.A. Gordon (1930-1935). The deputy minister, a departmental officer from 1899, had a clear understanding of the department's aims, i.e., to promote the discovery and utilization of mineral resources in helping to build the prosperity of Canada by the cooperation of all concerned. This cooperation extended across federal, provincial, and international lines. Camsell was a member or chairman of various inter-governmental and inter-agency committees such as the National Research Council, Advisory Committee on Mining Regulations, Lignite Utilization Board, Turner Valley Waste Gas Committee, Alberta Bituminous Sands Administrative Committee, the Imperial Institute (U.K.) and other bodies. In-house he was chairman of the Dominion Fuel Board and of the Canadian Committee of the World Power Conference.

Because of the protectionist tariff policy of the United States, Canada decided in the early 1920's to diversify its export of minerals by promoting sales to the British Empire and Europe. Related to this export drive, Camsell, who estimated that Canada in a normal year was capable of exporting up to 300,000 tons of mixed metals and minerals, instituted in his annual reports a list of papers and addresses on the scope of the departmental interests. A weekly newsletter service on mining conditions and mineral resources to the Canadian High Commissioner's office in London, England was organized by him for distribution to press, mining companies, brokers, etc.

Probably the wisest action taken by the management of the department was its efforts during the depression to retain the well motivated staff. Many of the persons employed in the Mines Branch had acquired or perfected specialized skills on the job because at that time in Canada there were comparatively few specialists that had the training or experience in the science and technology of mineral resources.

CHAPTER 5

WORLD WAR II - PRELUDE, HOSTILITIES AND AFTERMATH (1936-1951)

DEPARTMENT OF MINES AND RESOURCES, 1936-1949

The departmental reorganization of December 1936 arising from dissolution of the Department of Mines and creation of the Department of Mines and Resources brought about administrative but not technically substantive changes until the start of World War II. The name Mines Branch was changed to Bureau of Mines and the director became chief who reported to the director of the Mines and Geology Branch.

The minister and deputy minister remained the same - Crerar until 1945 and Camsell until 1946, with 10 and 26 years' service respectively in the two departments. The ministers who followed were J.F. Glenn (1945 - 1948), and J.F. McKinnon (1948 - 1949). The deputy minister was Hugh L. Keenleyside from 1947 to 1950. At the inauguration of the Department of Mines and Technical Surveys in 1950, J.J. McCann was the first minister followed by George Prudham. The deputy minister was Marc Boyer.

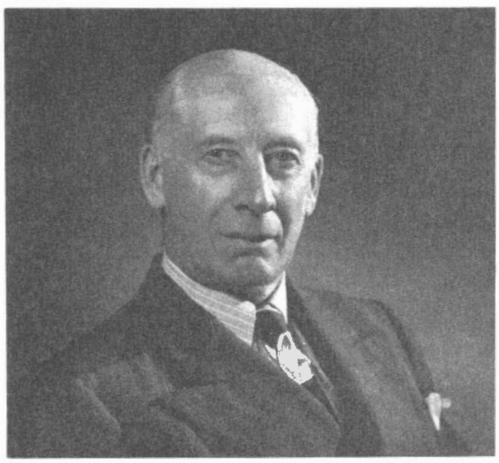
McLeish was promoted to director of the Mines and Geology Branch, where he remained until his retirement on May 1, 1941. Wilson joined McLeish as technical consultant at the branch level, also retiring in 1941.

Not surprisingly, Timm was promoted to be chief of the Bureau of Mines, and Parsons advanced to the position of chief of the Ore Dressing and Metallurgical Division, renamed the Division of Metallic Minerals.

The retirement of McLeish in 1941 resulted in the promotion of Timm to succeed him as director of the Mines and Geology Branch, but Parsons remained chief of the Metallic Minerals Division until March 1946. Thus in the period of fourteen years that the Department of Mines and Resources lasted, the organization had two heads with considerable prior experience in the Mines Branch, and both had demonstrated leadership and creative qualities. This chapter will cover the period to 1951 when Parsons retired.

WILLIAM BENJAMIN TIMM, THIRD HEAD OF MINES BRANCH (BUREAU OF MINES)

Bill Timm, as he became known to a large mining constituency, was born on July 15, 1884 in Westmeath, Ontario. He was educated at Westmeath Public School and Renfrew High School, followed by training at Queen's University, graduating in 1906 with a Bachelor degree in Mining Engineering. He had pregraduate practical experience in 1901 and 1902 in smelter work at the Canada Copper Company, and in 1902 to 1906 in prospecting for Fraser and McLaren and underground work for Lake Superior Power Company. From 1906 to 1913 he had professional experience, first in Mexico starting as a cyanide shift boss and mine surveyor with the Guanajuato Mining Company and advancing to chief engineer and general superintendent of the company as



W.B. Timm, third head of Mines Branch (Bureau of Mi
(Photo NFB)

well as of the associated Carmen Gold and Republic mines. He returned to Canada in 1911 and applied to the Mines Branch for a position, but it was not until 1913 that a vacancy became available. Meanwhile, he served as foreman, superintendent and engineer at Deloro Mining and Smelting, Cordova Mines, and Canada Iron Mines, all in Ontario. When he joined the Mines Branch in 1913, he was at first assistant to Mackenzie, chief of the Ore Dressing and Metallurgical Laboratories, becoming superintendent of the laboratories in 1916. Following Mackenzie's resignation in 1919, he acted as chief of the division until the following year when it was made official, holding the position to December 1936. In 1920 there were about 35 employees. He enlarged the facilities in the late 20's and again in the late 30's, developing a broad and versatile centre of knowledge and research capability in the processing of metallic and non-metallic minerals up to the point of use in the fabrication and manufacturing industries.

All of this was achieved in a difficult time by a dedicated and frugally minded staff estimated to have been less than 50 in 1937. An exact figure is difficult to arrive at because of organizational changes.

Unquestionably, this period was one of the highlights in the history of the branch. An important factor was the confidence engendered in the industry by the competence of the staff and the significant assistance rendered by the laboratories. Timm, from the early days, travelled extensively in Canada visiting mine camps, metallurgical works and laboratories, and it was reported that at one time he knew personally every mine manager in the country.

Timm and his principal assistant, Parsons, were classical mining engineers of that period without any postgraduate training, but they both had a respect for science as an important component of R & D work. A considerable amount of development work and some basic research was pursued during this period to which scientists and particularly chemists contributed.

During the period of Timm's tenure of office as chief of the Bureau, the organization moved forward rapidly as the depression years were succeeded by World War II when Canada entered a period of upswing closely related to the war effort. Before Timm finally relinquished his responsibility for the Bureau of Mines in 1946, the tempo of work was accelerating, particularly because of the war effort requirements in physical metallurgy for which laboratories were built in 1943. On December 3, 1941, Timm was promoted to director of the Mines and Geology Branch following McLeish's retirement. He continued as acting chief of the Bureau of Mines until 1946. In 1947, when a departmental reorganization was made with the object of assembling all the scientific and engineering resource groups in one branch called Mines, Forests and Scientific Services, he became its director-general.

Timm possessed a quiet, unassuming personality unless roused. He was a determined man and had a high degree of responsibility towards the public, particularly to the industry. Following his retirement on February 11, 1950, having served about 36-1/2 years with the department and its successor, there was a special gathering of 250 mining men from all parts of Canada to pay tribute to Bill Timm. A complimentary dinner under the chairmanship of R.W. Diamond of Cominco was held at the King Edward Hotel, Toronto, in April 1950. He was presented with a Dodge Custom sedan, probably the sole occasion of a retired civil servant being honoured in this way by the mining industry. As George Bateman said, the occasion "served admirably to express to one of the best known of Canada's mining fraternity the affectionate regard in which he is held from coast to coast and from the international boundary to the Arctic Islands".

Timm was honoured by the King on Dominion Day, 1946, by the award of Commander of the Order of the British Empire (Civil) - C.B.E. On May 21, 1949, he was awarded an honorary degree of Doctor of Laws by his Alma Mater, Queen's University "for his services over many years in developing and processing of Canadian mineral wealth". Timm lived quietly at Westmeath until his death on January 8, 1961, at the age of 77.

CECIL STEWART PARSONS, FOURTH HEAD OF MINES BRANCH (BUREAU OF MINES)

Parsons, known as "C.S.", was born on November 8, 1891, in Springhill, Nova Scotia, where his father was an engineer at the coal mines. This was the year of the mine explosion when 125 men perished. On his mother's side Parsons was related to Sir Charles Tupper. He attended King's College School and King's University, Windsor, Nova Scotia. In 1908 he went to Queen's University where he graduated in mining engineering in 1913. From 1908 to 1912 he spent his summers in surveying, both civil and mining, in construction work, building an iron concentrator and a steel foundry, and in chemical laboratory work; during the summer of 1913 he was in charge of a Mines Branch party surveying iron sands at Natashquan, Quebec.

In 1914 he was appointed to the Mines Branch as assistant engineer to Timm, conducting a variety of processing tests on metallic and non-metallic ores and specializing almost from the start in flotation. During World War I he was appointed a member of the Munitions Resources Commission under Captain Cantley's chairmanship, undertaking a number of investigations for the Commission including surveys for strategic

C.S. Parsons, fourth head of Mines Branch (Bureau of Mines) metals such as manganese and molybdenum, electric smelting of ferro alloys, and electric furnace production of pig iron.

Parsons left the Mines Branch in 1918 for an appointment as superintendent of the American Graphite Company, where he redesigned the plant from water concentration to flotation. The mine closed down after the war because of the drop in prices. In 1920, he accepted the position of field engineer with the Mining Corporation of Canada in Toronto. He returned to the Mines Branch in 1921 and again became Timm's principal assistant in R & D on metallic minerals processing, becoming section head in 1928. A large measure of credit for building up the laboratory for treating complex Canadian ores and for the international renown that the laboratories earned is due to "C.S.". In December 1936, when Timm became chief of the Bureau of Mines, Parsons was promoted to chief of the Ore Dressing and Metallurgical Laboratories. Between 1936 and 1939 the Ore Dressing Laboratories on Lydia Street were designed and built under Parsons' supervision. He served as chief of the Metallic Minerals Division during the whole of World War II. He recognized the importance of metallurgy in the supply of strategic metals and in the production of such armaments as guns, tanks, etc. He established close liaison with the Department of National Defence which resulted in the Bureau of Mines becoming a principal advisor on metallurgical projects, not only for that department, but also for the Department of Munitions and Supply. Thus in 1942 Parsons became official consultant to that department. Much of the war interest was centred on physical metallurgy. In 1936 there were only one or two officers with any knowledge of physical metallurgy, and the research was done in cramped quarters at 552 Booth Street. In the space of about two years, by 1943, spacious laboratories were built at 568 Booth Street, and when he retired in 1951 there was a staff in excess of 100.

Parsons and some of his associates were substantially involved in the initial stages of the Canadian Atomic Energy Project in the treatment of radioactive ores and in physical metallurgy of atomic reactors. This was largely due to the long standing close cooperation enjoyed by the Bureau of Mines and its predecessor with the National Research Council, which was responsible for the R & D work in this project. Furthermore, Dr. C.J. MacKenzie, President of NRC during World War II, must have had considerable confidence in Parsons as a capable organizer.

Following the 1943 Quebec Conference between Roosevelt and Winston Churchill it was decided to enlarge the Canadian role in atomic energy and provide for the building of an atomic reactor. Already in 1942 the British proposed that an important section of research on the military aspect of uranium fission should be carried on in Canada. A laboratory was established in Montreal under NRC administration for joint research by allied scientists. This work was closely coordinated with a massive effort by the U.S.A. and led to the establishment of a pilot plant at Chalk River, Ont., for the production of atomic bomb materials. The NRC extended research to applications in industry and medicine. The Atomic Energy Control Act was passed by the Federal Parliament in 1946 and the Board formally requested NRC to manage the atomic energy project at Chalk River. Dr. D.A. Keys, MacDonald Professor of Physics at McGill University, became head in February 1947.

Some time after the Quebec Conference, Parsons was apprised of the nature of the atomic energy project and important classified physical metallurgical work was undertaken at the Bureau of Mines. In 1948 in conjunction with MacKenzie he organized a group of metallurgists who eventually numbered some 40 who took up residence at Chalk River under the direction of Dr. M.J. Lavigne. By 1949 the entire physical metallurgy group had become the largest division in the Bureau. Parallel with this development, Parsons organized a special group of research chemists on radioactive ores in 1945 to optimize the recovery of uranium. This was followed by creation of the Radioactivity Division in 1948.

During 1946 and 1947 Parsons became special advisor to General McNaughton, head of the Canadian delegation to the United Nations Atomic Energy Commission at Lake Success, New York. At this time Parsons was Canadian delegate at meetings dealing with raw materials for atomic energy.

Much of the national defence and atomic energy work was necessarily secret and personally demanding on senior staff. Probably this was a principal reason for delaying Parsons' appointment to chief of the Bureau of Mines until March 20, 1946.

With dissolution of the Department of Mines and Resources in December 1949 and creation of the Department of Mines and Technical Surveys, the bureau changed back to its original name, the Mines Branch. Parsons became director on January 18, 1950. He built up the divisions of the branch during the six years he was head. The budget passed the $1 million mark in the fiscal year 1948-49. He retired at 60 on November 15, 1951 after nearly 37 years of service.

For his service during World War II, he was awarded the Order of the British Empire (O.B.E.) by the King in 1946. He was also awarded the Inco Medal of the Canadian Institute of Mining and Metallurgy in April 1951 and the Honorary Degree of Doctor of Engineering by the Howe School of Engineering at Dalhousie University in 1953.

Parsons was energetic, a "doer" and had foresight. He was an engineer of the old school but he brought into the Mines Branch a number of graduate scientists with research experience when they were not as plentiful as they are today because he realized that a purely pragmatic approach to research and development was no longer acceptable. He was outspoken and at times impatient but he believed in cooperation which he received from many individuals and agencies with whom he dealt.

He was strongly oriented towards the mining industry with his mining background from early childhood. He knew better than most the difficulties of the mining industry in obtaining a profitable return on the processing of complex ores.

John F. Thompson, president of International Nickel Company of Canada Ltd., presenting Parsons with the Inco Medal, said inter alia in his tribute "...this type of unselfish and foresighted cooperation with the mining industry has marked Mr. Parsons' career - Stewart Parsons has achieved distinction and in achieving it he has greatly enriched his country's heritage".

After retirement he was active as consulting engineer for some 15 years. He died at Kentville, Nova Scotia on September 7, 1972 at the age of 80.

Organization of Bureau of Mines

From a compact two-branch department in 1936 with closely related objectives to a large department with diverse functions and objectives was quite a transition (Chapter 2). The Mines and Resources Act of 1936 was the only act in the history of the Mines Branch that specified the infrastructure to the branch level. This resulted in the name of the branch being changed to bureau and of the director to chief. Heads of divisions were still named chiefs. At this time the salary range for the chief of the Bureau of Mines was $4500 to $5400, and for the technical divisions $4440 to $4980, excepting the chief of the Economics Division (formerly Mineral Resources) which was $3720 to $4620.

John McLeish was promoted on December 1, 1936 to director of the Mines and Geology Branch, and on the same day W.B. Timm was promoted to chief of the Bureau of Mines.

Departmental reorganization brought about some substantial changes in infrastructure but not immediately in the technical programs. Thus, the number of technical divisions remained the same at five, but some of the previous divisions ceased to exist and became sections of new divisions. The Explosives Division lost its departmental status and became part of the Bureau of Mines. Most of the divisions were renamed as follows:

Division of Economics (former Mineral Resources Division):
Chief, A.H.A. Robinson (1911 - 1938). Succeeded by G.C. Monture (1939 - 1956). Library and Draughting transferred from Administration. Industrial Minerals, including Industrial Waters (resources, recovery, marketing and uses), transferred to the new division of Industrial Minerals, and Bituminous Sands to Fuels Division.

Division of Metallic Minerals (former Ore Dressing and Metallurgical Division):
Chief, C.S. Parsons (1914 - 1951 exclusive of 1919 - 1920). The former Chemistry Division was incorporated with the Metallic Minerals Division and the Non-Metallics Laboratory was transferred to a new division.

Division of Industrial Minerals:
Chief, Howells Fréchette, retired 1946 (1908 - 1946). Transferred part from the former Mineral Resources Division and the Non-Metallics Laboratory, also Ceramics and Road Materials Division.

Division of Fuels (former Division of Fuels and Fuel Testing):
Chief, B.F. Haanel (1905 - 1946); succeeded by R.E. Gilmore (1917 - 1954, exclusive of 1920 - 1921). Bituminous Sands transferred from Mineral Resources Division and Mine Gas Analysis returned from Chemistry Division.

Division of Explosives:
W.P. Campbell transferred in 1937 to Inspection Services for the Western Provinces; analytical work taken over by Fuels Division.

Administration of the Maintenance Section under A.W. Mantle was transferred to the Director's Office from the Fuels and Fuel Testing Division in 1928. Mantle, who joined the Mines Branch in 1910, retired in 1939 and was replaced by S.J. Hayes in 1941.

The phasing out of the Chemistry Division probably demonstrated to the Civil Service Commission that their view regarding chemists in a support position was justified. For many years until the present research scientist classification, chemists were placed at the disadvantage of having to accept lower salaries than other scientists in the branch. It will be recalled from Chapter 3 the importance Haanel attached to chemistry in the R & D work of the branch, often describing them as engineering chemists.

In 1937 government funds became less restricted and the bureau embarked on a program of laboratory construction and expansion as existing facilities were becoming inadequate to handle the workload. This was done in two phases: in the first, a third floor was added to the Fuels Building at 562 Booth Street, providing room for an expanded oil and gas laboratory and including mine air analysis. Between 1937 and 1939 two buildings were added to Lydia Street, No. 20 and 40 - the present Ore Dressing Laboratory and an Industrial Minerals Building at the Rochester Street corner.

The new 60 x 100-ft Ore Dressing Building with three floors and basement was started in the autumn of 1937 and was equipped ready for use by the end of 1938. All equipment was removed from the old building and additional facilities were provided for sampling lots of up to 100 tons at a rate of up to five tons per hour. A small gold cyanide plant of 1-1/2-tons per day capacity was also installed. A tailings disposal plant was put into operation and additions were made for roasting of ores and refractory concentrates.

The 60 x 100-ft Industrial Minerals Building with three floors, a basement and a sub-basement adjoining the non-metallic milling laboratory was also started in 1937 and completed by December 1938.

The staff of the Economics Division, including the Library, but not the Draughting Section, (which had moved out to the Elgin Annex because of space) was the first to move into the new building at 40 Lydia Street, followed by the engineering, laboratory and clerical staff of the Industrial Minerals Division during the period of January to March 1939.

This extensive program of construction and updating of equipment occurred at a propitious time just before World War II. It made new demands on the organization but also probably saved money and avoided delays in research work. This was not unlike the branch undergoing expansion of facilities shortly before the depression.

The Explosives Division was provided in 1937 with a separate building for carrying out not only analytical but test work, and this remained on the Booth Street site until new facilities were set up at NRC in 1942. The administration and inspectorate of the division moved from their headquarters on Cliff Street to the Sussex Building, and the Draughting Section returned from the Elgin Annex when the Bureau of Mines laboratories left the building in 1939. The Bureau of Mines administration remained at Sussex Street until

Fuel Research Laboratories, 562 Booth Street, Ottawa, 1939.

Ore Dressing Laboratories, Bureau of Mines, 20 Lydia Street

1941 when it moved to the Motor Building, 238 Sparks Street. The last Bureau of Mines employee at Sussex Street was D. Lafrenière who retired in 1943.

In 1942 the Sussex Building was taken over by the Tariff Board, National Defence, and some other wartime agencies. Later, an overflow from various government departments made use of this building and this included several groups of the Geological Survey, notably the mineralogical, which was scattered throughout the city until its new building at 601 Booth St. was erected in 1959. At the time of writing, the National Capital Commission, NCC, is occupying it. There was talk in the 60's during the period of modernization of downtown Ottawa, that the building would be demolished. Dr. B.R. MacKay, then president of the Historical Society of Ottawa, who had served in the Geological Survey for over 40 years, made a plea to the Minister of Public Works to save this historical building which had been home for the Geological Survey and the Mines Branch for some 60 years after a colourful past of having served as a tavern, a garrison, a hospital, and a luxury hotel, dating to the very early days of Bytown. Through MacKay's efforts the building was saved and designated as a museum.

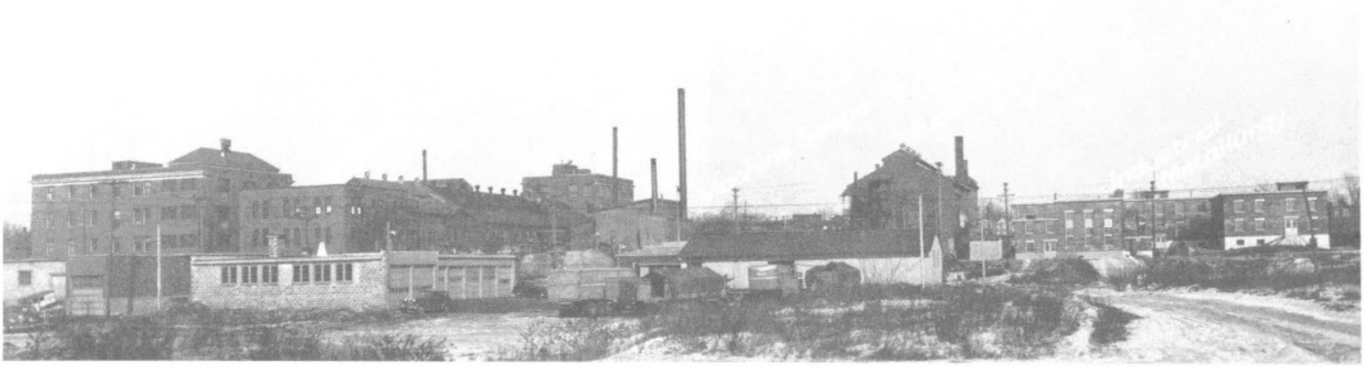
It will be recalled that Timm was appointed director of the Mines and Geology Branch in 1941 and was also acting chief of the Bureau of Mines. M.M. Farnham, secretary of the bureau, assisted him with its administration until 1946, when the latter retired and Parsons became chief. Timm remained at the Motor Building until his retirement in 1950. Parsons continued at 552 Booth Street, headquarters of the Ore Dressing and Metallurgical Laboratories of the Department of Mines. Later he transferred the chief's office to 568 Booth Street which housed the Physical Metallurgy Division.

In 1945 Howells Fréchette retired and Timm asked Parsons to take on the responsibility of supervising the R & D work of the Industrial Minerals Division. E.S. Martindale, then acting chief of the Economics Division, was responsible for the mineral resources aspects of the industrial minerals. This may have been a logical step at the time, as Parsons and others in the Ore Dressing Laboratories had considerable experience in the treatment of non-metallics. However, the Industrial Minerals Division was re-established in June 1950 because of the "increasing importance of the industrial minerals in the Canadian economy and the need for more extensive research, particularly on the utilization of these minerals" (quotation from the annual report of the Department of Mines & Technical Surveys for the fiscal year 1950-51). M.F. Goudge was appointed chief.

The second phase of construction occurred during the war in 1942 when, on the recommendation of a special committee of the war departments, a start was made on building the Physical Metallurgy Research Laboratories at 568 Booth Street. These comprised a group of three buildings designed eventually to provide facilities such as melting furnaces and a foundry, rolling mill equipment, die casting, extrusion presses, heat treatment, strength of materials testing with low temperature test rooms, creep testing, and microscopic, spectrographic and X-ray laboratories. The laboratories were completed in 1943 and were considered the best equipped in the country.

When Parsons became chief of the Bureau of Mines in 1946, the Metallic Minerals Division was renamed Mineral Dressing and Metallurgy Division and Traill was appointed chief. The division comprised the following sections: Mineral Dressing and Extractive Metallurgy, Ceramic, and Physical Metallurgy Research Laboratories. The Economics Division was renamed to the old appellation, Mineral Resources Division. The division was enlarged to comprise two main sections: Industrial Minerals, which included laboratory work on the non-metallic commodities, and the Economics Section of the prior Economics Division, as well as the library. G.C. Monture, who spent most of the war working with the Metals Controller, returned to take up responsibility for this enlarged division.

On November 1, 1947 a limited reorganization of the department was put into effect whereby all research groups were brought together in the Mines, Forests and Scientific Services Branch, with Timm as the director.



Bureau of Mines Complex on Booth Street, 1945. Photo taken from rear looking east.

The eight bureaux, as they were called, were as follows: Geological Survey of Canada, G.S. Hume, chief; Bureau of Mines, C.S. Parsons, chief; National Museum of Canada, F.J. Alcock, chief curator; Dominion Forest Service, D.A. MacDonald, Dominion Forester; Surveys and Mapping Bureau, F.H. Peters, chief; Water and Power Bureau, Victor Meek, controller and chief engineer; Dominion Observatory, C.S. Beals, Dominion astronomer; Geographical Bureau, Trevor Lloyd, chief.

The special mineral projects administered by the Mines and Geology Branch were transferred to the Bureau of Mines.

In 1948 the Radioactivity Division was created; its first chief was Arvid Thunaes, and in 1949 the Physical Metallurgy Research Laboratories were given the status of a division named Physical Metallurgy Division, the first chief being Dr. John Convey. Simultaneously, the name of Mineral Dressing and Metallurgy Division was changed to Mineral Dressing and Process Metallurgy Division. It may be of interest to review briefly the staff establishment and expenditures during the war. It will be recalled that in 1937 the staff of the Bureau of Mines numbered 180. By 1946 the staff had grown only to 215 which did not take into account any temporary manpower paid by the special war appropriation or supplied by government agencies or industry.

The ordinary expenditures for the Bureau of Mines reported in the annual reports of the department in rounded dollars are set out in the table below.

An event that should be recorded took place during this period. It will be recalled that Jessie Orme started as secretary to Dr. Haanel in 1901. She retired on July 9, 1945 after nearly 44 years of public service, most of it in the Mines Branch and Bureau of Mines. In this period she either acted as a secretary or head of a stenographic pool in direct contact with the director's administration. Her grade at retirement was Stenographer 3 at an annual salary over the last five years of $1,680.

The Mines Branch has been fortunate in the continuity that has existed with the secretaries in the director's office throughout its history. Following Jessie Orme's retirement there was an interregnum of three years that included service by Betty Macfarlane,

Bureau of Mines Expenditures and Supplementary War Funds, 1938-1951

Fiscal year ending March 31	Ordinary expenditure $	Special war expenditures Mines and Geology Branch $	Demobilization and reconstruction $
1938	473,090		
1939	455,074		
1940	455,568		
1941	423,285		
1942	429,121	70,020	
1943	433,727	685,464	
1944	437,267	1,792,960	
1945	429,742	1,388,926	
1946	455,596	1,706,646	
1947	548,991		1,735,817
1948	707,377		517,523
1949	1,476,412		81,893*
1950	1,891,756		14,816*
1951	2,013,717		

* (Bureau of Mines only)

but the real successor to Jessie Orme in the director's office has been Nola Ferguson, serving since 1948 under three directors - C.S. Parsons, Dr. John Convey and the present incumbent, Dr. D.F. Coates.

Unfortunately continuity of vital stenographic and clerical support to scientists and engineers who were responsible for the written product of the branch and the management of their specific areas seemingly could never be achieved because of the classification of support staff being linked to the seniority of the individual for whom they worked instead of the skill and years of service of the support staff member.

The War Effort

The period under review was dominated by World War II. Due to the increase in population and productive capacity, Canada was able to contribute very much more in World War II than in World War I, and fortunately, with fewer casualties. In 1937 the depression, as far as the Canadian mining industry as a whole was concerned, had already passed.

Canadian Mineral Production, 1914-1946

Year	Value of production,$	Value per capita,$	
1914	128,863,075	16.72	
1918	211,301,897	25.37	World War I peak
1919	176,686,390	20.84	
1920	227,859,665	26.40	
1921	171,923,342	19.56	
1929	310,850,246	31.00	
1930	279,873,578	27.42	
1932	191,228,225	18.20	Depression low
1933	221,495,253	20.74	
1935	312,344,457	28.56	
1937	457,359,092	41.13	
1940	529,825,035	46.39	
1942	566,768,672	48.62	World War II peak
1946	502,816,251	40.86	

The table above gives the value of mineral production in unadjusted dollars for selected years from 1914 to 1946 (source: Statistics Canada).

It will be noted that the value per capita doubled in the period between the two world wars in spite of an increase in population.

As a stimulus to the mining industry and by way of providing assistance to the unemployed, the government in 1936 started a program of building mine access roads, two thirds of the cost being funded by the federal government and one third by the provinces. Thus in the fiscal year 1936-37 some 124 road projects were administered by the Mines and Geology Branch. The contribution from a special fund in the department for that fiscal year was $1,882,900, and this included full costs for the Yukon and Northwest Territories. It provided 3,555,000 man days of work, and in October of 1936, a peak of 5,000 persons were employed.

Apart from building up its own armed forces, Canada rapidly had to develop a supply and manufacturing base for aiding Great Britain and its allies during the precarious period after the fall of continental Europe, before the full impact of the U.S.A. war effort was attained following the attack on Pearl Harbor.

In 1939 three special studies, the first under supervision of the deputy minister, were made by the Economics Division. These concerned:

- the transport of crude oil from Turner Valley, Alberta, to the Lakehead in Ontario by pipeline and thence by tanker, undertaken because of reliance on imported oil
- Canada's requirements of war minerals - stocks on hand and sources of supply, undertaken with cooperation of the Dominion Bureau of Statistics
- less-developed mineral deposits, with the cooperation of the Mining and Prospectors' Association.

Further studies were also made in 1939:

- on the possible effect of providing iron ore bounties to reduce Canada's large importation of iron and steel products
- on the shortage of tankers for importing oil into Canada due to a shortfall of tankers of British registry employed elsewhere and to the prohibition against U.S.A. tankers entering the Gulf of St. Lawrence because of U.S.A. neutrality.

These studies were, so to speak, "curtain raisers" for the almost total involvement of the bureau in Canada's war effort.

Aside from energy sources, it was of course apparent that priorities in strategic mineral commodities would be metals for armaments and munitions, industrial minerals (chemicals) for munitions and explosives, and gold for a strong international financial position for the prosecution of the war.

In July 1940, representatives of the federal government including the department and the Bank of Canada, met in conference with the gold mining industry with the aim of increasing gold production. Two officers of the Economics Division visited the mines of Ontario and Quebec as representatives of the deputy minister to obtain reliable figures on current production and estimates of possible expansion. The data collected were subsequently extended to the whole of the Dominion and must have been reliable because they were very close to actual output in 1940 and closely approximated those for 1941, the peak year for gold production.

Some of the metals that received early attention in the bureau laboratories were iron and the alloying metals - molybdenum, chromium, manganese and tungsten. Similarly, a number of industrial minerals were selected for special effort - graphite, fluorspar, potash, and brucite. The energy minerals - coal, oil and natural gas - were of course vital to the war effort.

Four important wartime offices were set up in relation to strategic materials. They were those of Metals, Steel, and Oil Controllers attached to the Department of Munitions and Supply, and the Coal Administrator attached to the Department of Wartime Prices and Trade. Some members of the bureau staff were seconded to the controllers and much of the R & D work in bureau laboratories was essentially involved in the war effort at the behest of the controllers and other wartime agencies.

Metals had priority in the Bureau of Mines wartime program. The emphasis was mostly in relation to problems encountered in fabricating armament and munitions; in fact, the well-equipped and well-staffed Physical Metallurgy Research Laboratories were the creation of World War II. Energy continued to be of national concern and the problems enhanced by the war were given priority by the Fuels Division. Because of the decline in oil production in Turner Valley, Wartime Oils Ltd. a crown agency was set up. The Industrial Minerals Division was busy on commodities that were a source of important chemicals, on refractories, on source minerals for light metals such as magnesium and aluminum, and on stabilizing soils in airfield construction.

The Special Mineral Projects Division was set up in 1942 at the Mines and Geology Branch level to administer the war appropriation for special exploration development work in connection with the supply of strategic minerals, for investigation of petroliferous deposits, and to assist provincial governments in providing transportation facilities including winter maintenance of roads to strategic mineral properties. The earlier mine road assistance grants were virtually merged into this program.

METALS

Gold

The R & D work in the Ore Dressing Laboratories of the Bureau of Mines reflected the rapid changes that occurred in the gold mining industry during the decade of the forties. The following table shows the number of investigations carried out on gold and silver ores and their products in relation to that of total metal and mineral investigations. The largest proportion of these was at the request of industry.

It is probable that with few exceptions all the gold ores of Canada at that time received the attention of the laboratories on Booth Street. Unquestionably, the slump in gold production following the peak in 1941 did not encourage new producers. It should also be noted that the divisional laboratories became heavily involved in work more directly concerned with the war effort, particularly in physical metallurgy, and had to refuse a proportion of industrial requests. Even in the late 30's the bureau had to appeal to industry to assist with manpower. The record of 169 investigations completed in 1939, which represented samples ranging from a few pounds to carload lots was preceded by an impressive workload of 142 investigations in 1938. The new Ore Dressing Building was completed in 1938 and was ready for occupation by early 1939.

Bureau of Mines Investigations, Gold and Total

Year	Gold Investigations	Total Investigations
1936	66	99
1937	66	127
1938	71	142
1939	77	169
1940	70	121
1941	45	93
1942	20	54
1943	1	27
1944	5	20
1945	5	18
1946	17	34
1947	18	48
1948	20	40
1949*	14	38
1950*	14	30

After the war the Ore Dressing Laboratories concentrated on obtaining improved gold and silver recoveries and doing work on complex primary gold ores such as those of the Northwest Territories and the Red Lake area of Ontario. This work had been postponed largely due to the war effort. In 1945 the first shipment of ore was received for testing from the Giant Yellowknife Gold mine. This was followed by others and an investigation led to the design of a flowsheet to treat complex arsenical gold ore. The practice of allowing industry and consultants to work in the laboratories was continued, and thus in 1945 the laboratories were utilized by Wasa Lake Gold Mines, Francoeur Gold Mines and by Canadian Industries Limited (CIL) on behalf of Cochenour Willans Gold Mines.

Canadian gold production peaked in 1941 at 5,345,179 fine ounces. During this period silver production peaked in 1940 at 23.8 million ounces; in 1941 it was 21.75 million and thereafter continued to drop to 12.5 million in 1946. Gold was the leading metal from 1932 to 1941, providing the nation with one third of the wealth derived from the entire mining industry. By the end of the war gold production fell to about 50% of the 1941 production. Thus in 1946 it was 2.83 million ounces.

It should be recalled that from 1858 to 1930 gold was valued at $20.67 per fine ounce in American funds, and this was internationally accepted as the gold standard price. In 1931 the U.K. went off the gold standard and in 1933 the U.S. followed. The gold price related to the U.S. dollar went up to $35.00 per ounce, a price that remained fixed by international agreement for many years. The Canadian dollar in this period was discounted at 10%, giving the Canadian gold producers a price of $38.50 in Canadian funds. However, the return of the Canadian dollar to parity with the U.S. dollar in July 1946 made some of the operations unprofitable due to increasing costs and low grade. To avoid closure of mines and unemployment at the gold mining camps, the "Emergency Gold Mining Assistance Act" was passed in 1948. This Act authorized the minister to make assistance payments to operators of primary gold mines during 1948, 1949, and 1950. It was subsequently renewed from time to time and finally terminated on June 30, 1976 as no request for payment was made after 1971. Over $300 million was paid out in this federal subsidy. Payments in 1948 were made on 87.4% of the gold production for that year. The average assistance payment was $3.18 per ounce. It is ironical to reflect on the drastic change that took place in the Canadian gold industry in a span of only seven years; this indicates the limited resources in profitable grades and the high cost of underground mining of primary gold.

Industry made efforts to improve recoveries even after the Act was passed. Thus in 1950, of the 14 samples of gold and silver ore and tailings received, 8 were to improve gold recoveries and 2 samples were for the recovery of silver from tailings.

It may be appropriate to note the maximum production reached by the platinum group during the war. Platinum rose from an average annual production of 130,000 fine ounces between 1934 and 1941 to 258,228 ounces in 1942, falling to 121,771 ounces in 1946. Production of palladium and other precious metals averaged 103,000 fine ounces per annum from 1934 to 1945; in 1945 production was 458,674 ounces, dropping to 117,566 ounces in 1946. The principal source of these precious metals was the Sudbury nickel-copper ores.

Iron

The resumption of iron ore production in Canada occurred in 1939 with a shipment of 123,598 tons of iron carbonate (siderite) from the new Helen mine of Algoma Ore Properties Ltd. in northern Ontario. This was followed by shipping grade hematite from Steep Rock

* fiscal year to March 31 of the year following

Iron Mines in 1944. Magnetic concentration tests were made on treated siderite ore from the Helen mine in the Ore Dressing Laboratories of the Bureau of Mines in 1938 and later during the war. By 1946 iron ore production from these two mines reached 1,549,523 tons, well above any previous Canadian output.

The war renewed interest in some of the mines and prospects of lower grade ores in central Ontario and to some extent in other parts of Canada. In 1941, nine samples of iron ore, five from the small mines along the Central Ontario Railway which were under exploration and development by the Frobisher Exploration Company, were concentrated in the bureau's laboratories. Because of the staff shortage this company was given facilities in the laboratories to carry out its own beneficiation tests. Ventures Limited was also carrying out exploration on iron ores and sending samples to the laboratories. In 1944 the sintering facilities were placed at the disposal of Michipicoten Mines Limited with the Bureau of Mines staff assisting the company staff.

Some titanium ores were also treated, about 70,000 tons being produced in Canada in 1943, increasing from 10,000 tons in 1942 and falling to 34,000 tons in 1944.

Four alloying or additive metals - tungsten, molybdenum, chromium and manganese - were in increased demand during the war and two - chromium and manganese - in particular were in short supply.

Tungsten

A search for new sources and development of known occurrences of tungsten ore were promoted during the war by the Bureau of Mines. Many of the gold mines started to extract the scheelite associated with their ores. An increased number of individual samples were received by the Ore Dressing Laboratories after the start of the war. To encourage and accelerate production of tungsten ore from the smaller mines, concentration of these ores was carried out from 1939 to 1944 on a custom basis. A total of 210 short tons of ore was received for a yield of 126,000 pounds of concentrate in the form of tungsten trioxide. Canada's peak production during the war was 1,508,626 pounds in 1943.

Molybdenum

Next to tungsten, molybdenum received the most attention from the Ore Dressing Laboratories. The production of molybdenite in World War II was smaller than in World War I in spite of the price being about three times higher; in the peak year of 1944 only 1,062 tons of molybdenite and concentrates were produced compared with 1,554 tons in 1917.

By 1942 the supply was getting tight and the Metals Controller authorized the operation of La Corne Mines near Val d'Or, Quebec, and arranged to buy the output of the Indian mine of Dome Mines Ltd. in Preissac County, Quebec. On the basis of the bureau's investigations, suitable concentration plants were designed and at La Corne a process to separate bismuth from molybdenum was developed. A low-grade orebody was found by diamond drilling on the old Quyon property, Pontiac County, Quebec. A mill was also designed for this ore by the Bureau of Mines staff.

Chromium

Chrome ores were somewhat in the same position as tungsten and molybdenum. A number of samples, mostly from Quebec but also from Manitoba and B.C., were investigated. Five carloads from Bird River, Manitoba, were concentrated by various methods and the concentrates were melted at Sault Ste. Marie at the Chromium Mining and Smelting Company to determine their commercial possibilities.

By 1942 chromite was becoming scarce. Following beneficiation tests in Ottawa, a mill of 150-ton daily capacity was erected at St. Cyr and operated under supervision of the bureau. It produced a 48-50% chromium concentrate. A 600-ton per day mill was erected on the Bélanger property near Thetford Mines operated by the War Metals Corporation. The peak of Canadian chromite production in the Second World War was in 1943 at 29,525 tons compared with 36,725 tons in 1917.

Manganese

This was a metal in short supply in Canada and every effort by the Metals Controller was made to encourage prospecting and development of low-grade manganese deposits. Samples from all parts of Canada but particularly from the Maritimes including Newfoundland were treated at the laboratories in Ottawa. The maximum Canadian production of manganese ore was recorded in 1942 at 435 tons, again less than in World War I when in 1916 it was 957 tons.

Nickel

Several samples of nickel ores were tested in the laboratories in Ottawa. Sudbury ores fully met war needs in Canada and overseas - from a high of 100 million pounds in 1929, production fell to 30 million pounds in 1932 and then increased to the wartime peak in 1943 of 288 million pounds.

Cobalt

Several cobalt ores were tested during the war but the metal was in surplus and was stockpiled at Deloro, Ontario. Actually, production during the war was well below the approximate 600,000-pound average annual output from 1926 to 1940. In 1940 the production was 794,000 pounds, decreasing to 263,257 pounds in 1941 and to 70,205 pounds in 1946.

Tantalum

Towards the end of the war, there was a demand for this metal which is malleable (reactive) at high temperature, possibly for producing tantalum carbide and such other uses as surgical instruments and as a substitute for platinum. The bureau received several samples of tantalite for concentration tests from the Northwest Territories and Quebec.

Base Metals - Copper, Lead, Zinc

Although the Ore Dressing Laboratories received several samples of complex ores for treatment, it was fortunate that the separation techniques were already

Canadian production of base metals

Year	Copper lbs	Copper $	Lead lbs	Lead $	Zinc lbs	Zinc $
1930	303,478,356	37,948,359	332,894,163	13,102,635	267,643,505	9,635,166
1932	247,679,070	15,294,070	255,947,378	5,409,704	172,283,558	4,144,454
1937	530,028,615	68,917,219	411,999,484	21,053,173	370,337,589	18,153,949
1940	655,593,441 (War peak)	65,773,061	471,850,256	15,863,605	424,028,862	14,463,624
1942			512,142,562 (War peak)	17,218,233	580,257,373	19,792,579
1943					610,754,354 (War peak)	24,430,174

Source: Dominion Bureau of Statistics, Cat No. 26-501, 1957

largely worked out through advances in differential flotation. This led to Canada entering the war with a good productive and export surplus capability. Actually these metals had not been too seriously affected by the depression except in individual cases and of course by lower prices and lower profits as may be seen from the preceding table compiled by the Dominion Bureau of Statistics.

Aluminum

Although aluminum metal was and still is produced from imported ores, achievements by Canada during World War II merit recording. These were made essentially through the prodigious efforts of the Aluminum Company of Canada. Furthermore, the Bureau of Mines carried out research work related to the substitution of imported ores.

In 1918, the peak year of World War I for metal production, 23.5 million pounds of aluminum was produced; in 1939 the production had risen to 165.7 million and by 1942 to 681.2 million when Canada was supplying 40% of the quantity used by the allies. Production peaked in 1943 at 991.5 million pounds. At present with two companies operating - the Aluminum Company and the Canadian Reynolds Metals Company of Canada - output is about 2 billion pounds of metal annually.

The Aluminum Company's war effort to maximize aluminum production in Canada required rapid planning and execution. Smelter facilities were enlarged at Arvida and Shawinigan Falls, particularly at the latter, and two pot lines were built, both at LaTuque and at Beauharnois, as a temporary measure. Fabricating facilities kept pace with smelter expansion. There was already a plant in Toronto but a new foundry was built at Etobicoke and a Munitions Division was started at Lambton near Toronto. The present large plant at Kingston was also built during this period with a sheet mill, tube mill and an extrusion plant for aircraft parts. Aluminium Laboratories Limited was set up as a subsidiary research organization.

Prior to the war, fluorspar required in the smelting process was obtained from Newfoundland, Europe and U.S.A. During the war only the Newfoundland supply was available to the company and this had to be substantially increased. This target was achieved within a year.

In 1941, the American Nepheline Corporation in cooperation with Alcan devised a process in the Ore Dressing Laboratories of the Bureau of Mines for the extraction and recovery of aluminum with potash and soda ash as byproducts from the large deposits of nepheline syenite in Ontario. Full details were sent to the British Government for eventual use of the process in the extraction of aluminum from British clays and low-grade bauxite deposits in Ireland. Some research was also done in the Metallic Minerals Division on the extraction of aluminum from Canadian clays.

The R & D work on magnesium, another light metal often used in alloys with aluminum, is reported under Industrial Minerals as a substantial proportion of this metal was used in the oxide form in refractories which were non-metallic.

Organization of Mineral Dressing and Process Metallurgy

Parsons insisted on results of investigations undertaken for industry to be reported without delay. His division was the last to discontinue the printed "Investigations" series. The last issue was published in 1941 for work completed during the half year of July to December 1939 (MB Rep 806). The division and its successors published unclassified material at the divisional level or in the technical press until the new Mines Branch Series was established in the late fifties.

The Metallic Minerals Division underwent a reorganization in 1947 and was named the Mineral Dressing and Metallurgy Division. In 1949 when the Physical Metallurgy Division was formed, it was renamed Mineral Dressing and Process Metallurgy - the organization and principal staff of the latter as at February 1, 1951 were:

Chief - R.J. Traill
Ore Dressing Laboratory - A.K. Anderson, C.H. Freeman
Extractive Metallurgy - Dr. K.W. Downes, G. Thomas
Chemical Metallurgy - Dr. R.R. Rogers, G.E. Viens
Chemical Laboratory - Chief chemist - J.A. Fournier, R.A. Rogers
Spectrographic Laboratory - M.H. Haycock, B.J. Stallwood
Mineragraphic Laboratory - A.R. Graham
Physical and Crystal Chemistry - Dr. A.T. Prince, S.A. Forman, P.D.S. St. Pierre
Water Analysis - Cap. W.R. Inman, RCNR, D.J. Charette
Plant Foreman - G.A. Renaud

Uranium

Processing Research

Prior to World War II, Spence of the Industrial Minerals Division continued with the resource studies

M.H. Haycock

of radioactive ores. Samples from various lacations in Canada were analyzed and some treatment tests were conducted in the metallic minerals laboratories.

Contact was maintained with Eldorado Gold Mines at the Great Bear Lake mine, at Port Radium, N.W.T., and with the refinery at Port Hope, Ontario, the principal aim being to improve recoveries. Operations of the mine and refinery was taken over in 1944 by the Crown company, Eldorado Mining and Refining Co. (1944) Ltd.

In 1945, Parsons started to organize the recruitment of well qualified scientists and engineers for a group to undertake the development of improved analytical and treatment techniques, not only of Great Bear Lake ore but of a variety of ore samples from various parts of Canada. Most of the ores were lean and complex with less than 1% uranium oxide (U_3O_8). Up to that time high grade ore from Port Radium was analyzed and treated for the recovery of radium. There was no fully developed technology for the rapid analysis and optimum recovery of uranium from lean ores. Over the next decade intensive R & D in both areas solved the analytical problems and perfected several hydrometallurgical techniques such as acid and alkaline leaching, and ion exchange solvent extraction, and made improvements in known physical methods that reduced losses in the mill tailings to a minimum. F.T. Rabbitts was the pioneer in analytical chemistry of this group, having been recruited immediately after his demobilization from the Air Force in 1945. He had to start from scratch with no apparatus available for dealing with samples of low radioactive content. Countries like the U.S.A. and U.K. concerned with atomic energy were, of course, active in the field and the Canadian group was in touch with developments. However, the Canadian group as a contemporary of this international effort was able to make real contributions. Several methods that were reasonably rapid and reliable were developed, one of which - the fluorometric - was capable of determining uranium oxide contents in ore and mill products of less than 0.001%. In this latter connection, J.B. Zimmerman who was seconded to the Rabbitts group made a valuable contribution. At the formation of the Radioactivity Division, Rabbitts became senior chemist.

Parsons decided in 1946 that the bureau required guidance from an expert in treating uranium ores. Professor A.M. Gaudin of the Massachusetts Institute of Technology, who was connected with the "Manhattan Project", was hired as a consultant. He in turn recommended Arvid Thunaes as an experienced engineer who had graduated from the Trondheim Institute of Technology in 1923. He had twenty years' experience in treating complex ores, including a period at Cominco's Sullivan mine where he conducted flotation research on tin under Gaudin's guidance. Thunaes joined the bureau in March 1947 and became chief of the newly formed Radioactivity Division in 1948.

Dr. P.E. Gishler had been loaned to the bureau by NRC prior to Thunaes' appointment but was requested to return and was replaced by Dr. E.A. Brown who graduated with a doctoral degree in physical chemistry from McGill University in 1940 when he joined NRC. Brown worked there under Dr. A. Van Winsen on asbestos, on the L.M. Pidgeon process on magnesium metal, and with Gishler on recovery of sulphur from pyrites. Brown became assistant to Thunaes and in 1953 replaced him as chief of the Radioactivity Division.

A decision by the federal government in March 1948 to purchase all uranium concentrates of Canadian origin meeting specified requirements resulted in a marked increase in the number of samples of radioactive ores received at the bureau.

The Radioactivity Division was established in 1948 and in 1950 was set up in two fenced-off Quonset huts with the address of 30 Lydia Street.

The division assisted in the search for uranium, analyzed samples received and undertook R & D work in the concentration and treatment of bulk ores preliminary to working out the most appropriate flowsheets.

F.T. Rabbitts

A. Thunaes, chief of Radioactivity Division

Chemical and physical tests were perfected. The fluorometric method was found to give results more rapidly, particularly for low-grade ores. In making physical analyses for level of radioactivity, samples did not require crushing or grinding.

The division conveyed unclassified information on analytical methods and treatment of ores as quickly as possible to industry and others concerned. It published divisional reports, both topical and special, as well as reports in the bureau's Memorandum Series. Articles were also prepared as well as papers for presentation such as one presented by Thunaes in 1950 to the CIM on ore treatment but without classified information relating to leaching (CIM Bull 460; p 454, Aug. 1950). In the fiscal years of 1950 and 1951, 29 reports were published of which the following were in the Memorandum Series:

No. 96 "Determination of uranium in ores by field analysis" by F.E. Senftle, C. McMahon and G.G. Eichholz, 1949; revised in 1955.

No. 103 "Determination of uranium in ores, modified mercury cathode-cupferron method" by F.T. Rabbitts, 1949.

No. 105 "Determination of U_3O_8 in ores and solutions, cellulose column method" by F.T. Rabbitts, 1949.

No. 106 "Use of a high-pressure ionization chamber in assaying uncrushed ore samples" by J.L. Horwood and C. McMahon, 1950.

No. 110 "The chemical determination of thorium in its ores" by J.C. Ingles, 1951.

No. 114 "The determination of uranium in ores, fluorophotometric method" by J.B. Zimmerman, 1951.

No. 115 "Radioassay of uranium ore with the Geiger type equilibrium counter" by R.D. Wilmot and C. McMahon, 1951.

Private industry wanting to start up mines sent bulk samples for concentration and treatment. Thus in the fiscal year 1949-50, 9 complete confidential reports were issued in addition to 32 confidential technical reports sent to the Atomic Energy Control Board. In the following year of 1950-51, 22 concentration and treatment investigations were reported together with 63 sent to the AECB. It may be noted that the Australian Commonwealth Scientific and Industrial Research organization, CSIRO, was interested in the work of this division and in 1948-49 D.F. Kelsall spent several months in the laboratory working on the Dutch State Mines' cyclone as applied to the heavy media separation in the preconcentration of uranium ore. (Topical Report of the Radioactivity Division No. 27-1950).

It is fair comment to record that a very large number of uranium mills commissioned in Elliot Lake during the Korean war owed their technology to the small group of scientists in the Radioactivity Division. This was analogous to earlier Mines Branch contributions by Parsons and his small group in solving the treatment of complex base metal ores by selective flotation.

The total staff of the Radioactivity Division as of February 1951 numbered approximately 40 and its organization and principal members were:

Chief - A. Thunaes
Assistant - Dr. E.A. Brown
Ore Dressing and Extractive Metallurgy - H.W. Smith, W.A. Gow; Foreman - E.H. Devine
Mineralogy - S. Kaiman
Analytical Chemistry - F.T. Rabbitts, F.P. Roloson, J.C. Ingles
Physics and Electronics - G.G. Eichholz, J.B. Zimmerman, R.D. Wilmot

The exceptional effort of this division is more fully reported in Chapter 6.

Physical Metallurgy Research Including Atomic Reactors

The contrast in the science and technology of metals and metal alloys between World War I and World War II was striking. Basically, World War II was a war of movement not only in the air and on the oceans but also on land, requiring a large assortment of vehicles and armament capable of withstanding and delivering increased firepower. Hence a whole range of metals and alloys had to be designed for planes, ships and land vehicles with the accompanying armament.

In 1940 Britain found itself alone in Europe and had to rely on her Commonwealth partners for aid in the war effort. Canada, as a neighbour of the U.S.A. was also geographically the closest and the most advanced of the Dominions in most branches of metallurgy. The U.S.A. gave a helping hand with certain supplies and expertise but until she entered the conflict and gave herself to all-out war, much of the more secret work had to be performed by the U.K. and her partners in the Commonwealth, particularly Canada.

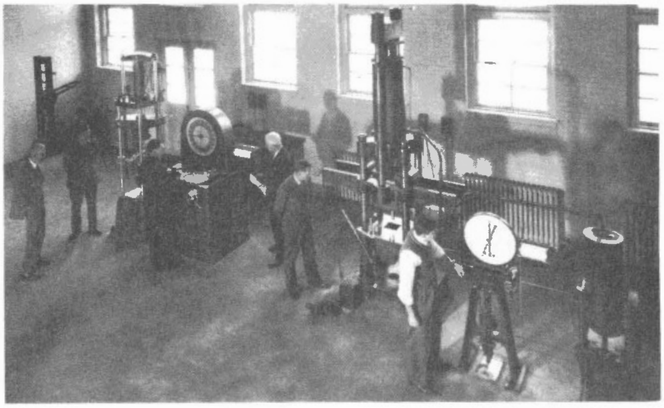
It is not surprising therefore that the Bureau of Mines as a federal government institution, with its initial experience in the elements of physical metallurgy going back to World War I, and enlarged by the creation in 1928 of the iron and steel section in the Ore Dressing and Metallurgical Division, was destined to play an important role in the absence of other facilities in the country.

The scope of knowledge and the research and development capability had to embrace all three of the elements of physical metallurgy that ensure that metals meet all requirements of rigorous service - compositional and treatment aspects for specific uses; metallurgical process operations like melting, casting, metal forming, welding, etc.; and diagnosis of service failures.

With a nucleus of only three men - G.S. Farnham, N.B. Brown and M.H. Haycock - Parsons had to build up an organization in 1940 that in ten years grew to over 100 to cope with the number of investigations originated mostly by the Department of National Defence. By 1943 the investigations had increased to about 700 whereas before 1940 their annual average was only about 20. In addition to Reports of Investigations, "informational" memoranda were prepared on various physical metallurgy topics as specialist information to the war agencies. A series was also established to report on visits to plants engaged in war work. Furthermore, the laboratories were set up to carry out special heat treatment of ordnance parts. Thus by 1943, before the new facilities were built, 13,000 items weighing 26,588 pounds were treated. Most of this work was of a confidential nature and the distribution of reports was only to authorized persons.

The three-building construction at 568 Booth Street was commenced in 1942 and completed by the end of 1943. Not all the facilities were available immediately but were added gradually over the next three years or so. Thus, in 1944, the Experimental Foundry was provided. In 1946, the High Temperature Creep Testing Laboratory and shot peening equipment for improving fatigue resistance of components used repetitively in machines were added. In 1947, the Metal Forming Laboratory containing a rolling mill, a horizontal hydraulic extrusion press, a vertical hydraulic press and a forging hammer together with drawing benches, etc., costing in excess of $600,000, provided a comprehensive range of metal-forming operations. This laboratory was supervised until his retirement in 1974

N.B. Brown, Physical Metallurgy Research Laboratories



Test facilities of Physical Metallurgy Research Laboratories on Booth St. being used to determine mechanical properties of metallic materials of military interest, 1944. From left to right: C.S. Parsons, unidentified representative of Department of National Defence and technician, G.R. Brabazon, N.C. MacPhee, N.B. Brown, S.L. Gertsman.

by John Perry, head of the Metal Forming Section, who had joined the bureau in 1945.

Perhaps at this point the aid given to the war effort by the laboratories should be recorded. This is best expressed in information released on page 47 of the annual report of the department for the fiscal year ending March 31, 1946 as follows:

> "Development of the materials of war led to a wide range of investigations in the Physical Metallurgy Research Laboratories. For instance: nearly every part of the snowmobile developed under the Department of Munitions and Supply for the Canadian Army was submitted for examination. The service life of tank tracks in 1940 was only 500 miles. As the result of 150 investigations made of tank parts, notably of track and track pins, the service life had been extended to 5,000 miles in 1943. The only small arms projectile capable of penetrating the armour of the Tiger tank needed a core of tungsten carbide. The first of these cores made in North America was produced in the Bureau of Mines. Production of the optimum qualities in steel demanded extensive research in heat treatment and in alloying elements. The fine quality of armour plate developed in Canada is tangible evidence of the success of these investigations. Similarly, the first successful armour-piercing shot made in Canada was a product of the bureau. When imports of aircraft control cables ceased it became necessary to produce the cable in Canada, and a testing machine was built in the laboratories. In conjunction with the RCAF and manufacturers, a cable of satisfactory quality was soon in full production. Scientific principles of sampling were studied and applied to the inspection of mass-produced articles with resultant great economy in the work needed in gauging quality of the batch of material.
>
> "The reports and the number in each case that were prepared on metals and their application were:

Foundry Section Staff, 1945: Left to right - H. Fairfield (engineer), A. Murton (engineer), Ed Morin (labourer), Hugh McCann (truck driver), Marcel Lorte (lead melter), P. Petalimone (labourer), J. Kosowan (heat treater), J. Buck (magnesium melter), Mike Peltrin (superintendent), A. Plouffe (labourer), Ray Piché (moulder), Val Traversy (electrician); sitting - George Stanley (labourer)

Subject	Number of reports
Carbon steels	965
Alloy steels	886
Bronze	323
Aluminum	230
Ferro alloys	169
Magnesium	164
Welded metal joints	119
Brass	112
Corrosion of metals	92
White metal	52
Malleable iron	31
Copper and alloys	26
Zinc alloys	22
Bearing alloys	19
Scientific inspection methods	17
Measurement of stress in metal	10
Tool steel	7

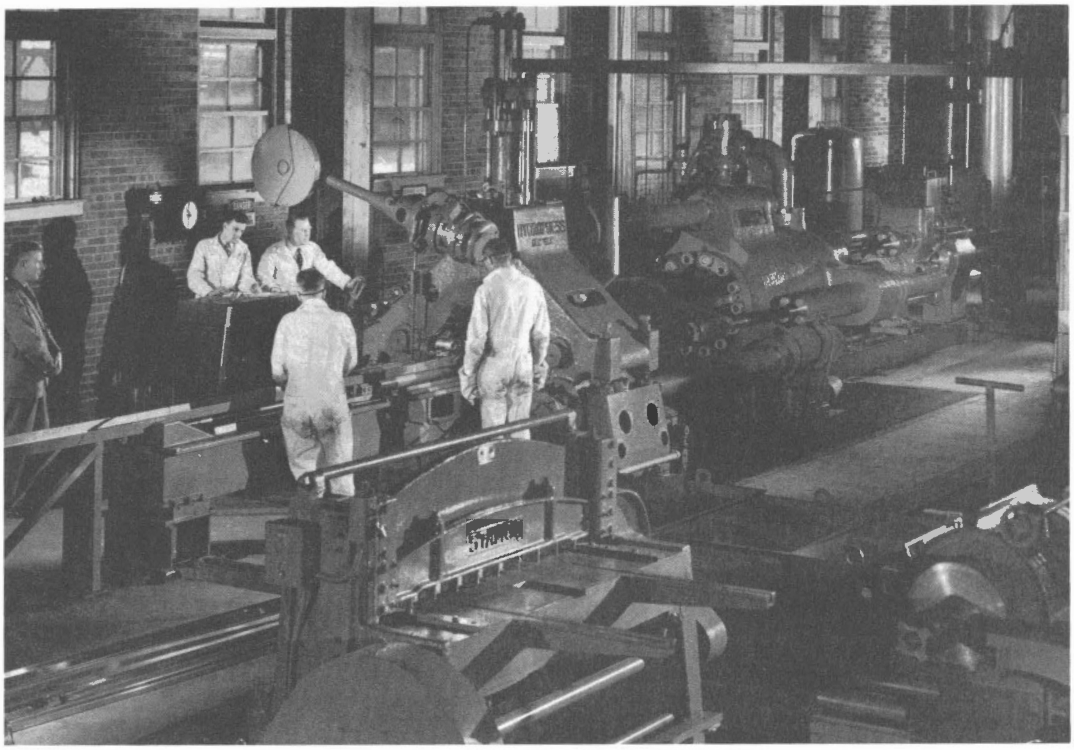
"Reports were also published dealing with tungsten carbide, nickel tungsten, powdered iron, copper nickel, copper beryllium, nickel plate, cadmium plate, tin plate, chromium plate, tin, nickel, cobalt, lead, zinc, and uranium."

The scope of the laboratories was expanded after the war when they turned largely to peacetime activities. They assisted the metallurgical industry and devoted more time to R & D in metal physics and special alloys, making improvements to industrial metallurgical processes and to metal service performance, etc.

Parsons believed in close cooperation with industry, so that many projects were conducted in conjunction with industry associations such as the Steel Castings Institute of Canada, Canadian Welding Society, Magnesium Association, and American Foundrymen's Association.

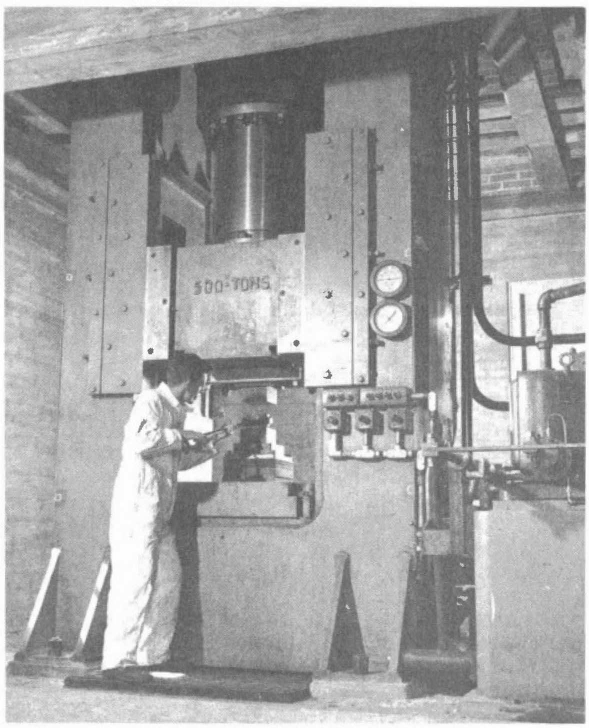
At war end Canada had on the average doubled primary metal production, substantially increasing the domestic use of metals and alloys as well as of exports, particularly in the decade of the fifties during the post-war reconstruction period. This upsurge of consumption and trade required participation in the development and revision of national and international standards. The Physical Metallurgy Division was in the vanguard of this work that required considerable technical and experimental input to the various committees, particularly to the Non-Ferrous Metals Section because of the large number of different metals and alloys involved. In this regard Meier and Edwards had to devote considerable time during their careers to this work. Zinc was a good example; its production had more than doubled since 1929; in 1949 about 280,000 tons was exported of which more than half was of die-casting grade. The U.S.A. was then using a specification based on a thermal metal refining method, whereas Canadians produced by electrolytic means. Detailed experimental data on impurity limits of zinc alloys was developed on the division's die-casting machine eventually leading to acceptance of the data for the adoption of standards. A Canadian R & D Zinc Committee composed of producers, manufacturers and Mines Branch representatives was the result.

Parsons worked in close association with the National Research Council. Thus a study on improving alloys for blades of jet propulsion engines was done in conjunction with the Council. Nickel-aluminum-vanadium, nickel-aluminum-chromium, and nickel-aluminum-molybdenum alloy systems were studied. H.V. Kinsey, who joined the bureau on January 12, 1942, was responsible for developing a nickel-aluminum-molybdenum alloy with high-temperature stress resistance properties for which a patent was issued in 1949. The alloy was named "Kinsalloy".



Metal Forming Laboratory, Booth Street - Experimental extrusion press - extrustion of magnesium alloy shape. From left to right: J. Perry, S. Herwig, I. Dafoe, A. Baker, D. Dowling

A. Baker adjusts magnesium slab during rolling operations



S. Herwig places aluminum test disc in 500-ton universal press

C.S. Parsons in discussion with Wing Commander A.J. Smith, J.W. Meier, and Squadron Leader, N.S. Spence. The latter joined the Atomic Energy Project at Chalk River, transferring to the Mines Branch in 1953

A major research program quite separate from the hydrometallurgical work on radioactive ores mentioned earlier was undertaken in cooperation with NRC which was responsible for Canada's Atomic Energy Project. It was related to materials of construction - the development of special purpose alloys and the fabrication of certain metal components - for the atomic energy plant at Chalk River. Parsons spoke of the excellent cooperation received from the president, C.J. MacKenzie, and the directors of the NRC divisions.

The involvement of the Physical Metallurgy Research Laboratories (PMRL) attests to the reputation in expertise of physical metallurgy that the bureau must have had not only in Canadian but also in British circles at that time; this was recognized in both the Canadian and British press after the war. The story is recounted by one of the PMRL scientists -

> "It was rumoured in 1944 that a group of British scientists had transferred to Montreal and was working on a very mysterious project related in some way to radioactivity. Professor J. Greenwood from England approached Stewart Parsons and asked for help in metallurgical work required for the project. As a start, he had with him a small bar of a very dense brownish metal and requested that someone determine its expansion characteristics on heating and cooling. Parsons introduced Professor Greenwood to Dr. R.L. Cunningham, in charge of the Metal Physics Section of PMRL. The professor would not say for whom he was working, what he was doing, nor state what the bar of metal was. He also insisted that Cunningham not mention it to anyone. It was obviously of high specific gravity, a quick determination showed it to be 19.0. A table of metal specific gravities indicated it could be only gold or uranium. Obviously it was not gold. It was only then that we realized we were part of the mysterious effort centred in Montreal.
>
> "The war in the Pacific came to a sudden end in August 1945 with the dropping of two atomic bombs on Japan, fabricated by the Americans. In fact, the Canadian reactors for which the uranium metal was required to produce the plutonium for the bomb did not go into operation until after the war.
>
> "The realization that atomic reactors could produce tremendous amounts of power for an energy-hungry world was quickly realized and Canada found itself in a very favourable position to become a leader in this effort. Problems associated with fuel element cladding, uranium stability, alloy development and corrosion all had to be solved. The British returned home, NRC took over the project and in 1946 enlisted the Bureau of Mines to do its metallurgical work on an interim basis. Under the direction of Dr. M.J. Lavigne, the bureau established a group at Chalk River, site of the first reactors in Canada, which eventually grew to a staff of 45. Atomic Energy of Canada Ltd. was formed in 1952 and by 1956 took over metallurgical research, resulting in 22 of the group returning to Mines Branch, Ottawa.
>
> "During the same period of 1946 to 1956, much work was also being conducted in PMRL on fuel rod assemblies for NRX and NRU reactors, notably by J.A. Perry on metal forming, H.J. Nichols on welding, Dr. C.M. Mitchell and J.F. Rowland on uranium stability, and R.L. Cunningham on uranium alloy systems. The year 1956 marked the end of the era of our intense activity in the atomic energy program."

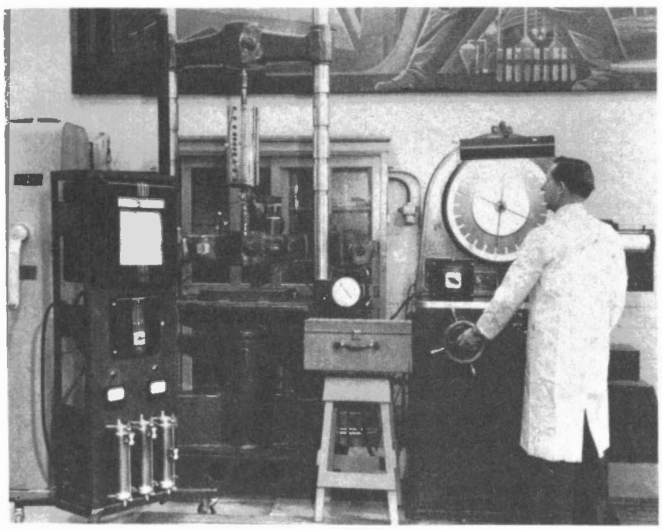
Meanwhile requests came for technical assistance from the Canadian iron and steel foundry industry in connection with substitutes because of shortages of

Visit of Queen Julianna of the Netherlands to the Mines Branch in April 1952. The work on the table was the first successful thin-wall sheath tubing in super pure aluminum for the N.R.V. reactor. Front left to right - J.A. Perry, Queen Julianna, Miss C.E.B. Roell, lady-in-waiting; Rear - J. Alius, British United Press, W. van Tets, chamberlin, R.J. Traill, acting director, Mines Branch, and A.H.J. Lovink, the Netherlands Ambassador to Canada. (Photo courtesy of IBM Canada Limited) pig iron, scrap and coke as well as with sand conditioning, and above all with metal penetration into core sand. A joint industry committee that included the Steel Castings Institute of Canada was formed to deal with some of the problems. Also joint studies were made such as one concerning the use of core oils. An improved "disposable" (wax) pattern casting machine was designed, built and patented in 1947. This was the invention of T. Eric Davis (1946-1960) research technician, an ex-prospector and die-tool maker who told an enquiring journalist that "prospecting and research were both on the frontier of knowledge".

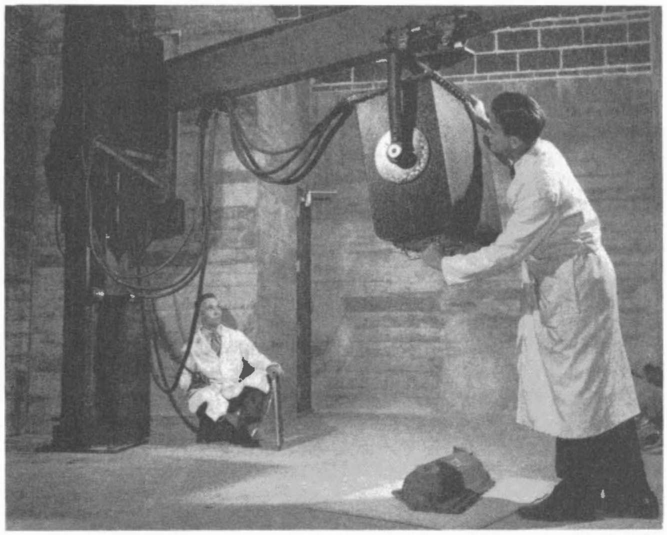
Jointly with the American Foundrymen's Society, R & D was done on the effect of centrifugal casting of light alloys to eliminate much of the machining and cleaning of castings previously required. Three reports were published in the Transactions of the American Foundrymen's Society, Vol. 57, 1949.

An industrial advisory committee on magnesium research was set up in 1945 that included not only industry but also the Armed Forces. Considerable R & D work was done to develop a magnesium alloy particularly for use in the aircraft industry. Such an alloy known as ZK61 containing 6% zinc and 1% zirconium was invented by J.W. Meier who joined the bureau in 1941, and M.W. Martinsen of Dominion Magnesium Limited who worked in the Physical Metallurgy Laboratories. This alloy possessed a high strength-to-weight ratio with corrosion resistance and had good casting properties.

A tragic accident occurred early in 1947 when Hugh Livingstone and Stuart Riopelle were injured, the former fatally. In preparing a magnesium-zirconium alloy, the water of hydration of zirconium chloride had not previously been removed by pre-heating. This water reacted with the molten magnesium to form hydrogen when the zirconium chloride was added to the melt, resulting in an explosion which scattered molten magnesium over a wide area of the foundry. This, it is believed, is the only fatal accident at work recorded in Mines Branch history.



D.A. MacDiarmid subjecting refractory alloy to tensile testing at elevated temperatures



H.J. Nichols positions X-ray head in radiographic examination of metal casting while W.P Campbell adjusts controls (Photo NFB)

Interest in titanium metal and alloys was renewed during and after the war because of the weight saving compared with stainless steels, its resistance to corrosion and creep, and its high melting point. Valuable and reasonably successful studies were made on melting, casting and hot rolling of titanium metal and alloys.

Laboratory equipment that expanded the analytical capability of the laboratories in measuring properties and soundness of metal stock and fabrication as well as studies of microscopic and submicroscopic metal structures such as X-ray diffraction spectrography in 1946 and electron microscopy provided by Defence Research Board in 1949, were constantly being added.

The foregoing is a very brief overview of the work and achievements of the Physical Metallurgy Research Laboratories, which became a division in 1950. Parsons was very proud of these laboratories which he considered the best in the country and amongst the best in the world.

Organization of Physical Metallurgy Research Laboratories

The senior staff of the Metallic Minerals Division concerned with physical metallurgy work as of March 1944 consisted of: Dr. G.S. Farnham: senior scientist, N.B. Brown, Dr. R.L. Cunningham, H.H. Fairfield, S.L. Gertsman, M.H. Haycock, H.V. Kinsey, H.L. Lexier, N.C. MacPhee, J.W. Meier, H.J. Nichols, Dr. G.T. Shaw and Dr. T.W. Wlodek.

Although no precise figures are available, the total staff as of February 1951 was in excess of 100 and the division was the largest in the bureau at that time.

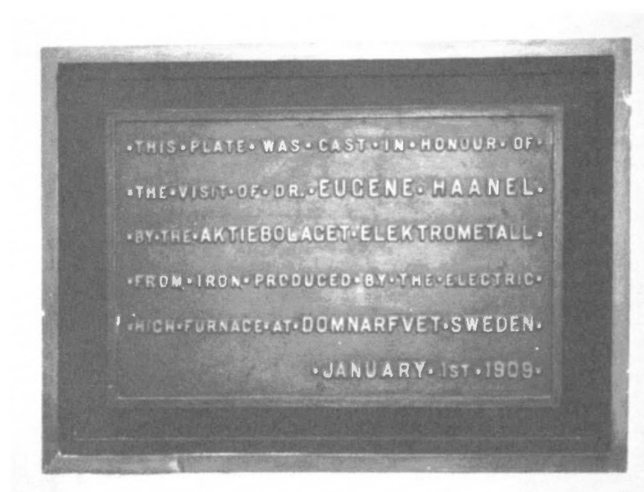
The principal staff of the Physical Metallurgy Research Laboratories was as follows:

Chief - Dr. John Convey
Assistant - N.C. MacPhee
Cast and Malleable Iron - J.E. Rehder
Steel and Steel Castings - S.L. Gertsman
Stainless Steels - T.V. Simpkinson
High Temperature Alloys - H.V. Kinsey, H.H. Bleakney
Non-Ferrous Metals - J.W. Meier, J.O. Edwards
Metal Physics - Dr. R.L. Cunningham
Mechanical Testing - Dr. T.W. Wlodek, N.B. Brown, R.C.A. Thurston
Metal Forming - J.A. Perry
Welding - H.J. Nichols
Sand Laboratory - A.E. Murton
Foundry - M. Feltrin

If it is remembered that all this progress was achieved in ten years, it can truly be said that it was a phenomenal achievement. It is not surprising that on his retirement in 1951 Parsons was specially honoured by the staff of the laboratories by a cast plaque designed by Eric Davis and cast in bronze in the foundry under the supervision of John Edwards, depicting Parsons' head in relief and bearing the following inscription: "In recognition of the work of C.S. Parsons, Director Mines Branch. His constant efforts through these years made possible the construction of these laboratories." On the left and right top corners, the years 1921 and 1951 respectively are given. This plaque is mounted at present in the outer lobby of 568 Booth Street.

It may be appropriate to mention that two other plaques related to the founder of the Mines Branch, Dr. Eugene Haanel, are mounted in the inner lobby of the Physical Metallurgy Division. One bears the words: "Hommage au Docteur Haanel et à sa mission. Fonte obtenue par réduction électrique directe du minerai de fer. Procédé Keller - Usine de Livet - mars 1904". The other plaque has the words: "This plate was cast in honour of the visit of Dr. Eugene Haanel by the Aktiebolaget Elektrometall from iron produced by the electric high furnace at Domnarfvet Sweden January 1st, 1909".

Plaque commemorating work of C.S. Parsons, 1921-51



Two plaques commemorating the work of E. Haanel

Dr. R.L. Cunningham

FUELS

By 1937 Canadian fossil fuels industries had recovered substantially from the sharp cutbacks of the early period of the depression as seen from the table which gives Canadian production data for selected years including the two peak war years of 1918 and 1942.

Canadian Fossil Fuel Production, 1918-1949

Year	Coal (short tons)	Petroleum crude (barrels)	Natural Gas (1000 cu ft)
1918	14,977,926	304,741	20,140,309
1929	17,496,557	1,117,368	28,378,462
1932	11,738,913	1,044,412	23,420,174
1937	15,835,954	2,943,750	32,380,991
1942	18,865,030	10,364,796	45,697,350
1944	17,026,499	10,099,404	45,067,158
1949	19,120,046	21,464,322	60,457,177

To give an indication of Canadian dependence on imports of fuels, the 1949 imports were as follows: coal - 22,800,144 short tons (the peak year to that date was 1948 when 31,726,746 tons of total solid fuels was imported); crude and petroleum products - 94,715,226 barrels (the peak year to that date was 1948 when it was 101,528,078 barrels); and natural gas - 14,511,965 cu ft (this was the approximate volume available to Ontario for some years and was insufficient for the demand). The small exports of solid fuels and petroleum crude and products have not been deducted from these figures.

The concern for Canada's dependence on large imports of oil led to the formation of Wartime Oils Ltd. a federal crown agency under the authority of the Oil Controller whose technical advisor was G.S. Hume of the Geological Survey. This agency was responsible for advancing funds to oil companies to develop increased oil production. Turner Valley was the main producer and most of the additional wells were drilled in that field. C.J. (Pete) Stewart was the manager based in Calgary who continued for several years after the war reporting to Hume, as the responsibility for receiving repayments was transferred to the Department of Mines and Technical Surveys.

Coal

Coal was the dominant energy source during World War II, representing about 60% of the energy source pool. The R & D work on coal was oriented toward extending the use of Canadian coals and cokes and dealing with problems in their utilization.

Resource Evaluation

The physical and chemical survey (P & C) of Nova Scotian seams was conducted in the field and in the laboratory by Swartzman in 1937 and was completed in 1938. Because of the relatively poor storage qualities of the high volatile Maritime coals, additional tests were conducted on this problem and on clinkering in combustion. Special laboratory tests and blending of several seams were done in these studies. Tests were made in 1939 at the CNR storage yard at Coteau, Quebec with mixtures of lime and alum to study their effect on the storage quality of Dominion Coal and was reported in a divisional report: "Report of Investigations of the Carbonization Section" (RICS 134, 1939).

The P & C survey was continued in New Brunswick in 1939 and also in some of the bituminous mines of northern Alberta. Samples from the latter area and those previously collected from the B.C. Crowsnest area were examined in the laboratory. The P & C survey continued in the west until all the mines producing over 10,000 tons a year were covered. A total of 153 reports in the P & C series was published in the RICS or the Fuels Research Laboratories series.

In 1947, under the Bureau of Mines Special Mine Projects, an agreement was entered into with the Yukon Coal Co., an affiliate of Ventures Limited, for mining coal as a substitute for more costly petroleum products for the Elsa Camp at Mayo, which like most of the Yukon was deficient in wood fuel. It was also hoped to develop other coal markets in the Yukon; this agreement provided for an advance of $300,000 by the federal government with a repayment by the company of $2.00 per ton.

A. Ignatieff, who joined the Bureau of Mines that year, was sent to the Tantalus Butte mine near Carmacks on the Lewes River to examine the property and the mining methods proposed by W.J. Dick, well-known mining engineer from Alberta (FRL Report 81). In 1948, Ignatieff visited the property again and collected channel and bulk samples for a laboratory investigation by Swartzman and a spreader stoker combustion test by Baltzer in Ottawa (FRL Reports 108 and 110). He also took part in a combustion test in the hand-fed marine boiler on S.S. Casca, a stern wheeler plying between Whitehorse and Dawson City. The test indicated that in the narrow sections of the Lewes River the reactivity of the coal compared with wood fuel was too low for the sudden demand for steam pressure when the vessel was faced with sudden wind gusts. The Tantalus Butte mine investigation still remains the only one north of 60 latitude of the type applied to coal resources in the southern area of Canada. At this writing the mine is supplying the Cyprus Anvil Mining property with coal for heating and concentrate drying. Random coal samples from the Arctic or near Arctic have, of course, been analyzed from time to time during the existence of the Mines Branch.

A number of consolidated coalfield reports was published in the Memorandum Series under the title "Physical and chemical survey of coal from Canadian collieries......". These were:

"Inverness County Coalfield, Nova Scotia", R.A. Strong et al., MS 74, 1939.
"Cumberland County Coalfield, Nova Scotia", by R.A. Strong et al., MS 78, 1940.
"Pictou County Coalfield, Nova Scotia", by R.A. Strong et al., MS 79, 1941.
"Minto Coalfield, New Brunswick" by E. Swartzman et al., MS 89, 1944.
"Drumheller Coalfield, Alberta" by E. Swartzman and J.H.H. Nicolls, MS 97, 1947.

Yukon field trip by A. Ignatieff, 1948: 1 - Dock and coal stockpile, Tantalus Butte mine, Lewes River; 2 - wood being loaded onto S.S. Casca at Erickson's wood camp; 3 - S.S. Casca and barge of supplies

Until the outbreak of war, laboratory and office work was pursued by Gilmore and his associates on coal standardization and specification and on property testing. Tumbler and drop shatter tests developed by the laboratory for measuring coal friability were written up as tentative standards and adopted by the ASTM. Studies on "capacity" moisture, weathering, ignitability, reactivity and plasticity were made and appropriate equipment was either procured or constructed. The staff worked closely with the NRC in their Associate Committee on Coal Classification and Analysis and Report No. 814 entitled "ASTM Standard Specification for classification of coals by rank and grade and their application to Canadian coals" was published; NRC also published "Specification No. 18-GP-1-1940 for the Canadian Government Purchasing Standards" that provided for regional differences in coal quality. The latter was of assistance to government departments purchasing coal and was drawn up essentially with the help of the Fuels Division.

The coal laboratory acted as analysts to several federal departments including National Defence, Munitions & Supply, Justice, Pensions and National Health, Transport, and Public Works. Solid fuel samples on the average accounted for about 50% of the total number of samples analyzed by the division, which for example in 1938 totalled 6851 of solid, liquid, and gaseous fuels.

Carbonization

Coal carbonization R & D was vigorously pursued up to the war. The two 500-lb ovens were used in evaluation, presumably because of the expense of conducting tests in the 2-ton byproduct coke oven and because the smaller units gave results that were comparable. Work included tests at mid-temperatures of about 500°C on coals that were not acceptable to the high-temperature industry to determine the possibility of producing satisfactory domestic coke.

A large-scale test carried out at the Hamilton By-Product Coke Ovens Limited established that a blend of about 35% Canadian coal - Dominion, Nova Scotia - with 65% imported coal would produce a satisfactory metallurgical coke.

The expansion property of Michel and of other coals of the Crowsnest area was a source of difficulty due to possible damage of the heating sidewalls in slot-type coke ovens. This problem occurred at the Winnipeg Electric Company's plant mentioned in Chapter 4. Blending with non-expanding coals eliminated the problem. An extensive test program was carried out in the Fuels Laboratory that included the use of a bottom or sole-heated "Bethlehem" coke oven. Later in 1949 this test oven procedure was standardized as in Appendix VI, ASTM Standards on Coal and Coke, October 1949. A cooperative program was carried out with U.S.A. laboratories and a meeting was held in Johnston, Pennsylvania in 1937. In the same year a test of Michel coal was conducted at the Radiant Fuel Corporation plant of West Frankfort, Illinois, in sole-heated "Curran Knowles" ovens in which the Mines Branch carbonization group participated. The Crow's Nest Pass Coal Company, Limited decided to expand its domestic coke market which had hitherto been supplied by the company's beehive ovens. A battery of 10 Curran Knowles byproduct ovens was built at Michel in 1939. The Curran Knowles process was satisfactory for expanding or swelling coals. Coking temperature was about 1000°C as used in high-temperature slotoven coking, but the coke was not of uniform property, the upper layers resembling the low-temperature carbonized product suitable for a domestic coke. The main byproduct was a coal tar high in creosote content and suitable as a wood preservative. Nevertheless the company was able to develop a market for its coke in the low shaft lead smelter at Trail, B.C. The guidance and assistance given by the Fuels Division, particularly by Burrough, was acknowledged by the Crow's Nest Pass Coal Company.

The New Brunswick coal producers pressed for studies of coking coals for the domestic market. In 1940 a carbonization test was carried out at the small Curran Knowles installation at Owen Sound, Ontario, which supplied the needs of the city and the surrounding country for city gas and coke. Two carloads from the Minto and Avon coal companies were crushed and cleaned by air table at the Fuels Research Laboratories in Ottawa. A satisfactory coke, despite a high sulphur content, was produced. (Report of Investigations of the Carbonization Section No. 148 by Strong, Burrough and Swartzman). A related combustion test was conducted in a domestic water heater in Ottawa by Malloch and Baltzer on the Owen Sound coke and the results compared favourably with anthracite. The tests are described in the appendix to Report 148.

The salient features of the Canadian carbonization and city gas industry and of the nearly two decades up to World War II of the Fuels Division carbonization program may be summarized for the sake of clarity as follows:

(1) The program was essentially oriented to enlarge the use of Canadian coal transformed to coke, particularly for the large household, institutional and commercial heating markets in urban centres of Quebec and Ontario and to some extent in Manitoba, which relied on the importation of American anthracite as a smokeless fuel.
(2) Until 1923, Halifax and Vancouver were the only city utilities that used Canadian coal. All others were using mostly U.S. bituminous coal which was readily available by lake transportation and at a reasonable price.
(3) The main product of city utilities was gas with a heating value of 500 Btu with coke as a byproduct, mostly produced in slot or wall-heated byproduct ovens. High temperature carbonization at about 1000°C produced more surplus gas and less coke and tar oils than low temperature carbonization at about 500°C.
(4) Low temperature carbonization possessed the advantage of producing a more ignitable or reactive coke. Disadvantages were that although the gas had a higher heating value, yield was only about 50% and it produced about one third more tar oils, which in the raw state was priced only as fuel oil.
(5) Haanel and Gilmore conceded in 1937 that low temperature carbonization in terms of successful European processes like Illingworth, Lurgi, etc., was not applicable to Canadian conditions. However, they indicated that the laboratory and large-scale tests carried out in Ottawa and in the industry were responsible for an estimated annual increase of 300,000 tons in the use of Canadian coals by the gas utilities (79).
(6) Their views were expressed before the first battery of ten Curran Knowles sole-heated ovens were installed at Michel, B.C., which in effect produced high-temperature coke at the sole and low-temperature coke at the upper layers of the oven. In any event, the process satisfied one of the requirements that Haanel and Gilmore considered important for low temperature carbonization: a lower capital cost compared with conventional slot byproduct ovens. Moreover the oven was suitable for the expanding coals of the area.
(7) As far as classical high temperature carbonization for metallurgical coal was concerned, the large steel companies of Ontario at Hamilton and Sault Ste. Marie were using U.S. bituminous coal, some of it from their own mines, for quality and cost preference. Exceptions were Dominion Iron and Steel Co. which used its own coal for making coke for its blast furnaces and the Crow's Nest Pass Coal Co. Ltd., producing coke for nonferrous smelting and other industries. It should be remembered that, until the latter part of the period under review, iron ore was also imported.
(8) After World War II, the rapid growth of the Canadian petroleum and natural gas industry virtually caused the demise of the domestic coke and city gas industry, as distinct from the metallurgical industry.

At the outbreak of World War II many of the peacetime projects had to be curtailed. Staff had to be used on wartime assignments, many of them in a consulting capacity because of the scarcity of expertise on fuels.

A study conducted principally by Burrough was made on activated carbon for use in gas masks. A large laboratory-scale activator was constructed in which different raw materials were tried that included coconut shells, peachnuts and selected coals; the best results were given by char made from coconut shells carbonized in hardwood distillation ovens.

Other wartime studies were concerned mostly with investigations and advice related to metallurgical coking and gas coals. Reactivity of beehive and byproduct coke was studied as well as weathering, freezing and thawing incident to the storage of coal. At the request of the Department of National Defence, recommendations were drawn up for correct coal handling.

Beneficiation

Degradation due to increased mine mechanization of high rank coal produced in the steam mines of Western Canada for the railway market revived interest in briquetting during the war. Coal operators installed briquetting plants including one employing a binderless high pressure process. Staff shortage in the Fuels Division postponed research on these coal fines until the end of the war, and by that time the problem had become even more pressing. However, binderless briquetting was investigated on Onakawana, Ontario lignite with encouraging results. A satisfactory procedure for preparing cement-bound blocks from coal fines was worked out for the Department of National Defence.

Also during the war, laboratory-scale briquetting tests of non-fuel minerals such as sodium sulphate, chromite ore mixtures, fluorspar concentrates, dolomite and ferrosilicon mixtures were undertaken at the request of other divisions of the branch or of the Metals Controller.

Because of the requests received, an extensive program of beneficiating products of degradation produced from low-rank coals and coke was carried out in preparing briquettes particularly of the smokeless or carbonized variety. A standard Komarek-Greaves two-pocket roll press with a capacity of about 1-1/4 tons per hour, together with binder preparation and mixing equipment was installed in Ottawa and this equipment was in great demand for about ten years. An extensive study was made in 1946 of the briquetting characteristics of the readily weathering low-rank coal from Pond Inlet, Baffin Island, which the administration of the Northwest Territories requested. The investigation was to determine whether a suitable briquetted product that would handle and store well could be produced as a substitute for United States anthracite that was being distributed in the Territories at a very high price. Two reports were prepared by Swartzman - FRL Reports No. 38 and 64. All of this briquetting work was carried out by Swartzman, who was also responsible for the preparation, crushing, sizing and cleaning in the division. In 1945 and 1946 he investigated the heavy media process and particularly the Driessen Dutch State Mines cyclone as an improved fine coal cleaning method.

The first petrographic studies of an elementary nature were commenced in 1943 as a tool for identifying the constituents of coal and thereby assisting separation and predicting coal utilization. Such studies were first made on coals from Nova Scotia and New Brunswick.

In 1951 Dr. Jan Visman of the Dutch State Mines, after meeting Gilmore at the 1950 International Coal Conference in Paris, elected to emigrate to Canada. In the light of increased mechanization in Western high rank coal mines giving rise to excessive fines coupled with high ash content of the mine run product, interest was developing in new cleaning methods. After a short stay in Ottawa Visman was posted to Calgary where he opened an office and an adapted laboratory.

Combustion

The combustion program in the period before World War II paralleled the carbonization program in its objectives to promote the burning of Canadian solid fuels, particularly in the domestic, institutional and commercial fields. A report was published in 1938 on a second series of tests of 45 coals, raw and briquetted, carried out between 1935 and 1938 in the same furnace as used in the first series. These were compared with the U.S. anthracite which was somewhat better in quality than in the preceding series (MB Rep 802; Baltzer and Malloch; 1940).

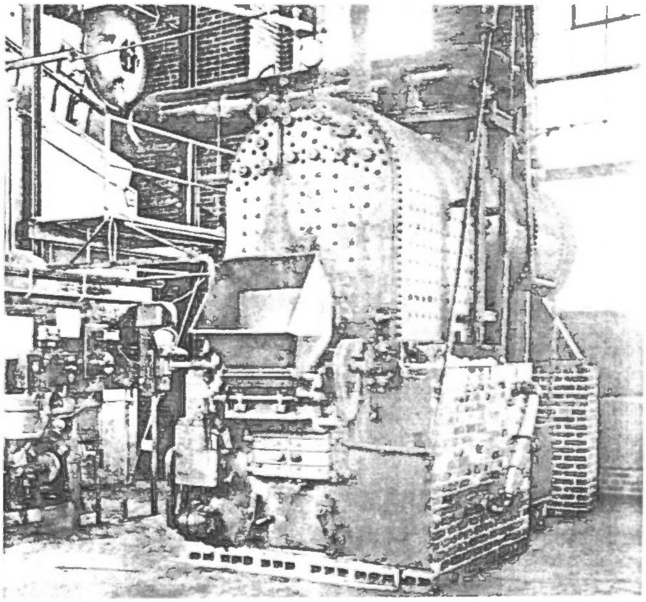
Furnaces for space heating of institutional and commercial buildings and some large dwellings were increasingly fitted with stokers and used forced draft. The first recorded test with the stoker in the Fuels Division dates to 1931 when an array of low-grade solid fuels, i.e., Onakawana lignite, peat, bituminous coal slacks, Welsh anthracite "buckwheat", and coke breeze were compared with a standard operating coal as used in previous pulverized fuel tests, both with and without preheated air, in a temporary installation of a locomotive-type boiler with Pyramid grates. The fuel was fed by hand or by Reco spreader stoker. Taking into account the difficult fuels and that conditions for the tests were not the best, the combustion results were encouraging. "Boiler tests on coals and other solid fuels: Part II. Results of 28 hand and stoker fired boiler trials made with various fuels on a patented grate". E.S. Malloch and C.E. Baltzer (MB Rep 725-3, 1933).

In 1935 and 1936 the domestic water heater furnace was equipped with "blower" equipment and tests were done on various Canadian coals, peat, coke fuels, and coarse and fine Welsh anthracite. A second series compared Nova Scotia coals fed into the furnace by an underfeed stoker. A third series reverted to hand-fed coal and coke.

The relative efficiencies of European and Canadian wood and wood waste burning stoves were evaluated in 1937 and 1938 in cooperation with Forest Products Laboratories. A sawdust unit was attached to a domestic hot water boiler and tests were made.

Several series of domestic hot water furnace tests were carried out for the NRC from 1938 to 1940. The experience gained over a period of more than ten years in evaluating contrasting fuels, mostly solid, in the domestic heating area was recognized by the NRC, which itself was testing domestic oil furnaces in its Fire Hazards Laboratory. NRC invited Malloch and Baltzer in 1939 to join the Associate Committee on the National Code as well as the Canadian Engineering Standards Committee. In 1942, the combustion group was invited to be represented on the NRC Associate Committee on Substitute Fuels for Mobile Internal Combustion Engines that included a sub-committee on producer gas.

With the outbreak of war, tests were turned to a greater degree to the least smoke-producing Canadian substitutes for Welsh or American anthracite such as admixing non-caking Canadian high volatile coals with non-clinkering buckwheat size of Canadian semi-anthracite. Work was also done on various solid fuels in station-type stoves for use in military hutments and



Experimental locomotive-type boiler, for testing peat, lower grade lignite and coal screenings other establishments of the Department of National Defence. Two series of tests were made in 1941, with mixtures of Onakawana lignite and bituminous coal on the locomotives of the Temiskaming and Northern Ontario Railway. In 1942, the chemical treatment of "blower" coals to produce an easily removable clinkering ash residue was patented and made available to the public.

Data on recording the degree days which is useful for estimating heating load were started for the city of Ottawa before the war but were extended to 45 additional representative cities during the war. These were made available to the Coal Administrator's Office. The service was terminated in 1947 when the Department of Transport Meteorological Service started the publication of these data as part of the weather service.

By 1942 there were five officers from the Fuels Division on part time assignment to the war agencies and one senior engineer with the Coal Administrator in the Department of Munitions and Supply full time as well as another officer with the Oil Controller; two more were working on strategic mineral projects at the branch level. With so many of the key staff seconded to advisory roles for the war effort, the laboratory and field activities were, of course, substantially affected. The staff had to undertake work outside their own specializations; thus Swartzman in addition to his usual work on coal preparation undertook studies on combustion.

After the war the Canadian coal industry was anxious to introduce wider use of small household stokers. In 1947 a cooperative agreement was entered into with the newly formed Stoker Institute of Canada and the Bituminous Coal Research (BCR) of Pittsburgh. Over 50 stokers were evaluated in Montreal, Toronto, Hamilton and Windsor. The BCR-2C smokeless heater using bituminous coal was investigated and several tests were carried out by the group.

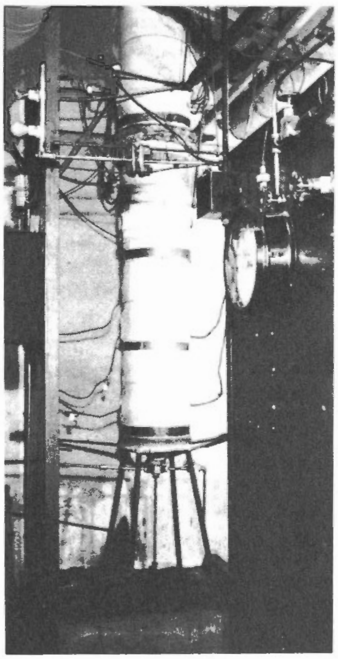
In 1946 the Locomotive Development Committee of BCR started a project to develop a coal-fired gas turbine. The salient feature of this system was that the turbine blades were not exposed to the erosive action of ash and solid particles carried over in the combustion gases as is the case with the direct-cycle turbine. This innovation, known as the exhaust-heated cycle, claimed up to one third less coal consumption than the standard coal-fired locomotive, no water requirement, and increased power in cold weather.

At first there were several United States laboratories and organizations involved in this project: Battelle Institute, Institute of Gas Technology, American Locomotive Company, and Northrop Hendy. Probably because of the lack of support from the U.S.A. railroads, due to their comparatively advanced diesel locomotive program, the project was eventually promoted in Canada where the railways, particularly CPR, supported the concept but did not contribute to its cost.

The initial role allocated to the Fuels Division was development of the pressurized pulverized fuel combustion. Warren was placed in charge of this project and by 1947 an experimental combustor was fabricated. The research had other implications in terms of studies of the mechanics of fluidizing, carbonization and oxidation of coal. Dr. D.S. Montgomery, who joined the division in 1948, carried out his first research project on the effect of pressure on the combustion rate. Later, research was done on the effect of ultrasonic energy on the burning rate which showed the rate was diffusion controlled and that it could be increased by turbulence using smaller combustion volumes. The latter was produced by a high intensity ultra sonic machine generator which was harmful to hearing. In later years the positive effect of turbulence was demonstrated in the combustion laboratory of the Mines Branch by using a swirl. A vortex combustor operating at atmospheric pressure was constructed and tried out with coal from the Pittsburgh No. 8 seam chosen by the cooperative laboratories for the project. Later, a series of 20 Canadian coals was tested in the combustor designed for the project that was eventually carried out at McGill University. In addition to Warren and Montgomery, others involved in the initial stage were H.P. Hudson, J.C. Mulligan and D.J. Robertson. By 1950 it was decided to enter into another agreement with McGill to construct and operate a demonstration plant employing a 500-hp aero turbine engine at its Ste. Anne de Bellevue Gas Dynamics Laboratory, the project being directed by Dean D.L. Mordell.

Hydrogenation

Between 1933 and 1940, Warren assisted by Bowles, carried out a comprehensive hydrogenation program on Canadian coals in a continuous process employing a 10-litre reactor operating usually at about 3,000 psi. The reactor stood on three legs to allow stirring the reaction liquid by hydrogen bubbles. The catalysts used were inorganic mostly stannous oxides. This plant was used later in the war and post war in the early experiments with Alberta bitumen. A report on the research was published in 1940 (80). It may be of interest to record the estimated yield of gasoline from the various materials treated - Canadian coals of various ranks, peat, oil sands bitumen, an American coal,



Ten-litre reaction chamber in hydrogenation pilot plant, 1938 (Photo, K.W. Bowles) and a coal from Yorkshire being used in the Bergius plant at that time operated by Imperial Chemical Industries (ICI) at Billingham, England.

Estimated yield of gasoline from various coals and other raw material, 1940
(Imperial gallon per short ton)

Material hydrogenated	Classification of coals and other material	Gal
Bitumen from McMurray, Alberta	Bitumen	194
Sydney, Nova Scotia (Princess mine)	Bituminous high volatile A	143
Pittsburgh, Pa (Bruceton)	Bituminous high volatile A	129
Durham County, England	Bituminous high volatile A	121
Nicola Valley, B.C. (Middlesborough)	Bituminous high volatile B	121
Vancouver Island, B.C. (Comox)	Bituminous high volatile A	112
Crowsnest, B.C. (Michel)	Bituminous medium volatile	111
Inverness, N.S. (Inverness)	Bituminous high volatile C	102
Drumheller, Alta. (Rosedale mine)	Subbituminous B	93
Saunders, Alta. (Alexo mine)	Bituminous high volatile C	89
Edmonton, Alta. (Black Diamond mine)	Subbituminous C	78
Bienfait, Sask.	Lignite	68
Onakawana, Ont.	Lignite	50
Peat (Alfred, Ont.)	Peat 30% moisture	59

The demand on Warren's time as adviser during the war terminated further research on conversion of coal to liquid fuel though the hydrogenation high pressure facilities were used for dehydrating Onakawana coal with high pressure steam. It is not surprising that when the hydrogenation program was renewed in 1943 it was continued on the oil sands bitumen. Before leaving the subject of hydrogenation of coal it may be worth recording that both Camsell and B.F. Haanel in the 20's referred in their respective reports to the developments in synthetic liquid fuels in Germany. Hence, Warren could rely on the initial support from the deputy minister's level for research which would be costly in equipment and demanding in time.

Mining

The first reasonably comprehensive survey of mining methods by staff members since J.G.S. Hudson's time was undertaken by Ignatieff in 1948 and continued with Brown and Casey in 1950. The object of this survey was to determine the influence of mechanization on the quality of coal produced. On visits to various coal mines in Canada and United States, in the latter case particularly to coalfields that resembled Canadian conditions, the general conclusions were that the geological and mining conditions were more severe in Canada, particularly in the mountain regions of the west. This limited the possibility of applying mechanization, as most U.S. machines were designed for flatter and thinner seams. Furthermore, many of the mountain deposits were subject to sudden outbursts of gas and coal which became the subject of study later. Another conclusion of the survey was that where the conditions approximated those in the United States, the productivities were comparable (81). The mining research and inspectorate centres of the U.S. Bureau of Mines were visited as well as the Gorgas mine in Alabama which was then the U.S. experimental site of underground gasification of coal. "Underground gasification of coal - Review of progress" by A. Ignatieff (CIM Bull; pp 599-605, Nov. 1949). In situ gasification was of interest to Canada at that time. The Joggins, Nova Scotia coalfield with thin and high ash seams was tentatively selected for gasification experiments. Swartzman wrote a report on this (FRL Report 19, July 1945). However, it was recognized that any demonstration test would require substantial funds which could not be made available.

The provincial ministers of Mines commenced their annual meetings in 1945 and at one of the earliest meetings, the coal committee of the conference identified the problem of certification of Canadian-made explosion-proof electrical equipment for use in mines. Ignatieff prepared a report on a proposal to establish a certification laboratory (FRL Report 134, 1950).

The mining section can be said to date from 1950 when the first field group commenced studies on the sudden release of stress in the Crowsnest area coal mines. F.L. Casey had joined Ignatieff in 1948 by transfer within the division, and A. Brown joined in 1949. T.S. Cochrane was appointed in 1951, taking up his residence at Blairmore, Alberta, and in the same year H. Zorychta joined the group as resident engineer in Fernie, B.C.

A Royal Commission of Inquiry on the coal industry of Canada under the chairmanship of Justice N.F. Carroll was set up in 1944 to ascertain the various marketing and technical difficulties experienced by the industry. Staff members of the Bureau of Mines and of the Geological Survey provided specialist information.

Dr. B.R. MacKay of the Geological Survey revised the estimates of coal resources of Canada to one tenth of the 1913 figure of approximately one trillion tons. The Fuels Division technical personnel prepared a considerable number of written briefs to the Commission and attended many hearings. The main outcome of the Commission was the creation of the Dominion Coal Board by the Act of 1947 as an agency separate from the Department of Mines and Resources, first reporting to the Minister of Resources and Development, later to the Minister of Trade and Commerce, but in 1951 to the Minister of Mines and Technical Surveys. The first chairman was W.E. Uren, succeeded by G.L. McNaught and then by C.L. O'Brien, who retired in 1968. For a year or so before its dissolution in 1970 the Board was composed of members of the department. The Coal Board regarded the Fuels Division as its principal technical adviser and relations were close and cordial, largely due to a continuity provided by the service of C.L. O'Brien who had 12 years with the Dominion Fuel Board from 1935 to 1947 and 21 years with the Dominion Coal Board from 1947 to 1968. It will be recalled that O'Brien had also seen service in the Mines Branch from 1926 to 1935.

Peat

Following the abortive efforts at the Alfred peat bog in the late 20's to demonstrate the possibility of using peat fuel as a source of energy, a few tests comparing peat with other solid fuels were conducted in the Fuels Division as mentioned earlier in this chapter in the combustion and hydrogenation programs.

After termination of peat surveys by von Anrep in 1932 at the Geological Survey, the responsibility for maintaining an interest in this resource was transferred to Leverin in the Mineral Resources Division. After his retirement in 1945, the responsibility was returned to the Fuels Division with Swinnerton being the officer in charge of the surveys and of laboratory tests. This work was taken over by T.E. Tibbetts when Swinnerton retired in 1958.

Leverin reported that between 1932 and 1936 the average annual production of peat fuel was 1788 tons from two bogs at St. Alsemne, Quebec, and Morewood, Ontario. Peat fuel was used as fuel and fertilizer filler.

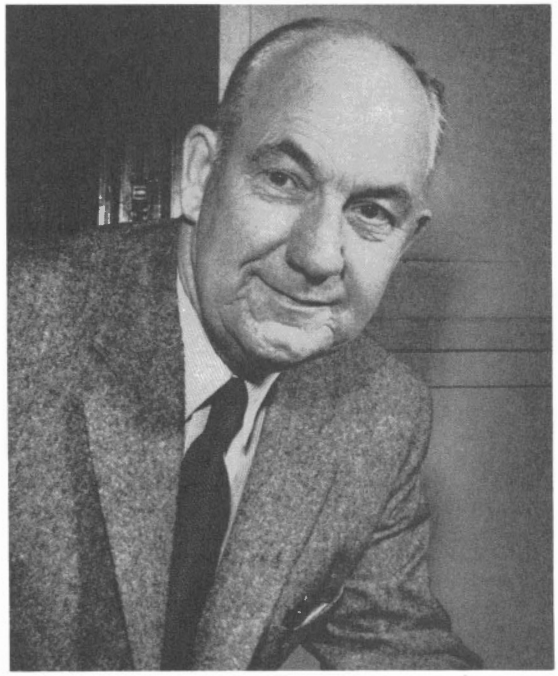
Production of peat moss on the other hand was developing into an industry. In 1937 there were ten bogs located across Canada with the exception of the Maritimes. There were no exact figures on production but in the period from 1932 to 1936 there was an average annual export to the United States of 1513 tons. Peat moss was being used for litter, humus, soil conditioner, insulation and packing. At the outbreak of the war a demand developed from the United States because of interruption of imports from Europe. In 1940, at the request of the Department of Mines of New Brunswick and Nova Scotia, Leverin carried out a number of bog surveys. In the same year he made a special investigation of the peat moss deposits in Temiscouata County, Quebec, for the Department of National Defence with special reference to proposed use of peat moss in the manufacture of munitions. Leverin before he retired prepared a final report (82) preceded by a series of regional reports published in the Memorandum series from 1940 to 1943.

Swinnerton reported for 1944 that the Canadian production of peat moss had risen to 63,149 tons valued at $1,554,606 from 32 plants. Swinnerton published in the Memorandum series a report "Peat moss industry in Canada" (Report No. 90, Engl or Fr; 1946, and Report 107, Engl only, 1950). He brought these reports up to date in the new Mines Branch publication series of Information Circulars (83).

Oil Sands

Based on prior hydrogenation research in the Fuels Research Laboratories, Warren prepared two reports in 1941 "Yield of gasoline by hydrogenation of various Canadian raw materials" and "Cost of a hydrogenation plant for production of aviation base stock from Alberta bitumen" for the NRC Committee on Substitute Fuels and for the Oil Controller. The discussion that followed resulted in the inauguration in 1942 of an R & D program of bitumen separation and refining that has been pursued by the fuels group up to the present.

Because of the historical and national importance of the program, it is worth recording that there was an interval of three years between conclusion of experiments on coal hydrogenation and the decision to concentrate on a comprehensive program of bitumen hydrogenation. Thus in the annual departmental report for



A.A. Swinnerton (photo by Newton)

the fiscal year ending March 31, 1940, the statement is made "The work on the hydrogenation of coal was discontinued to make way for investigations of more immediate wartime importance" (p 53); in the departmental report for the fiscal year ending March 31, 1943, it is stated "Further experimental work on the high-pressure processing of Alberta bitumen by both liquid and vapour phase hydrogenation as a source of aviation gasoline and other petroleum products was begun" (p 56).

The laboratory-scale research consisted of both liquid- and vapour-phase treatment of bitumen using the 10-litre reactor pilot plant mentioned earlier in the coal section that produced an oil with a sulphur content reduced from 5% to 2% in the first step and a gaseous product that was made in the second step having a sulphur content of only 0.02% sulphur. This result encouraged Warren and he made improvements to the liquid-phase apparatus which gave a high yield of recoverable oil product. Numerous liquid-phase catalysts were tested. Distillation equipment was developed for separating the liquid-phase product into a recycled fraction and a feedstock for hydrogenation in the vapour phase. Optimum temperature and catalyst durability were also tested in the vapour phase. The distillation equipment was improved for accurate fractionation of gasoline and gas oil: "Hydrogenation of Alberta bitumen Part I. Preliminary report on production of low-sulphur gasoline" by T.E. Warren and K.W. Bowles (Fuels Div. Rep 1943) and "Hydrogenation of Alberta bitumen liquid- and vapour-phase experiments" by K.W. Bowles and T.E. Warren (ERL Rep 96, 1948).

During the period that these laboratory-scale tests were being undertaken, W.J. Dyck evolved a rapid laboratory and field method for the determination of bitumen content in the sands (Memorandum Series 87, 1944). A study was also undertaken on the estimation of the large and intractable asphaltene component of the bitumen. An ultimate analysis of the bitumen was determined to prepare a flowsheet for converting bitumen to gasoline, the main aim at that time. Some experiments and calculations were made for the in situ thermal recovery of oil from bitumen.

The first recorded experiments were made in the Bureau of Mines' Fuels Division in 1943 in cooperation with the Dorr Company, for removing mineral matter by settling from the separated bitumen. It should also be noted that in 1945 the Ore Dressing Laboratory carried out a laboratory-scale investigation wherein the "cold water" method was apparently used for the first time. (Investigation No. 1917 Metallic Mineral Div., H.L. Beer, 1945).

All this research activity took place between 1942 and 1945. Meanwhile discussions were being carried on with the NRC and U.S. Bureau of Mines as well as with the Department of Public Works which related to the setting up of a pilot plant that provided for a separate building. The decision to proceed was postponed in 1945 when Warren spent 2-1/2 months in Germany under the auspices of the Department of Reconstruction and Supply inspecting four Bergius installations (two-step conversion of coal by hydrogenation from the liquid phase) and six Fisher-Tropsch installations (liquid fuels from synthesis gas produced from complete gasification of coal). Warren obtained useful information which was recorded on microfilm. Specifications and a list of parts for the proposed plant in Ottawa were revised in the light of the information gained by Warren in Germany. The Bergius hydrogenation pilot plant referred to in the foregoing was to be located in a separate building on the present site of the Geological Survey but this plan was never implemented and smaller-scale equipment was installed on the northwest side of the Fuels Building at 562 Booth.

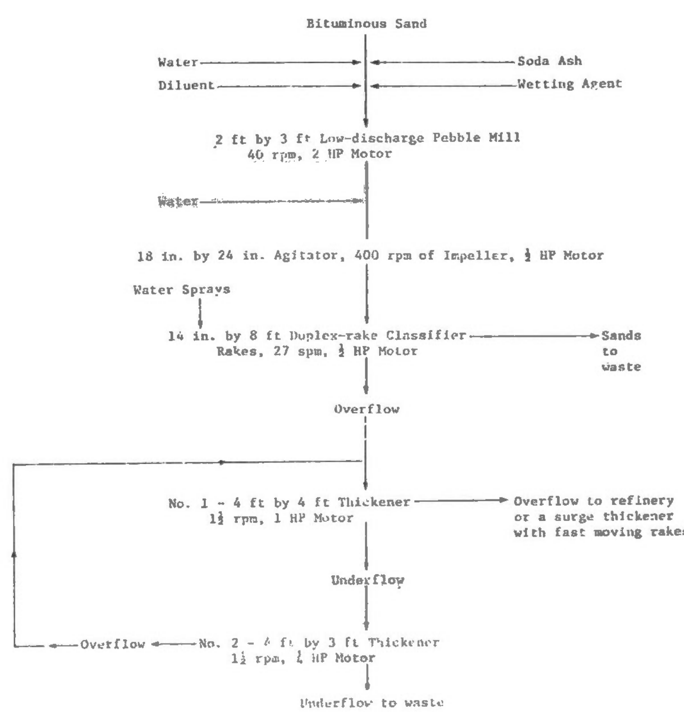
Discussions were held in 1946 with the U.S. Office of Synthetic Liquid Fuels which was embarking on a large-scale development project of coal hydrogenation. By tacit agreement with that office and the U.S. Bureau of Mines, the Canadian effort was to continue the work on the oil sands bitumen whereas the U.S. effort would be on coal. To permit the use of active catalysts in contact with catalyst poisons: sulphur, oxygen, and nitrogen in the asphalt materials, it was decided to remodel the hydrogenation plant so that high pressure could be employed. Design was started on equipment capable of operating up to 20,000 pounds per square inch, and later contracts were let for the construction of chromium-plated high-pressure vessels. A field study was made in 1946 in Western Canada on the possible use of natural gas as a raw material for the production of synthetic gasoline and other products by a modified Fisher-Tropsch process.

An investigation was made to demonstrate on a larger scale the possibility of separating bitumen from the sands at room temperature. This was done with the aid of kerosene as a recoverable dilutent in an amount equal to the bitumen content of about 15% by weight and some general conclusions were drawn. These were that consistent and complete recoveries could be made, that a clay content up to 10% would not hinder separation, and that samples of oil sands from different locations had substantially the same composition from a refining viewpoint. A pilot plant was set up in 1948 employing ball milling, centrifugal agitation and rake classification to separate bitumen using water at 70°F. The idea was to combine this research with the further refining treatment of the separated bitumen to produce a "synthetic crude" that could be piped from McMurray to Edmonton. The separation step was carried out in a hut on the site of the present Technical Services Division on a cooperative basis with the Mineral Dressing and Metallurgy Division. L.E. Djingheuzian, who had just joined the Bureau of Mines, worked with Warren, Montgomery, F.L. Booth (1945 -) R.E. Carson (1945 -) and W.H. Merrill (1947 -) in the hydrogenation group. Some 90 barrels of good-quality bitumen were produced. This material was dehydrated and coked, in which work Burrough assisted. (A study of cold-water separation of bitumen from Alberta bituminous sand on a pilot plant-scale by L.E. Djingheuzian and T.E. Warren, Can Journal of Technology, vol 29, pp 170-189, April 1951). To advance the scientific knowledge of the separation process, Montgomery carried out a study of the surface properties of the oil sand constituents as well as of surfactants.

Following the separation work, desulphurization experiments at relatively low pressures were carried out in 1950-51 on the coker distillate referred to earlier in a small-scale pilot plant designed and constructed by Warren and his hydrogenation group. The R & D work was continued under Montgomery (see Chapter 6).

During the war two potentially important projects in oil sands were managed by the Mines and Geology Branch of the department, in which the Fuels Division was involved.

The department made an agreement in 1942, first with Cominco on a non-profit basis, but later with



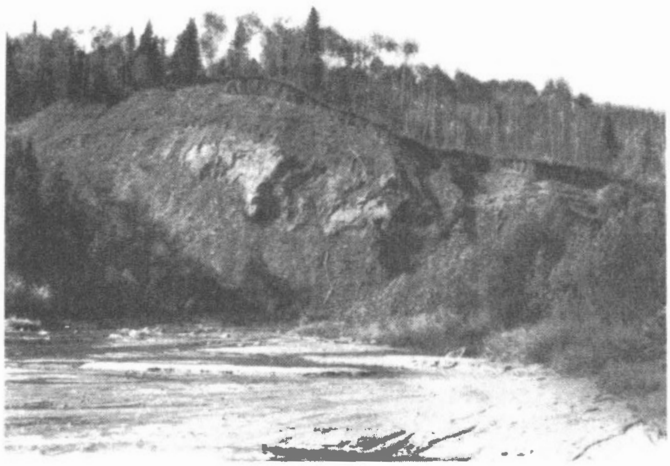
Final flowsheet for cold-water separation of bitumen from Alberta bituminous sands (Can Journal Technology)

Boyles Brothers to carry out a drilling exploration program of oil sand areas north of Fort McMurray close to the plant of Abasand Oils Limited owned by Max Ball. The probable aim of this "demonstration" project if the bitumen grade were found to be economically satisfactory was to have produced sufficient sand for a large-scale test of separation and refining to be undertaken in the Abasand plant.

The areas investigated were Wheeler Island, Steep Bank River, Horse River Reserve, Muskeg River, Mildred and Ruth Lakes. Over a period of four years the total number of holes drilled was close to 250, totalling nearly 50,000 ft. The best results were recorded in the Mildred-Ruth-Eight Lakes area. H.A. Graves, who joined the Bureau of Mines in 1947, monitored the drilling for a period. Assaying of the almost 3700 samples was done in the Fuels Division, in large part by Chantler and Seely, the project being supervised by Swinnerton. The approximate cost of drilling was $700,000. The project was discontinued due to exhaustion of funds early in 1947. A complete report with drilling and sampling records and charts was published in 1949 (84). An addendum was published in 1964 by Bowles and Draper (MB Rep TB 62, 1964).

The second project was connected with the agreement in 1943 for the government to take over the Abasand plant for operation as a pilot plant for testing methods of extracting the bitumen from the sand and "in the production of such products as asphalt, road oils and diesel fuel and in obtaining operating cost data". The plant required remodelling and the General Engineering Company was hired for this work. The projected daily throughput was 600 tons and a total of $850,000 was allocated for the expenditures involved.

Drilling for bituminous sand in the Steepbank area, Alberta



Outcrop of bituminous sand

Blasting bituminous sand at plant of Abasand Oils Limited, McMurray, Alta.

The separation plant was completed and the refinery was under construction when the plant was nearly entirely destroyed by fire on June 6, 1945. The cessation of hostilities and the petroleum discoveries of the late 1940's that followed terminated the federal interest in this enterprise.

Oil Shales

At the suggestion of the New Brunswick government, an exploration drilling program was carried out in 1942 in Albert and Westmoreland Counties of New Brunswick. The agreement between the provincial and federal governments was to fund the project on a 75% federal contribution and a 25% provincial contribution, totalling $50,000. The project was managed by the Mines and Geology Branch with assistance from Fuels Division, notably Swinnerton.

Forty-three holes were drilled in the Rosevale and Taylor Village area of Westmoreland County. These indicated about 100 million tons of oil shales with an oil content of 10.6 gallons per ton. This was considered too low to be of economic importance. A report was issued after the war (85).

Petroleum and Natural Gas

Resource work on petroleum and natural gas commenced in the 20's and was continued until the war, on a systematic basis, from all producing provinces but largely from Alberta. A preliminary study was made of sulphur forms in the natural gas, and the study of oxidation of lubricating oil was continued. The war terminated this work. No branch report on the analyses of crudes appeared until 1951 (86). Most natural gas samples were analyzed for helium but no reports were published.

Responsibility for mine air analysis was returned to Fuels Division from Sussex Street in 1937 and J. Moran was reinstalled as the chemist in charge of this work. It will be recalled that he joined in 1916 and retired in 1940. Most of the requests for analysis came from Alberta and British Columbia.

The gasoline survey continued and from 1933, when the annual Investigation Report series of the Division ceased, they were published at the Mines Branch level to 1938 (MB Rep 746 and 764 for 1933 and 1934, and 787 and 794 for 1935-36 and 1937). The surveys were not published during the war but at the request of the Oil Controller were made somewhat more frequently than previously; two reports for that period were published in 1947 (Memorandum Series 93, "Gasoline surveys for seven summers between 1939 and 1946", and Memorandum Series 94, "Gasoline surveys for five winters 1941-42 through 1945-46"; both reports being by P.V. Rosewarne, H. McD. Chantler and P.B. Seely).

The laboratory cooperated with the Canadian Government Purchasing Standards Committee, the NRC Committee on Petroleum, and the Dominion Fire Marshall's Association. It attended to many inquiries from federal departments, provincial governments and the public.

Rosewarne spent most of his time during the war in the Oil Controller's office and Chantler had to carry much of the load, which increased substantially because of the demands of the Armed Forces and of both Canadian and other wartime agencies. It is fair to say that his laboratory with less staff than the Coal Laboratory was always involved in considerable advisory and problem solving work, which probably evoked the remark from Rosewarne before he retired, to the writer that "some inquirers expected a short course on petroleum chemistry on the telephone".

Early in 1940, Warren and his hydrogenation group undertook a special wartime investigation concerned with raising the octane rating of Turner Valley crude oil to make it suitable for aviation and to determine whether this crude could be a source of toluene and other aromatic hydrocarbons for the explosives industry. It was found possible by catalytic reforming to increase the octane number of Turner Valley gasoline making it suitable for aviation use. A method was developed for producing toluene of high purity from Turner Valley, and in an amount large enough that could be used for the manufacture of trinitrotoluene (TNT). A comprehensive survey of Canadian and imported crude oils was conducted in collaboration with the Shell Oil Company and its development affiliate to determine the best sources of toluene. Of the six crudes selected, Turner Valley gave a higher yield than any of the imported oils, and Fort Norman oil indicated a yield equal to the average from Illinois, Texas and Venezuela.

Research was conducted on the dehydration and demulsification of coal tar and certain crude oils, and an apparatus and process were evolved for the continuous dehydration of emulsified products. At the request of the Oil Controller, an investigation was carried out on the dehydration of troublesome water-oil emulsions from the Vermilion, Alberta field, for which efforts were being made to increase output.

Following the Leduc oil and associated natural gas discovery in 1947 the departmental heads in 1948 were of the opinion that some quantified assessments should be made of the natural gas resources of the Prairie Provinces as a prelude to any export to the east. Depletion of reservoirs in southwestern Ontario had caused shortages amongst household and other customers, particularly during the severe winter of 1947-48. G.S. Hume, then director of the Geological Survey, with a lengthy background of work on stratigraphy and petroliferous deposits, together with Ignatieff made up a two-man team for this project and were assisted by officers of the Geological Survey - Dr. J.F. Caley in Ottawa, and by Dr. Helen Belyea in Calgary, as well as by G.E.G. Liesemer of the Alberta Petroleum and Natural Gas Conservation Board in Calgary. The oil companies cooperated in supplying data. A special report of the Geological Survey was published in May 1948 with a supplement in December 1948 that indicated proven and probable reserves in place amounting to 4.3 trillion cubic feet. In 1950 Hume, then the director-general of Scientific Services in the new Department of Mines and Technical Surveys, considered that updating of this estimate should be made. A further full report was published that showed that the reserves in place, both proven and probable, had risen to 6.4 trillion cubic feet. The estimates included Saskatchewan but they were very small indeed compared with those of Alberta (87). In 1952 Pacific Petroleums Limited was anxious to start exporting natural gas to the B.C. coast and United States from the virgin sources in adjoining areas of the Peace River district in B.C. and Alberta. Hume and Ignatieff again combined to bring out a report covering those reservoirs that indicated in situ proven and probable reserves of 2.5 trillion cubic feet of which 1.58 trillion cubic feet were located in B.C. (88).

Organization of the Fuels Division

The organization and principal staff of the Fuels Division as at February 1951 was:

Chief - R.E. Gilmore (B.F. Haanel retired in 1946 with nearly 42 years services and Gilmore was appointed in 1947)
Administrative officer - A.J. Reynolds
Mining - A. Ignatieff, A. Brown, F.L. Casey, T.S. Cochrane, H. Zorychta
Coal Evaluation and Preparation - E. Swartzman
Coal Preparation in Western Canada - J. Visman
Carbonization - E.J. Burrough, J. Botham, G.T. Shaw

R.E. Gilmore

Combustion - C.E. Baltzer, E.R. Mitchell, H.P. Hudson, R.T. Skerry
Solid Fuels Laboratory - W.J. Montgomery, R.J. Young
Peat and Oil Shale - A.A. Swinnerton
Oil and Gas Laboratory - P.V. Rosewarne, H. McD. Chantler, Frances Goodspeed, P.B. Seely, R.J. Offord, R.J. Draper
Hydrogenation and Physical Chemistry Research - Dr. T.E. Warren, K.W. Bowles, F.L. Booth, R.E. Carson, W.H. Merrill
Scientists - Dr. D.S. Montgomery and Dr. Mary Boyd

Blasting Explosives

It will be recalled in Chapter 3 that with promulgation of the Explosives Act in 1920, the appointment of Lt. Col. G. Ogilvie as Chief Inspector of Explosives, and the transfer of J.G.S. Hudson from the Mines Branch to the Explosives Division, this division was given departmental status that lasted until dissolution of the Department of Mines in 1936, the division then becoming a part of the Bureau of Mines in the Department of Mines and Resources. Dr. A.E. McIntyre was appointed chief chemist, with G.B. Frost serving as chemist until he resigned at the end of 1920 and was succeeded by M.C. Fletcher.

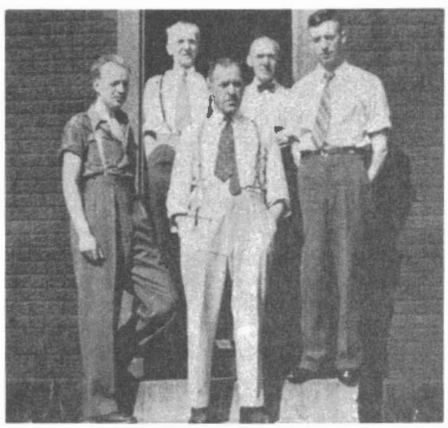
The explosives chemical work and some physical tests were first done in a building on Victoria Street but later in various locations of the city until the retirement of McIntyre in 1931. The chemical work was then transferred to the Oil and Gas Laboratory in the Fuels Building on Booth Street. Campbell undertook this work under Rosewarne until 1937 when the former joined the inspectorate. The work was then taken over by Mohr under Fletcher in a separate building on Booth Street which he described as, "though not being a large building, was the best housing the Explosives Laboratory had since its inception". Mohr transferred to the Explosives Division in 1940. Ogilvie moved to the Department of National Defence in 1936 and was replaced by Lt. Col. F.E. Leach, who had been inspector of the Western Region since 1921.

At the outbreak of World War II, much greater demands were made on the Explosives Division relating to the manufacture of explosive substance required for the war effort. By arrangement with NRC, a new Explosives Laboratory consisting of three separate buildings was built on Montreal Road in Ottawa, The new buildings were occupied in 1942 and the NRC supplied additional staff to cope with the increased demands. All the equipment and instruments were transferred from Booth Street and new equipment such as a ballistic mortar, friction pendulum, chronograph and presses were set up.

An Associate Committee on Explosives, consisting of representatives from the Department of Mines and Resources, Division of Chemistry, NRC, Munitions and Supply, Inspection Board of Canada and U.K. and a number of universities all working on problems of military explosives, was organized to guide the work of the laboratory.

In 1945, Campbell was appointed to succeed Leach who had retired as chief inspector. The Explosives Act of 1920 was revised in 1946, some of the wartime provisions that experience had shown to be desirable being incorporated in the new regulations (Chapter 2).

Lt. Col. F.E. Leach, Chief Inspector of Explosives, 1937-45



Explosives Laboratory staff, Booth Street, 1942; Rear - M.C. Fletcher, N. Randall; Front - D. Downing, C.B. Mohr, R. Gillies.

In 1945 the Department of Transport requested the Explosives Laboratory to investigate the storage and shipment of ammonium nitrate fertilizer or nitraprills, particularly as to the suitability of six-ply paper bag containers as a substitute for metal drums. The NRC convened a conference in 1946 on this subject with representatives of NRC, manufacturers, harbour authorities, Departments of Transport and Mines and Resources. This predated the two destructive explosions of ammonium nitrate that had taken place in 1947 in Texas and France. Three interim reports were issued by the Explosives Division. The general conclusion was that if ammonium nitrate were heated when not confined only a vigorous reaction takes place; on the other hand if the compound is confined a detonation may result.

The Explosives Division transferred to the jurisdiction of the director general of Scientific Services in 1950 following the formation of the Department of Mines and Technical Surveys. At that time the staff of inspectors of explosives was composed of W.P. Campbell, Chief Inspector of Explosives; W.B. Paton, responsible for the Prairie Provinces, British Columbia and the Territories; R.P. Quinn, for Ontario and the north shore of the St. Lawrence in Quebec; H.P. Kimball, for the south shore of the St. Lawrence in Quebec and the Maritimes. The professional staff of the laboratory on Montreal Road was composed of M.C. Fletcher, C.B. Mohr and N. Randall, the last being in charge of physical tests. Fletcher was due for retirement later in 1950 and was succeeded by Mohr. Randall retired in 1952. The laboratory returned to the jurisdiction of the Mines Branch in 1959 and at present is with CANMET.

INDUSTRIAL MINERALS

The Industrial Minerals Division was created as a separate unit with Howells Fréchette as chief at the formation of the Department of Mines and Resources in

W.P. Campbell, Chief Inspector of Explosives, 1945-55.

1936. The new division was composed of three sections: Industrial Minerals by transfer from the former Mineral Resources Division of mineral specialists, the Non-Metallics Laboratory of the Ore Dressing and Metallurgical Division, and by the assignment of staff to the Ceramics Laboratory and Road Materials Section from the dissolved Ceramic and Road Materials Division.

Objectives of the division were:

(1) study of economic characteristics, mining, marketing, and uses of industrial minerals
(2) crushing, grinding and purification of these minerals
(3) solving processing problems in the manufacture of mineral products, particularly ceramic products.

The division moved in 1939 from 541 Sussex Street into the new building that bears the name of Industrial Minerals Laboratories at 40 Lydia Street, now 405 Rochester Street. Carnochan remained with the division until his retirement in 1940; his close chemical associate, R.A. Rogers, joined the chemical group in the Metallic Minerals Division which became responsible for all analytical work other than fuels.

Small-scale testing was done on industrial minerals in the Lydia Street building, but larger-scale purification of these minerals was carried out in the milling laboratory immediately to the south of the main building. However, minerals requiring more complex or larger-scale treatment had to be handled in the Ore Dressing Laboratory of the Metallic Minerals Division. Hence, on Fréchette's retirement in 1945, Parsons was placed in charge of the beneficiation of industrial minerals, with E.S. Martindale acting for Monture as Chief of Mineral Resources Division with responsibility for the mineral specialists who had transferred from the old Mineral Resources Division in 1936 to the Industrial Minerals Division. These included Cole, Eardley-Wilmot, Freeman, Goudge, Leverin, Picher and Spence who continued their responsibilities for the same mineral commodities in which they specialized in previous years.

At the outbreak of World War II activities of the division were oriented almost entirely to the war effort, with emphasis on materials in short supply on the North American continent and on substitutes. Many of the studies were carried out at the request of the Metals Controller, who was responsible not only for metallic but for non-metallic ores. Information was developed for the wartime agencies, both Canadian and allied, and more particularly for the Departments of National Defence and Munitions and Supply. The minerals that received most attention are described in the following review.

Nepheline Syenite

This rock consists of a mixture of the feldspathoid mineral nepheline (a silicate of aluminum and soda) and potash and soda feldspars, together with small amounts of other minerals including magnetite removed by magnetic separation. The resource work on this mineral was Spence's responsibility. A deposit was identified at Blue Mountain in Methuen Township, Ont. about 27 miles northeast of Lakefield. Initial production in 1936 was some 36,000 tons. Several samples of the mineral from Canadian Nepheline Limited, Peterborough and two other sources were examined in the

Industrial Minerals Laboratory. The first test for removing iron was done in the Ore Dressing and Metallurgical Laboratories in 1931 (MB Rep 728, 1932). As a subsidiary of Canadian Nepheline, American Nepheline erected a crushing and processing plant at Rochester, N.Y., to prepare the Canadian raw material for the U.S. market.

This mineral supplanted feldspar in the glass industry. It is now used by the ceramics industry as well as being a filler in the plastics, paint, rubber, and paper industries. Canada is now the world's foremost producer of nepheline syenite. Production is about 500,000 tons of which 80% is exported, mostly to the United States.

Talc and Soapstone

The source of the best talc continued to be Ontario and Quebec. Soapstone for crayons and sculptures came mostly from Quebec. There was an exportable surplus during the war of about 11,000 tons per annum. The peak production for the period was in 1941 when 34,600 tons was produced, about twice the output of former years except for 1930 when it was approximately 27,000 tons.

Spence prepared a second edition of the monograph on talc steatite (massive or lava talc), soapstone and pyrophyllite. During the war, electric insulators were first manufactured in Canada from steatite, these being found particularly suitable for radio and radar equipment. Pyrophyllite is similar to talc but contains much more alumina; because it does not flux when heated it has value for the manufacture of high-grade refractory ceramics and cements. Though there was a reported occurrence of pyrophyllite on Vancouver Island, the important deposit was at Manuels in Newfoundland (89).

The following four paragraphs deal with sources for producing magnesium metal and magnesium oxide for refractories. The resource specialist in this area was essentially Goudge.

Brucite (Hydrated Magnesia)

In his surveys of limestones and related rocks in 1937 and 1938, Goudge discovered what were considered at the time to be the largest deposits of brucite in the world at Rutherglen, Ontario, and Bryson and Wakefield in Quebec. Goudge developed a magnesia and hydrated lime recovery process on a small scale and in 1939 he and the milling section embarked on a large-scale test for extracting magnesia. A preliminary report on the mode of occurrence, treatment and commercial possibilities was published in 1939 (90). The Aluminum Company of Canada set up a plant near Wakefield for the commercial recovery of magnesia granules of high purity for the manufacture of magnesite refractory brick and other uses such as fertilizers. Hydrated lime was a byproduct. The company was assisted by Goudge's expertise. This plant insured that all of Canada's requirements in refractory brick were satisfied and also provided an exportable surplus. During the war Alcan also produced some magnesium metal at Arvida from the brucite operation at Wakefield.

Dolomite

From 1939, large samples of up to 100 tons of surface-mined dolomite from the deposit of Dominion Magnesium Limited at Haley, Ontario, were calcined, crushed and ground as well as briquetted at the Industrial Minerals Laboratory with assistance from Swartzman on the briquetting. There was no advantage in using magnesitic dolomite with its higher magnesium content over ordinary dolomite in this process. This work was carried out in relation to development of the Pidgeon ferrosilicon process at the NRC laboratories. In 1942 the plant was put into operation at Haley and by 1944 had attained 5000 tons of metal per annum. The plant is still the only producer of magnesium metal in Canada with present output being about 10,000 short tons per annum.

Magnesium Silicate

Because of the high content of about 23% of magnesia in asbestos waste rock, which is mainly serpentine, the Metallic Minerals Laboratory in 1942 evolved a method of producing magnesium chloride which was converted to magnesium metal electrolytically, but peacetime economics were not favourable for this method.

Magnesitic Dolomite

Deposits in Argenteuil County of Quebec of limestone high in magnesium content have been worked since 1908 for producing refractory material as lining for furnaces in a variety of thermal processes. Originally, open pit mining was practised but in 1937 Canadian Refractories Limited, the principal company, commenced underground mining at Kilmar. In the same year the company erected a modern, high-temperature tunnel furnace for making magnesite brick. Extensive studies were made in the Ore Dressing and in the Industrial Minerals Laboratories of the Bureau of Mines on methods of purifying the ore. The Ceramics Laboratory assisted in this work with petrographic studies that included polished and thin sections as well as the examination of powdered samples and flotation products.

Potash

The presence of potash in the Malagash salt deposits in Nova Scotia had been noticed. With the outbreak of war and a possible shortage of imported potash, the Malagash mine was sampled and a drilling program was undertaken jointly by the company and the Nova Scotia government in consultation with the Bureau of Mines. The program indicated there were beds of potash parallel to the salt beds, though potassium content was low. A method was under development but not yet commercially applied for the recovery of potash in the form of potassium chloride as a byproduct from the manufacture of evaporated salt. On the other hand, purification of common salt from associated anhydride for "fishery salt" was apparently successful after several years of research. At the end of 1944, a pilot plant was set up by the Department of Fisheries, the Nova Scotia Department of Mines and the Malagash company. Interest in potash shifted in 1946 to the west where 17 deep wells drilled for oil between Elk Point in east central Alberta to Radville in southern Saskatchewan discovered salt and potash beds, the latter being, of course, the important mineral sought for in the East to make Canada self sufficient in potash fertilizer.

Phosphate

It will be recalled that prior to World War II there was some apatite production associated with the mining of mica in the Lièvre River district of Buckingham, Quebec. In the light of the progress made with flotation technique in the concentration of minerals, an attempt was made during World War II to produce a phosphate of fertilizer grade. Small- and large-scale flotation tests were carried out in 1941 to 1943 in the Metallic Minerals Ore Dressing Laboratories on apatite ore from Buckingham. Two five-ton samples of apatite from Frontenac County, Ontario, were submitted in 1944 and 1945 by Ontario Phosphate Industries Limited for laboratory and pilot plant flotation tests. The end of the war terminated the investigations on fertilizers from low-grade sources in Canada.

Mica

At the Metals Controller's request a large number of samples of phlogopite mica from different properties in Ontario and Quebec were tested to determine their heat resistance and possible use in the production of aviation spark plugs. The dielectric strength and power factor were determined on a number of muscovite micas. A study was made for the British Admiralty Technical Mission on the suitability of muscovite for marine compass dials. The Colonial Mica Corporation, purchasing agency of the U.S. government, kept in close touch with the division on all technical aspects of Canadian mica. Several treatment investigations were made for enterprises engaged in mica mining.

Miscellaneous Industrial Minerals

In addition to the foregoing industrial minerals, laboratory and pilot plant investigations were carried out by the division on asbestos, barite, feldspar, fluorite, graphite, gypsum, ilmenite, china clay, bentonite, corundum, garnet, diatomite, quartzite, sandstone, sand, slate, and sericite.

The staff supplemented their knowledge by visiting many of the properties. There was an upsurge of inquiries from prospectors particularly interested in the economics of the prospects. Considerable time was spent in preparing memoranda related to the resources of Canadian industrial minerals for various wartime agencies.

Road and Airfield Material

Prior to the war, Picher spent most of his time surveying local soil and rocks for road improvement and maintenance purposes as well as for the stabilization of road sub-grades, base courses and surfaces (91). The use of sodium and calcium chlorides was studied. Several deposits of gravel and conglomerate were investigated in 1938 at the request of the government of Prince Edward Island (Memorandum Series 101; 1948).

Mine wastes and tailings in northeast Ontario were examined early in 1939 for their suitability in constructing low-cost access roads.

At the outbreak of World War II, Picher's attention was particularly directed to the stabilization of airfield runways. Throughout the war laboratory tests to determine whether stabilization of soils and clays could be achieved with cement were made in connection with military camps as well as for airfields.

Sodium chloride-treated road east of Port Carling, Ont.

At the request in 1941, of the Lands, Parks and Forests Branch, the main highway route through the Cape Breton Highlands National Park was investigated for suitability of local materials for building, improving and maintaining park roads. The use of gypsum and anhydrite for improving stabilization was also investigated. In the same year samples of gravels used in the Banff and Jasper National Parks were tested.

At the request of the Naval Service in 1942, field work was carried out in the Maritimes with gravel for making "plastic armour". This was composed of cemented aggregates mounted on iron sheets and was used for protecting personnel in exposed parts of merchant ships from enemy attack by small calibre weapons. Samples of stone and gravel were tested as ballast on eastern lines of the Canadian National Railway, and a memorandum on local availabilities was prepared. Laboratory tests were also made for the Department of Public Works in relation to the building of jetties, and for the Department of Transport for the building of airfields.

Ceramics

In the period before the war, the Ceramics Laboratory completed physical tests on Canadian building bricks, and a report was issued after the war (92). The tests included dimensional variation, volume, absorption properties, transverse and compression strengths, hardness and toughness and changes during ten cycles of freezing and thawing as well as freezing destruction. Picher assisted in many of these tests.

Laboratory work was also done on clay as a plasticizer in masonry mortars, and tests were conducted on full bricks, plastic refractories and high temperature cements. A report by Phillips on improving the properties of clays and shales was published (MB Rep 793, 1938). Physical properties of structural tile were also determined and a report was published (93). An economic method of improving surface texture and colour of structural clay products to resemble Roman pottery (terra sigillata) was developed.

Samples of sodium uranate and other uranium products were tested for Eldorado Gold Mines Limited to assist the company in producing a uniform and mutually acceptable material for ceramic glazing.

Investigation work was carried out in 1940 to assist a Toronto dental supply company in the development of dental filling material similar to a product previously imported but unobtainable during the war.

Advice was given on exploring a recently discovered kaolin deposit at the Thirty-One Mile Lake, Hull County, Quebec, and on processing and bleaching in a new preparation plant at an older deposit at Lac Remi, Papineau County. Information was also given to guide the Department of National Defence in the purchase of tableware of Canadian manufacture for the Armed Forces.

Considerable attention was paid to refractories, particularly for the Department of National Defence in marine and stationary boilers. Tests were made to improve the refractoriness of Canadian firebrick by adding bauxite tailings.

An extensive program of petrographic analysis was carried out in support of the beneficiation tests of the milling section on raw materials and products subsequent to treatment, and on refractories. From the early days of the NRC magnesium metal Pidgeon process, petrographic control was used on the raw material as well as during treatment, and in the Ceramics Laboratory generally in the preparation of refractories.

Research was undertaken in 1946 on magnesia produced from brucite in the preparation of oxychloride and oxysulphate cements. A floor tile made of wood waste bonded with magnesium sulphate was developed in cooperation with industry and was then marketed.

Changes in Industrial Minerals Organization

Because of the many changes in staff due to retirements and internal reorganization of the bureau in relation to the Industrial Minerals Division which took place twice in five years, a note on the changes may be appropriate to avoid confusion.

Parsons was made responsible for the large-scale laboratory aspects of the Industrial Minerals Division in 1945. Martindale was made responsible for the Mineral Resources field and small-scale laboratory work including the Ceramics and Road Materials groups. When Monture returned from wartime assignments in 1946, the Mineral Resources Division was recreated incorporating the Industrial Minerals, Industrial Waters, Ceramics, and Road Materials groups. The Ceramics group suffered most of the changes in staff even before the war. Collin, the post World War I head had died in 1938 and was succeeded by Phillips who gave able service until he retired in 1956. Phillips' prior position was filled by G.A. Kirkendale who served from 1939 to 1947. McMahon resigned in 1936 and was succeeded by H.C. Watts who served from 1938 to 1948. On the other hand Miss R.L. McLeish served the Ceramics Laboratory as technician from 1924 to 1950 when she completed 42 years of continuous service from 1908 in the Mines Branch/Bureau of Mines. Dr. A.T. Prince joined the Bureau of Mines in 1946 and was assigned as head of the Ceramic Section in the Mineral Dressing and Metallurgy Division, renamed from the former Metallic Minerals Division in the same year. This section was later renamed the Crystal and Physical Chemistry Section. Though the first report by Prince was a resource oriented publication on sampling and the examination of clay and shale deposits (MB Memorandum Series 95; 1947), his research project was to obtain an insight through the study of high-temperature phase equilibrium systems into the complex reactions when a ceramic body is subjected to heat. The first refractory oxides he studied were lime, magnesia, alumina, and silica. In 1948 special work was started on refractory oxides of thorium, beryllium and zirconium for assisting the Atomic Energy Project.

In the same year a project was started on the system that concerned the composition of ceramic whiteware in which nepheline syenite was combined with clay, flint, and feldspar; 58 glass compositions were synthesized and 118 quenching studies were made on them. The data provided whiteware manufacturers with information on the reactions in the firing process and on the effects that might be expected from certain compositions (94). Advice and testing was provided on refractories in response to enquiries from government agencies and industry. The old Ceramic Section was revived in the reconstituted Industrial Minerals Division in 1950 and Prince's group became a specialized research unit in the chemistry and mineralogy of slags, minerals and ceramic refractories.

Prince, like Montgomery in Fuels, Downes in the Mineral Dressing and Metallurgy Division and others, was of a generation of research-trained men with doctoral degrees, whom Timm and Parsons hired after World War II to introduce improved scientific reasoning into the research and development work of the bureau.

Commander W.R. Inman and D.J. Charette were appointed in 1946 to take care of industrial water activity after Leverin's retirement in 1944. They were also transferred to the Mineral Dressing and Metallurgy Division. The long-service technician, E. Lester, had been appointed plant foreman in the Ceramics Division in 1915, retiring in 1944. He was replaced by T.H. Flood who had joined the branch in 1916 and retired in 1949.

The senior ranking officer at the end of the first term of Industrial Minerals Division was Spence though Goudge was accepted as the officer in charge of the mineral specialists after Fréchette's retirement. Spence and Cole retired in 1949 after each had completed 39 years of dedicated service.

At this writing Cole lives in Ottawa at the age of 92. It is of interest to record that Spence, born in England but trained as a mining engineer in the Mining Academy of Freiberg, the foremost German mining school founded in the 18th century, was an authoritative mineralogist. The latter competence is the reason for his assuming responsibility for such a large variety of minerals during his long career at the Mines Branch/Bureau of Mines. A sample of the original Labine discovery of pitchblende at Great Slave Lake was brought for identification to the Department of the Interior in Ottawa which suggested the Department of Mines be contacted. Spence identified the sample. At this writing he has reached 90 years of age and lives in Ottawa*. It is appropriate to mention also that his son Neville Spence, a metallurgist, joined the Atomic Energy group at Chalk River in 1953 as assistant to

*Deceased 1977

Lavigne and from 1956 to 1975 served in a senior capacity in the Physical Metallury Division in Ottawa.

Goudge and Phillips were selected for study tours on industrial minerals in Germany, Austria and Italy, and on ceramics in United Kingdom and Germany during the periods of August-November 1945 and November 1945 - February 1946, respectively.

The Industrial Minerals Division was reformed in 1950 and lasted till Goudge's retirement in 1959. The principal staff as at February 1951 was as follows:

Chief - M.F. Goudge
Non-Metallic Minerals - V.L. Eardley-Wilmot, A.R. MacPherson, H.M. Woodrooffe, T.H. Janes, J.G. Matthews, C.G. Bruce, G.F. Carr and V.A. Haw
Ceramics - J.G. Phillips, S. Matthews, I.F. Wright, R.A. Shonk
Construction Materials - R.M. Picher and R.A. Simpson
Industrial Waters Section - J.F.J. Thomas and S. Romanchuk

Economics (Mineral Resources) Division

At the formation of the Department of Mines and Resources in 1936, the Mineral Resources Division was renamed the Economics Division, comprising four sections - Investigators, Records and Research Information, Library, and Draughting - the latter two sections serving the needs of the bureau.

The mineral specialists involved in field and laboratory investigations were assigned to the Industrial Minerals Division. Wilson became chief technical consultant in the office of the Mines and Geology Branch, the director of which was John McLeish. Others in the director's office who had served in the Mines Branch on the technical side were Bolton and Kirkconnell, general executive assistant and engineer respectively. On the clerical side were T.H. York, who was in the Fuels Division from 1927 to 1935, and a stenographer, Mary McCracken, who with Mary McFadden in later years were known affectionately as the "two Marys" when they served as personnel officers in the departmental personnel office.

The chief of the Bureau of Mines at this time was W.B. Timm, the secretary was M.M. Farnham, and the engineer was T.G. Madgwick, a petroleum specialist who joined Mineral Resources Division in 1932, serving the branch until 1946. There were also Jessie Orme from Dr. Haanel's time as senior stenographer with two other stenographers including Gordon Hetherington (1935-50) who was loaned to branch administration from the Metallic Minerals Division, and C.H. Norton as senior clerk with five other clerks. Norton joined the Mines Branch in 1924 and retired in 1958. A packer and helper made up the staff of 12 in the office of the chief of the Bureau of Mines.

The chief of the Economics Division until 1939 when he retired was Robinson, being succeeded by G.C. Monture, the departmental editor. On June 1, 1940, the government introduced control of minerals related to the war effort and established offices of the Metals, Oil, and Steel Controllers. Monture was seconded to the Office of the Metals Controller (G. Bateman) where he stayed throughout the war. E.S. Martindale became the acting chief. He and W.H. Norrish joined the Bureau of Mines on the dissolution of the Department of the Interior in 1936 and were classified as investigators, Grades 4 and 3 respectively. Another investigator who joined the bureau was G.A. Letendre, who resigned in 1945 to take up an appointment at Laval University where he became head of the Metallurgy Department.

In the Records and Research Information Section, Buisson was head and Casey the statistician, retiring in 1950 and 1946 with 35 and 37 years respectively in the same division. The other engineers in this section were E.H. Wait and W.E. White, who joined the bureau in 1923 and 1930 and retired in 1957 and 1961 with 34 and 31 years of service respectively. Two ladies, D.M. Stewart who joined Wilson in 1913 in the Metalliferous Deposits Division and became a research clerk in the Mineral Resources/Economics Division with 32 years service retired in 1945, and G. MacGregor who transferred with McLeish from the Geological Survey in 1907 and before retirement in 1940 was principal clerk, had 37 years service in the Mines Branch.

The chief librarian, O.P.R. Ogilvie, retired after 24 years of service in 1937 and was succeeded by Mary Reid who joined the Mines Branch in 1929 and retired in 1946. Madeleine Saulter joined the branch in 1930 and became chief librarian in 1946, retiring in 1963. In the Economics Division she was classified as Research Clerk Grade 2 as she acted as reference librarian. Marjorie Rice joined the library as an assistant in 1940 and was head librarian from 1963 to 1968.

The Draughting Section had four officers in 1936: L.H.S. Pereira, the head, two senior map draughtsmen, D. Westwood and W.J. Flood, and a map draughtsman, E. Juneau. Pereira, Westwood and Juneau all had long service in the Mines Branch, having joined in 1911, 1914 and 1913 respectively. Flood joined in 1924. In 1940 Juneau retired; in 1942 Flood was seconded to NRC; and in the same year Pereira and Westwood were transferred to the Map Draughting and Reproduction Section of the Geological Survey as a means of consolidating branch services. This virtually ended the history of formal cartography in the Bureau of Mines.

Publications

It will be recalled that all groups with the exception of the Draughting Section were moved in 1939 from 541 Sussex to the new Industrial Minerals Building at 40 Lydia Street. For the first three years until the outbreak of war, the small staff continued activities in the areas of their specialization: Buisson on records that included reviews for the technical press of Canada and the United Kingdom, the completion of new or revised editions of Lists of Operators in the Mineral Industry, preparation of a new edition of Canadian Mining Laws, etc.; Casey on annual reviews of petroleum fuels and commencing an investigation of competitiveness of Canadian fossil fuels; Wait worked on records of mining companies. Some field work was continued by Robinson, Buisson and Casey. A statement on the average production, import, export and consumption of 125 metals and minerals during the period from 1932 to 1936 was prepared.

Much of the division's work during the war was concerned with the preparation of memoranda of information for the various wartime agencies and departments concerned with the war effort, and this included the Commission of Income Tax in regard to the administration of the Income War Tax Act. Public information on minerals and mineral production had to be restricted, but the data were made available to those in the government and industry who were allowed access to such information. Staff was seconded to various wartime agencies and up to three officers worked on strategic minerals in the office of the director.

Towards the end of the war special studies were made on subjects such as the decline of gold mining and its effect on post-war employment, mining taxation, mining education for armed services, projects for post-war employment, base metal reserves, and mineral possibilities of areas adjacent to the Alaska Highway. Some of these studies provided a basis for papers published in the Bulletin of the Canadian Institute of Mining and Metallurgy.

Monture was retained by the Metals Controller until 1944, when he was loaned to the combined Production and Resources Board in Washington. He returned to the Bureau of Mines in 1946.

The original Mines Branch series of reports and maps started in 1903 and the mimeograph series, started in 1921, continued throughout this period but at a much reduced rate of publication during World War II and immediately after. Thus in the printed report and map series, No. 796 was reached in 1939, and No. 865 by 1959; in the Memorandum Series, which was a mimeographed publication, No. 75 was reached in 1939 and No. 137 by 1958 when the series was discontinued. Purpose of the latter series was to make reports of general interest quickly available to the public, and of course they were cheaper to produce.

During the war a high proportion of the work of the bureau was geared to the war effort and reports were typed in a small number of copies for restricted distribution that could not tolerate delay. This requirement of rapid communication favoured the production of limited circulation reports by the divisions, a practice that continued into the post-war period. Some of the material was consolidated and issued in the bureau's and later the branch's publication series set up in the period of the Department of Mines and Technical Surveys.

A mineral map of Canada was specially published for the New York World's Fair in 1939, being the first such separate publication although reviews of the Canadian mineral industry published from time to time were accompanied by maps of mineral areas and an overall mineral map of Canada.

As the mineral industries of Canada was the principal annual detailed description of the Canadian mining industry by mineral from 1933 to 1956 under the aegis of the Mines Branch, it may be appropriate to review its history. As mentioned in Chapter 3, this series was published on a periodic basis for distribution at world exhibitions and conferences from 1913 to 1933. From 1933 to 1938 it was published annually, followed by a break of five years during World War II when mimeographed reports were available to selected persons concerned with the war effort, resuming again on an annual basis in 1944. Publication dates with particulars of these reviews and their titles are as follows:

1913	"Economic minerals and mining industries of Canada", MB Rep 230 (Engl); 231 (Fr); prepared for the International Geological Congress in Canada and Industrial Exhibition at Ghent, Belgium.
1914	"Economic minerals and mining industries of Canada", MB Rep 322; prepared for the Panama Pacific Exposition, San Francisco, 1915.
1925	"The mineral industries of Canada", compiled by A.H.A. Robinson; MB Rep 611 (Engl); MB Rep 612 (Fr). Prepared for the British Empire Exhibition, Wembley, 1924-25.
1934	"The mineral industries of Canada, 1933" by A.H.A. Robinson; MB Rep 738 (Engl); MB Rep 739 (Fr); 1934 "The minerals industries of Canada, 1933" by A.H.A. Robinson; abridged edition, MB Rep 749 (Engl); MB Rep 750 (Fr); 1934.
1935 to 1939	"The Canadian mineral industry in 1934, 1935, 1936, 1937 and 1938"; MB Rep 760, 773, 786, 791, 804 respectively.
1945 to 1955	"The Canadian mineral industry in 1944 1945, 1946, 1947, 1948 and 1949"; MB Rep 815, 820, 824, 827, 829, 830 respectively. MB Rep 835, (Engl); 840 (Fr), 1950; 841, (Engl); 843 (Fr), 1951; 844, (Engl); 845 (Fr), 1952; 851, (Engl); 853 (Fr), 1953; Canadian mineral industry (name change) MB Rep 857, (Engl); 859 (Fr), 1954; and 862 (Engl); 863 (Fr), 1955. This latter volume included some commodities not produced in Canada but important to industry.

A special two-volume report, MB Rep 860, containing maps, charts and graphs, and 860S containing statistics was produced under the title "Minerals, Canada and the world" in 1957. This volume was published for the Commonwealth Mining and Metallurgical Congress held in Canada in 1957.

With transfer of the Mineral Resources Division to headquarters of the department in 1956, the series continued under the same title until 1963, when it was changed to "Canadian Minerals Yearbook".

A sound film, "Gold from gravels" was completed in 1939; this together with a prior film "Canada's Treasure Trove" were in active demand by audiences interested in the Dominion's growing gold mining industry. Mineral samples received mostly from prospectors were examined and reported. During the war years the division administered prospectors' identification cards issued by provincial mining recorders which were required under wartime employment and food rationing regulations. Three editions of the booklet "Prospector's guide for strategic minerals in Canada" were published.

Organization of Mineral Resources Division

Following reconstitution of the Industrial Minerals Division in 1950 for the second time, the professional staff of the reduced Mineral Resources Division as at February 1951 was as follows:

Chief - G.C. Monture
Engineers and investigators - E.S. Martindale, L.O. Thomas, W.M. Goodwin, R.E. Neelands, E.H. Wait, W.R. McClelland, R.J. Jones, H.A. Graves and E.A. Trevor

Statisticians - D.D. Campbell, B.F. Burke
Librarian - Madeleine Saulter

The division shared quarters with the Industrial Minerals Division at 40 Lydia Street.

Administration of Bureau of Mines (Mines Branch)

After completion of the Physical Metallurgy Laboratories at 568 Booth Street, headquarters of the chief of the Bureau of Mines moved there from 552 Booth Street. Parsons was appointed chief in 1946 and became director of the organization, renamed by its former appellation "The Mines Branch" in January 1950; he retired in November 1951. The organization of the director's administration in February 1951 was as follows:

Director - C.S. Parsons
Secretary - Nola Ferguson
Executive assistant - W.H. Norrish
Chief administrative officer - T. Hartley Hawkins
Personnel officer - J.E.H. Bowles
Classified documents - H.N. Pickford
Mechanical superintendent - S.J. Hayes
Electrical engineer - Chief, G.K. Brown
Stores - W.A. Martineau
Naval - V.A. McCourt

The Naval Section, with Cmdr. V.A. McCourt, RCNR in charge under the direct responsibility of the chief of the Bureau of Mines, was set up in 1948 after being transferred from the wartime location at Renfrew where L.H. Cole was in charge of a large staff. It was housed in the Physical Metallurgy Laboratories, and this group was concerned with classified work on the production and repair of anti-submarine equipment and processing quartz crystals for radio frequency controlled units. This group was renamed in 1965 the Preparation and Properties of Materials Section and attached to the Mineral Processing Division.

It should be noted that through Cole's innate modesty he never referred to the importance of his war work or the M.B.E. awarded by the King in recognition of his contribution.

Changes in Bureau of Mines Infrastructure, 1946-1950

The following recapitulation is intended to clarify changes in infrastructure of the bureau:

1946 - C.S. Parsons was appointed chief of Bureau of Mines
- Mineral Dressing and Metallurgy Division was formed from Metallic Minerals Division with R.J. Traill as chief. It comprised three sections:
  - Mineral Dressing and Extractive Metallurgy Section
  - Ceramics Section
  - Physical Metallurgy Research Laboratories, including Chemical Metallurgy Section.
- Economics Division was renamed Mineral Resources Division with G.C. Monture as chief. It comprised two sections:
  - Industrial Minerals Section (change from Industrial Minerals Division)
  - Economics Section.

1948 - Radioactive Division formed from Radioactive Ores Group with A. Thunaes as chief
- Mineral Dressing and Metallurgy Division changed section names. It comprised:
  - Mineral Dressing and Process Metallurgy Section
  - Spectrographic Laboratory (named as section)
  - Ceramics Section
  - Physical Metallurgy Research Laboratories (Dr. John Convey, appointed chief metallurgist)

1949 - Physical Metallurgy Division formed from section with John Convey as chief
- Mineral Dressing and Process Metallurgy Division renamed from Mineral Dressing and Metallurgy Division, with R.J. Traill as chief and comprising six sections:
  - Mineral Dressing Section
  - Extractive Metallurgy Section
  - Chemical Metallurgy Section
  - Ceramic Section
  - Chemical Section
  - Spectrographic Section.

1950 - Industrial Minerals Division reformed from section with M.F. Goudge as chief
- Mineral Dressing and Process Metallurgy Division changed section names:
  - Mineral Dressing Section
  - Extractive Metallurgy Section
  - Chemical Metallurgy Section
  - Physical and Crystal Chemistry Section
  - Chemical Analysis Section
  - Mineragraphic and Spectrographic Section.

The frequent alterations, particularly in the original Metallic Minerals Division, may be interpreted as a desire to avoid creating a large and unwieldy administrative unit of disparate scientists and engineers in the very broad applied science of metallurgy which had made rapid advances during the war period in several of its branches.

Changes at "grass roots" to ensure "discipline compatibility" within staff groups often yield productive results, but of course, unnecessary proliferation of separate units is best avoided. In the Radioactivity Division, security was a major concern and, judging from the achievements during its short existence, it was a highly productive group. As regards the Industrial Minerals Division it is difficult to understand the decision for the five-year suppression of its distinctive identity except perhaps for two reasons: to reconstitute the former Mineral Resources Division under Monture who had a strong personality, and the necessity by the Industrial Minerals group to share some of the larger equipment in the ore dressing laboratory, in which personnel of the Metallic Minerals Division were very skilled in treating all inorganic minerals. However, the reasoning behind creation of the non-metallics laboratory in the 20's and making it a division in 1936 appears still to have applied in the immediate post-war period as demonstrated by reconstitution of the division in 1950.

CHARLES CAMSELL

One cannot close this chapter without paying a tribute to Camsell, and to the men and women of various disciplines and callings responsible for advancing so much knowledge - from maps to products of mines - in the first half of this century. Camsell had served 46 years in the departments that were responsible almost exclusively for nonrenewable resources, and he gained a profound understanding of the meaning of "resource continuum", a phrase used by Dr. Jim Harrison, assistant deputy minister, in later years in describing the sequence in the evaluation of national resources by governments for profitable and responsible use by their nations.

This work was started in the Geological Survey in the last century and was prosecuted vigorously from the inauguration of the Department of Mines. The complete spectrum of mineral resources and their conversion to metals, non-metallic products and energy were included in this comprehensive evaluation by surveys, investigations and research, the last link in this chain being R & D in physical metallurgy on a significant scale as a major contribution to the World War II effort.

Camsell was conscious of the depleting character of mineral resources. He spoke of this in relation to the accelerated rate of depletion of mineral resources of the United States that provided an opportunity for Canada's then comparatively virgin resources and of the importance of mineral-based Canadian secondary industries. Thus in his annual report for the fiscal year ending March 31, 1924, he says:

> "To appreciate the dependence of modern civilization on the mining industry one has only to consider the condition of the world if production of coal, oil, iron and other metals were to cease. Such a thought brings home to us the fact that the mining industry is the very bedrock and foundation of modern civilization. It is a basic industry without which most of the other industries could not be carried on.
>
> "Only when we realize two points, namely, the importance of the mining industry in modern civilization and the enormous extent of our known and potential mineral resources, will we realize how fortunately we have been endowed by nature, the responsibilities and advantages that have fallen to us and the place that we must ultimately occupy among the nations of the earth.
>
> "Modern civilization, however, makes a terrific drain on mineral reserves. In spite of popular notions to the contrary, mineral reserves are limited and a mine produces only one crop. Older countries are gradually exhausting these reserves, and are being compelled to work lower-grade deposits or to seek for supplies in the newer countries where the higher-grade deposits are not yet exhausted. Herein lies Canada's opportunity. Her known wealth in mineral resources is great, but her potential wealth is greater still."

C. Camsell, C.M.G., LL.D., F.R.S.C., wearing medal of Companion of the Order of St. Michael and St. George

In his annual report for fiscal year ending March 31, 1925, he first returns to the theme of depletion and then mentions the importance of mineral-based domestic industries:

> "Especially among the western nations world consumption of minerals has increased at a far more rapid rate than the growth of population. According to the best estimates the population of the world during the last forty or forty-five years has grown by about 30 per cent. Within the same period coal production has risen by about 300 per cent, pig iron output by nearly 300 per cent, copper production by over 1000 per cent, and petroleum by more than 2000 per cent.
>
> "The significance of this to Canada is important because of her geographical relationship to the greatest mineral consuming nation of the world. With about 5 per cent of the world's population the United States is said to consume about 42 per cent of the world's output of coal, 53 per cent of the iron, 57 per cent of the steel, 44 per cent of the copper, and 73 per cent of the oil. The United States has enormous mineral resources of its own and has an exportable surplus of many important minerals, yet there is little doubt that its market will sooner or later place a premium upon every valuable mineral occurrence in the Dominion of Canada, just as it has already done with certain of our other natural resources.
>
> "The development of mineral manufacturing industries of necessity lags somewhat behind the mineral producing industries, but for a young and growing country of Canada's position in this respect shows that considerable progress has been and is being made. The number of plants in operation during 1924 and turning out manufactured articles of mineral origin was 10,719. These plants had a capital investment of

$1,550,000,000 and provided articles to the value of $879,000,000. The Department of Mines is not so much concerned with this phase of industry as it is with the primary industries of production and of later treatment and reduction of ores, but the position of the mineral manufacturing industries is cited as evidence of the relative strength and value to the country of these two groups of industries and the necessity of developing those secondary manufacturing industries that may be based on our own raw mineral products."

Camsell also appreciated the competition that Canadian minerals and mineral products had to meet in world markets. This is evident from the thrust he showed for developing British and other European markets in the 1920's. Camsell extended his personal technical interest in the programs of the department as both deputy minister and chairman of the Dominion Fuel Board. He was fully aware of the fossil fuel difficulties experienced by Canada in World War I and subsequently. He looked for alternatives, thus in his annual report for the fiscal year ending March 31, 1928, he says:

"In the autumn of 1927 the Deputy Minister accompanied the Minister of Mines on a visit to several European centres in which experimental work in the processing of fuels is in progress. The itinerary for this tour was planned in co-operation with the British Fuel Research Board and with official organizations in Germany, which permitted of a selection being made of the more advanced operations in both of these countries. Four low temperature retorts were inspected in Germany, and eight British plants, situated in South Wales, London, the Midlands, and in Scotland, were also examined. As a result of these investigations valuable information was gained which may have a bearing on the application of processing treatment to certain types of Canadian fuels should any of these developments prove applicable to Canadian conditions. Several processes designed to accomplish the liquefaction of coal or the conversion of coal into oil were examined. A small unit of the Bergius process installed in the British Fuel Research Station at Greenwich was inspected, and experiments in which the Fischer process is being essayed were witnessed at the Kaiser Wilhelm Institute of Coal Research at Mülheim in the Ruhr. Information was also secured in respect to a third process with which experiments are being made at Leuna in Germany. The possibilities involved in these different developments are of particular interest to Canadians because of our large reserves of low-grade coals. Although the liquefaction of coal is still in a comparatively early stage of advancement, important progress has already been made and it is highly desirable that further developments along these lines be carefully watched. While in Europe, the Deputy Minister participated in a meeting of the International Executive Council of the World Power Conference held at Cernobbio, near Como, Italy, September 5 to 10, and meetings in London of the Advisory Council on Minerals of the Imperial Institute."

This study tour may have influenced the hiring in 1930, of Dr. T.E. Warren who inaugurated the hydrogenation program in the Mines Branch, as well as for the extensive carbonization program that was carried out in the new Fuels Building erected in 1929. It should be noted that on some of his European trips when Camsell was attending the World Power Conference he was accompanied by B.F. Haanel, Chief of Fuels, who usually presented a paper. There is no doubt that energy questions relating to the Mines Branch were discussed during these trips. Such an intimate connection of the deputy minister with the research and development program area of the department was never equalled in later years.

It has been said that the Mines Branch and the Bureau of Mines were favoured by Camsell over the Geological Survey, but judging from the budgetary allocations this does not appear to be entirely so, as seen from the few examples of grants during the period of the Department of Mines and of ordinary expenditures during the period of the Department of Mines and Resources.

There was no question that Camsell built up the Mines Branch and the Bureau of Mines during his term of office. During World War II special funds for programs related to the war effort were advanced to the two bureaus, but the allocation was combined for the Mines and Geology Branch; for example, the war expenditures of the branch for fiscal year 1944-5 were $1,388,926 and it is quite possible that physical metallurgy received a large part of the special war allocation.

Camsell won the confidence and respect of the mining industry and of provincial and other agencies as he believed in cooperation. This reflected on the cordial relations that existed between industry and

Comparison of Mines Branch/Bureau of Mines and GSC Budgets ($)

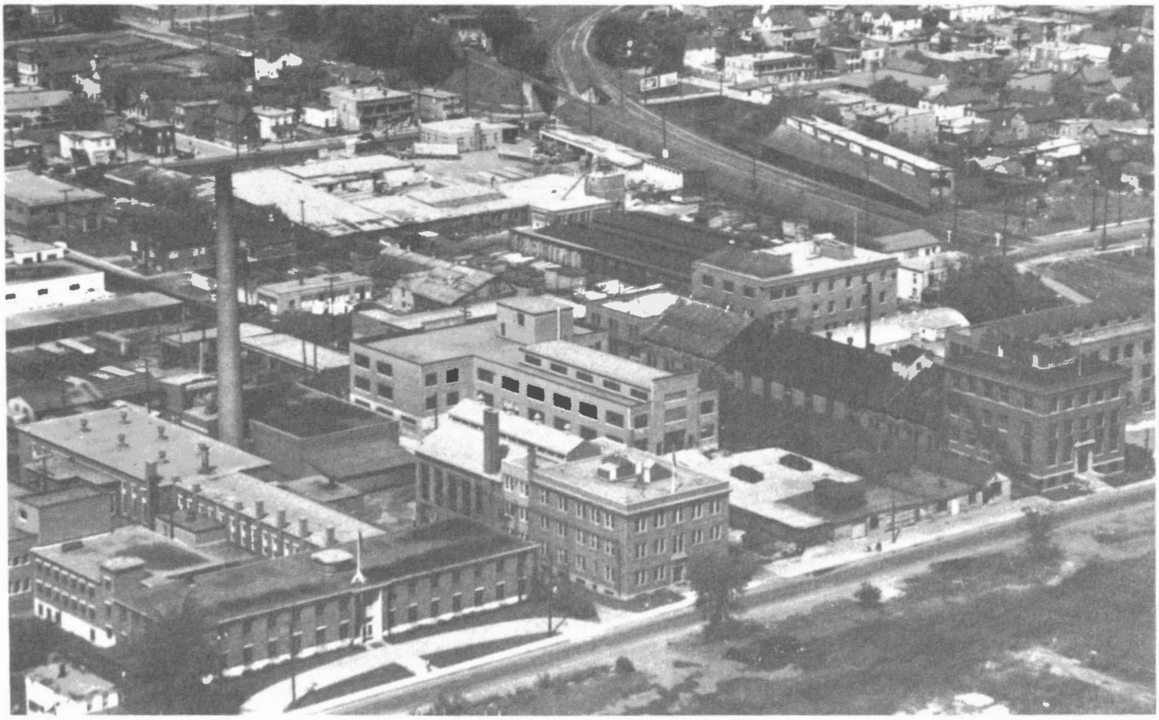
	Fiscal year ending	Mines Branch/ Bureau of Mines	GSC
Department of Mines			
Grants	March 31, 1924	422,619(1)	645,419(2)
Grants	March 31, 1929	654,460(1)	658,045(2)
Grants	March 31, 1933	467,990(1)	515,928(2)
Grants	March 31, 1936	439,705(1)	534,136(2)
Department of Mines and Resources			
Ordinary Expenditures	March 31, 1940	455,568	740,165
Ordinary Expenditures	March 31, 1945	429,742	712,551

(1)Includes expenditure of the Dominion Fuel Board
(2)Includes expenditure of the National Museum

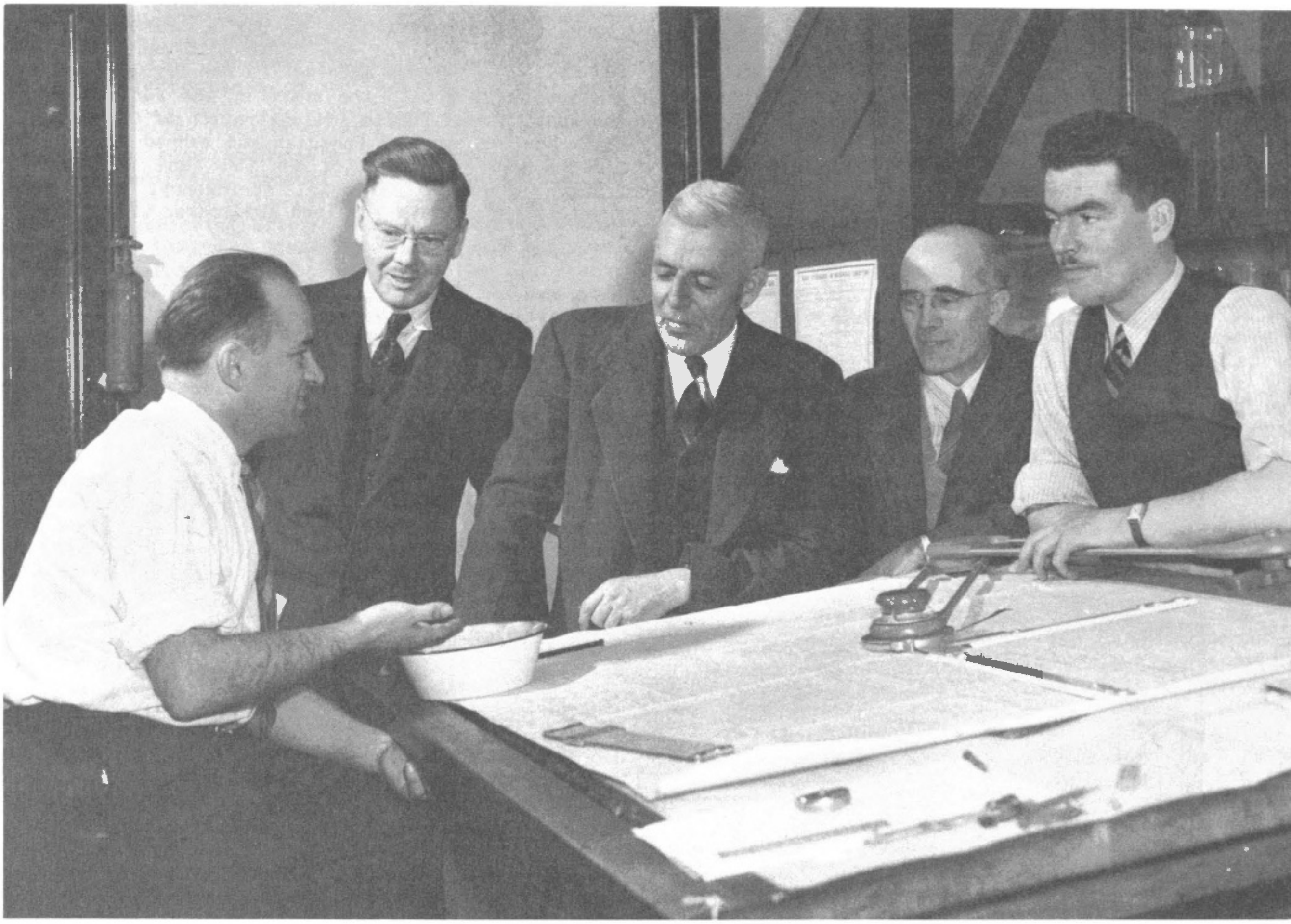
departmental staff. The "open door" to industries started in Dr. Haanel's day was continued with mutual benefit in exchange of knowledge and information; visits to properties and plants were unrestricted. All this encouraged the development of several generations of knowledgeable resource specialists.

Camsell guided the department through the difficult and contrasting years of the depression and war, ensuring that the human resources would not be bruised by either of these cataclysmal events. He had the confidence and support of ministers of both principal Canadian parties, Crerar and Gordon, as heads of the departments administering the Mines Branch and the Geological Survey of Canada. Camsell, the "Son of the north", indeed left his mark on Canadian life.

Up to the end of World War II, Canada as a whole practised frugality, particularly in the public sector. The population of this immense nation was less than half of the present population for most of the first half century. With the exception of managers, civil servants at the end of World War II were paid salaries in the approximate range of $1000 to $4500 per annum with the majority earning at the lower end of the range. It is appropriate to pay a tribute to these hard working souls of the first half century to whom the following remarks made at the honouring of Dr. G.C. Monture in 1966 with the award of the Vanier Medal of the Institute of Public Administration of Canada apply: "Slim Monture was one Canadian who served his apprenticeship with the rest of us long and well through arduous years of financial stringency, boredom and frustrations, yet he remained undismayed ....."



Mines Branch, Booth St. in early fifties



C.S. Parsons finds time from his involvement with the pressing atomic energy program in 1948 to discuss the Oil Sands program.

l-r: F.L. Booth, Dr. T.E. Warren, C.S. Parsons, E.J. Burrough and R.E. Carson

CHAPTER 6

THE YEARS OF CANADIAN GROWTH - EMPHASIS ON SCIENCE

(1951-1966)

DEPARTMENT OF MINES AND TECHNICAL SURVEYS, 1949-1966

The second half of the present century dawned on a promising note of Canadian mineral industry growth. Mineral production reached a mine peak value of $567 million in 1942 but trended downward until 1945 when it was only $499 million. It then rose again to $645 million in 1947 and continued growing at an accelerated rate over the next four years, doubling to $1,245 million in 1951. In the next nine years the value doubled again to $2,495 million in 1960; by 1966 it had reached $3,981 million. This represented a threefold increase in metallics from 1950, nearly fourfold in industrial minerals, and fivefold in fuels. Values were expressed in unadjusted dollars, but the rate of inflation was moderate until about 1964.

This mineral wealth was not only able to satisfy an expanding manufacturing industry but a surplus of about 60% of total production provided a sizable export income. Mineral and metal exports had grown from 1950 to 1967 at 10.3% per annum compared with 7.8% per annum for total merchandise exports, attaining a value of nearly $3.5 billion. This, of course, included added value in processing and represented 31% of total merchandise exports. In 1967, imports of ores, minerals and scrap totalled $780 million, of which fuels - coal and petroleum - amounted to $521 million. Compared with bygone days, the position was very satisfactory as it meant the country was almost self-sufficient in minerals. The foregoing figures were in unadjusted dollars with metal and other mineral prices being internationally controlled, fluctuating within narrow limits. The wholesale price index advanced at the rate of about 2% per annum during this period.

Some of the factors responsible for the prosperity in this period may be summarized as follows: (1) Improvement in the position of Canadian hydrocarbon fuels. The Leduc No. 1 well oil discovery in February 1947 was a milestone in the wave of exploration for petroleum and natural gas which within a few years would provide sufficient reserves to supply internal markets in the west and as far east as Port Hope, Ontario, requiring only the importation of cheaper crude oil to refineries in the Maritimes and Montreal to serve the Maritimes, Quebec and eastern Ontario. This situation allowed for exports in the West to the United States of about the same quantity of crude being imported in the East. (2) The achievement of self-sufficiency in domestic iron ore by production from Labrador and New Quebec with a substantial export surplus capability though some elective imports from U.S.A. continuing. (3) Brisk demand abroad for copper, nickel, zinc and asbestos. (4) This was a period of postwar reconstruction in Europe and elsewhere with third world competition being only nascent, hence, competition was not as serious as it became later. (5) Inflow of large amounts of capital making possible major new production ventures, particularly those based on open pits and large capacity earth moving machines perfected during the War, substantially reducing mining costs.

It may be of interest to compare the Gross National Product as an index of the Canadian economy at three dates, i.e., the years immediately before and after the war and 1966, in current and constant 1949 dollars.

Canada's Gross National Product

Year	Millions of current dollars	Millions of constant dollars (1949)
1939	5,636	9,536
1946	11,850	15,446
1966	58,120	36,028

These figures show more than doubling of the Canadian GNP in the 20 years after the war or an increase of 130% based on constant dollars, whereas population increased only about 40%. A negative feature was the accelerated rate of depletion of minerals. Thus from 1947 to 1966 the cumulative value of Canadian mineral production amounted to $41.4 billion, whereas in the 61-year period from the time records were first kept in 1886 to 1946, the cumulative total value of mineral production amounted to only $11.8 billion. These were in unadjusted dollars with moderate rates of inflation and fluctuations in international metal and mineral prices. On the other hand, in the following ten years from 1967 to 1976, the value was $80.8 billion with a considerable increase in inflation, particularly in the value of fuels and industrial minerals.

When the department was formed in 1949, George Prudham was appointed as a full-time minister, the first in the history of the Mines Branch, and was fully occupied with surveys, mines, and minerals. The inaugural report of the department for the fiscal year ending March 31, 1950 made a special reference to this fact and to the objectives of the new department as follows:

"The Department was established in view of the growing feeling, particularly among those interested in mining, that the importance of the mineral industry and of the Government's relations with the industry was such that there might well be a Minister of the Crown who would devote his full attention to the fields of mines and mining.

"In setting up the Department the Government met the wishes of the industry by transferring to other departments the administration of such branches of the former Department of Mines and Resources as Indian Affairs, Forestry, and Immigration, and as now constituted, the Department of Mines and Technical Surveys is an integrated organization whose primary function is to provide technological assistance in the development of Canada's mineral resources through studies, investigations and research in the field of geology, mineral dressing and metallurgy, and topographical, geodetic and other surveys. Although the department had been functioning only a few months, by the end of the fiscal year editorial and other comment in the technical and mining press was mainly to the effect that the establishment received favourable reception in Canadian mining circles."

This mineral-oriented attitude continued with Dr. G.S. Hume as the director-general of Scientific Services until 1956, when he resigned to take up an appointment in the oil and gas industry. He was replaced by Dr. W.E. van Steenburgh, who while recognizing the importance of the mineral industry, viewed the department as a scientific organization of wide scope principally engaged in long-term research on natural resources as exemplified by the following statements from the annual reports of 1958 and 1961 respectively: "In 1958 the Department of Mines and Technical Surveys carried forward its program of basic and applied research on an ever widening plane. The immediate technological problems of the mineral industry were still an important part of the work, but many of the year's projects reflected an acute need for fundamental scientific studies." "In 1961 the Department of Mines and Technical Surveys pressed forward with a broad field and research program of benefit to many aspects of Canadian endeavour and adding substantially to Canada's stature in the world of science." There were other statements of this nature during this period.

Actions were taken to implement this change in policy. Thus in 1959 the Polar Continental Shelf Project and the oceanographic research program were commenced. The latter resulted in the formation of the Marine Sciences Division in 1960 in the Surveys and Mapping Branch. A separate Marine Sciences Branch was formed in 1961 and a centre of oceanographic research composed of a laboratory building known as the Bedford Institute of Oceanography and associated oceanographic ships was established in 1962. The build-up of the marine sciences that included the Canadian Hydrographic Service became a priority in the department with a budget substantially higher than the budgets of the older branches. The swing to non-mineral science is illustrated in the table summarizing ordinary expenditures of the largest branches in the department in the period from 1959 to 1962, expressed in millions of dollars to the nearest thousand.

Ordinary expenditures - Department of Mines & Technical Surveys ($000)

Year	Surveys & Mapping	Geological Survey	Mines Branch	Marine Sciences
1959	9,029*	3,367	3,690	-
1960	11,300*	4,133	4,258	-
1961	15,550*	5,346	4,837	-
1962	6,012	6,026	5,002	11,514

*Oceanographic Research Division included

The Marine Sciences Branch did not stay long in association with the mineral (nonrenewable) resources and was transferred in 1970 to the Department of Environment, which included all water resources except that used for energy.

In fairness to Dr. van Steenburgh and Dr. Marc Boyer, the deputy minister, the decision to set up marine sciences research was a Cabinet decision which is explained in the following paragraph of the annual report for 1961:

> "The Polar Continental Shelf Project was set up pursuant to a decision of the Federal Cabinet in 1958 to 'conduct surveys in scientific research in the Continental Shelf area of arctic Canada'. This decision had itself been prompted mainly by one of the resolutions adopted by the International Conference on the Laws of the Sea held in Geneva last year to the effect that mineral and other resources underlying continental shelves should be considered the property of the country claiming the coastline adjacent to the shelf."

To some extent therefore the Canadian Arctic and Continental Shelf program had an importance related to Canadian sovereignty in the north.

Dr. van Steenburgh, in trying to attract top calibre scientists for all these programs, considered that the then current classification category Scientific Officer, Mines (3 grades) and Senior Scientific Officer, Mines (3 grades) established in 1954 that superseded the previous classification from the Department of Mines and Resources period of Scientist, Mines or Engineer, Mines, was inadequate. He became a pioneer in developing the continuous career progression for research scientists whereby a research scientist entering public service could look to progression of his career subject to evidence of creative productivity that was evaluated annually by branch and departmental evaluation committees. This progression was through three grades - Research Scientist (RS) 1 to 3, and in exceptional cases to RS 4. Very attractive salary rates were attached to these classifications. The Professional Institute of the Public Service recognized van Steenburgh by awarding him the Gold Medal of the Institute for his endeavours in this field. Considerable time was spent by the branches and the senior scientists in implementing this new classification scheme.

In the case of the Mines Branch, some difficulties were experienced. The scheme favoured the scientist with a doctoral degree as formal proof of completion of research training and who continued during his career to publish scientific papers. In the Mines Branch, a large amount of engineering included not only operation of scaled-up plants but frequently their design, adaptation and assembly, requiring creative skills regarded in industrial laboratories as part of the R & D process. Such skills however, could not be given credit under this scheme which was one of its principal difficulties.

Another was with chemists who had to deal with complex materials which demanded the development of special analytical procedures and research and only later could be standardized. The Treasury Board, which set up the rules of classification, was apt to regard the function of most chemists as being regulatory (quality control). Finally, much of the R & D work was performed by groups possessing a collective assortment of scientific and engineering qualifications. The director fully recognized the importance of the team effort in an organization such as the Mines Branch and the absence of homogeneity of the professional staff. His criterion of qualification for the research science category was a research capability demonstrated on the job. Gradually the branch evaluation system was adopted and on the whole was accepted by the staff. It was a pity that career progression could not be applied more widely as an incentive to increased productivity in the Public Service.

Towards the end of the period under review, an era of popular interrelated public attitudes, albeit by small vocal groups, appeared not only in Canada but in various degrees throughout the Western World. These attitudes may be summarized as follows:

(1) greater social consciousness
(2) distrust of nuclear energy and of involvement by scientists in "destructive" technology
(3) concern for pollution of the environment, and
(4) concern for unrestricted depletion of resources.

The general effect on governments of these views was to give greater priority to social and cultural aspirations of their populations in a broader concept of quality of life for all. Public interest and sympathy turned away from the physical sciences and "growth" technology, showing more interest and sympathy in life sciences, particularly ecology. Canada has followed this path from the late 60's to the present.

Another important trend in government appeared at the end of this period. This was the system of program planning and budgeting, largely adapted from the U.S.A. This departed from the older system of funding by grants, departments and agencies, and instead substituted the funding of programs requiring detailed justification by their implementers for continuation. This in turn brought about a priority approach for decision makers by ranking programs with a view to reducing or disallowing funds for programs of lower priority. For well-defined long-term research, in particular, the institutional rather than the program approach was, of course, more appropriate. However, the government at that time was beginning not to accept this viewpoint and tended to equate R & D programs with the more definitive service-to-the-public programs. The adjustments that had to be made by the department and branches in converting institutional to formal R & D programs occupied much time by senior personnel continuing into the 1970's. In fairness to research scientists who have been accused of dragging out their projects, few of them would pursue unproductive routes as they are usually motivated to complete their projects with positive results.

JOHN CONVEY, FIFTH DIRECTOR OF THE MINES BRANCH

John Convey, known to many of his associates and friends as "Dr. John", served as director of the Mines Branch longer than any of his predecessors - 22 years - from November 1951 to November 1973. He then became the senior departmental advisor in mining and metallurgy, retiring in March 1975 with 27 years of service in the department.

Convey was born in 1910 into a coal mining family at Craighead, County Durham, England, where he received primary and secondary education which he completed with distinction. He also showed skill in sports, playing association football, better known as soccer in Canada, and was almost enticed to become professional. He came to Canada in 1929 with his family, settling at Clandonald in Alberta. He attended the University of Alberta, graduating in 1933 in Honours Physics, and continued as demonstrator and lecturer in 1936 and 1937, earning a Master's Degree in 1936 in Atomic Physics, a high school teaching diploma and a Henry Tory bursary. In 1938 he was awarded an NRC bursary and in 1939 a studentship which enabled him to complete graduate studies at the University of Toronto where he graduated with an honours PhD degree in atomic physics in 1940.

John Convey, fifth director of Mines Branch
(Photo - George Hunter)

Convey enlisted in the RCNVR in March 1940; after receiving his commission he went immediately to Britain on secondment to the Royal Navy. He was shore based after Dunkirk and served at Portsmouth, but for most of the time he was at the Sheffield Laboratories of the Royal Navy Scientific Research Department, working on operations research in metallurgy related to the war effort. He worked closely with British universities and industrial laboratories. In 1942 the British Institute of Physics elected him a Fellow and awarded him the Sorby Prize for original research. In 1944 and 1945 he spent time in the United States and Canada on special duties that involved visits to industrial and governmental laboratories; early in 1946 he headed a British intelligence group in interviewing scientists in metal and nuclear physics in Germany.

After demobilization in 1946 he was appointed as associate professor at the University of Toronto where he organized the Physics Department extension at Ajax for 400 undergraduate and 12 graduate postwar students with a staff of 12 professionals.

In 1948 Convey accepted the position of chief metallurgist in the Physical Metallurgy Laboratories and was appointed chief of the Physical Metallurgy Division when it was formed in 1949. It will be recalled that Dr. G.S. Farnham was head scientist in PMRL until 1946 when he left to take up an appointment with the International Nickel Company of Canada, Ltd. In the same year Parsons was made chief of the Bureau of Mines and for two years was looking for a trained research scientist with experience in nuclear and metal physics, as he recognized the importance and complexity of atomic energy. Convey's academic and research achievements over a period of 15 years from graduation at the Bachelor level were impressive and led to his appointment as director of the Mines Branch when Parsons retired in 1951.

While retaining his special interest in physical metallurgy, he widened his scope into the sciences as applied to mineral resources, soon becoming one of Canada's principal spokesmen for R & D in the mineral and metal fields. His lucid style of lecturing and presenting papers attracted attention both in Canada and internationally, resulting in considerable demand from various scientific organizations and others. His advice was sought by universities and other organizations. Thus he was made a member of advisory boards or committees of the Faculties of Applied Science in the Universities of Ottawa and McMaster respectively, of the metallurgical panel of the Atomic Energy Project, the British Non-Ferrous Metals Research Committee and the Board of Directors of the Canadian Welding Bureau. He was also advisor on metallurgy to the Defence Research Board and Chairman of the Canadian Magnesium Research Committee. All these were appointments in the early period of his career at the Mines Branch. To avoid becoming a "committee man", he brought in branch associates to take his place at many meetings, and in general delegated responsibility to his staff. In addition to the respect in which he was held, as demonstrated by requests for his advice, his achievements in a short period of time were recognized by awards: the Blaylock Medal of the Canadian Institute of Mining and Metallurgy in 1956 for his contribution to the development of controlled atomic energy in Canada and honorary degrees of Doctors of Science from McMaster University in 1959 and from Windsor University in 1965. He found time to teach a course of physics and mechanics at the Ottawa University on Saturdays to be "on the bit" as he said by answering searching questions from his sharp-minded students.

In later years the culmination of Convey's recognition for his contribution to metallurgy in particular and to the R & D in applied sciences in general was expressed by the following appointments: in 1962-63, member of the National Productivity Council and chairman of the Subcommittee on Applied Research; in 1962-63 election to the Executive Committee for seven years, the Presidency for 1966 and 1967 and in 1970 Fellowship of the American Society for Metals, the largest professional association of metallurgists in the world; appointment to the Chairmanship of the Technical Committee and General Chairmanship of two Commonwealth Mining and Metallurgical Congresses - the Sixth in 1957 and the Tenth in 1974 respectively; and president for a 2-year term of the Canadian Standards Association in 1974. The foregoing is not a complete list of memberships and awards that Convey held and received during his career.

The Mines Branch developed and prospered during his tenure, in part due to the general prosperity enjoyed by Canada for the first fifteen years of the second half of the century. Government funding was generous, rising from approximately $2 million in 1952 to nearly $4 million in 1960 and nearly $6 million in 1965. Thereafter the incremental rate was lower as other units of the department were given larger allocations. The staff increased by 40% from approximately 500 to 700 in the fourteen years between 1952 and 1965.

With the resignation of George Hume in 1956 and the appointment of van Steenburgh to the position of director-general of Scientific Services, the scientific orientation of the department, as noted in the preamble to this chapter, produced a somewhat ironic situation. Here was a director of the branch with academic and research credentials, probably the best in the senior ranks of the department at that time, who could undoubtedly have led the branch into a highly scientific or even an academic role, thus straying from its historic aim of assisting industry in the optimum recovery of the national mineral resources. It is to Convey's credit that he did not follow the then popular path. Basic scientific research was done in the branch but Convey recognized that scientific research generally must cross the threshhold into technology. Processing was a good example where a mix of science and engineering was required in a team approach.

Convey's leadership extended into the era of the present Department of Energy, Mines and Resources formed in 1966. By the Resources and Technical Surveys Act the department, through its minister, received a strong policy-making mandate in minerals, energy and waters, resulting in the organization of an intermediate level of policy advisors to the minister and senior management, thereby downplaying the advisory role of the operations branches with their detailed knowledge of the various sciences and technologies. Convey was proud of the various Mines Branch specialists, many of whom possessed a practical knowledge of economics related to their particular fields; he regarded this change in department policy as creating an additional layer of bureaucracy. On the other hand the departmental management somewhat resented his attitude of nonchalance towards the department, placing the branch in a certain degree of isolation.

Convey's style in dealing with the staff and people generally was very informal and relaxed. His office door was open to all. He granted considerable autonomy to the chiefs of divisions and senior personnel of the branch. In effect, he conducted the affairs of the branch in the liberal tradition of a university. He encouraged aspirants to higher academic qualifications to undertake additional academic training in their spare time. Staff members who were unhappy in their jobs were moved where they fitted in better. This was much appreciated by those who were able to improve and develop their careers. However, there was some criticism of Convey being complacent in dealing with the weak and the unproductive. He disliked formal administrative and procedural systems that are the bureaucrat's credo, and this caused some friction with the departmental administration.

Convey and the branch had inherited the "esprit de corps" that was present from the early days of the branch, probably because of the degree of teamwork necessary in much of its activities. He improved on it in the context of a much larger community. Perhaps the particular attribute that past and present generations of Mines Branch personnel will remember Dr. Convey for was his humanism.

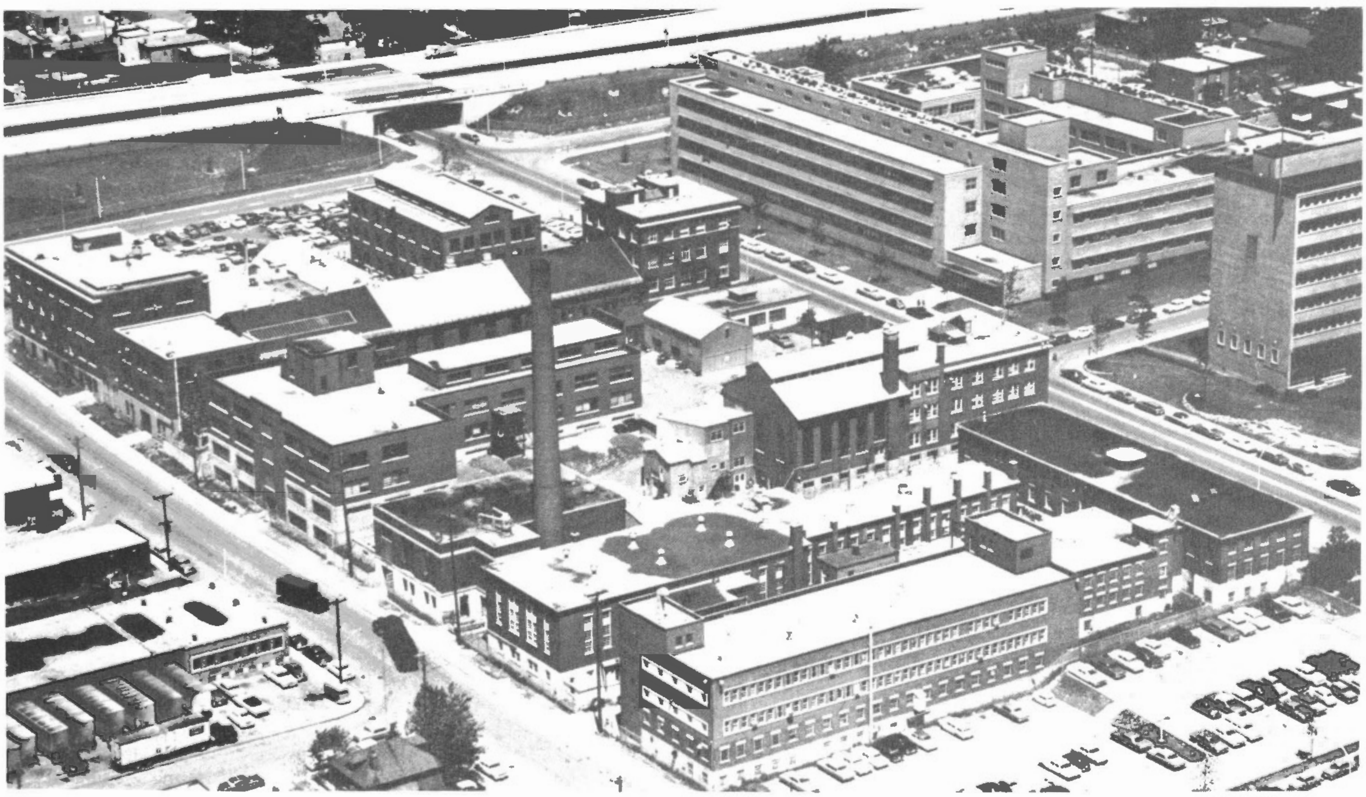
Building and Decentralization

During the existence of the Department of Mines and Technical Surveys there was considerable enlargement of departmental facilities, both laboratory and office. Resources in both staff and funds were made available. The spirit of frugality so evident in former days diminished as Canada advanced into prosperity. A great boon to most civil servants was the installation of more telephones which previously were limited to one serving several employees, located in different rooms.

In the early part of the period the headquarters of the department was at 70 Lyon Street, then at 294 Albert Street before moving in 1960 to the newly constructed building at 588 Booth Street at the corner of Carling Avenue. The Geological Survey Building was completed in 1959 and the Surveys and Mapping Building in 1961.

Mines Branch construction commenced in 1950 with new workshops and maintenance building erected at 556 Booth Street between the Mineral Dressing and Process Metallurgy building at 552 Booth Street and the Fuels Division at 562 Booth Street. In the same year two storeys were added to one of the buildings in the Physical Metallurgy Laboratories.

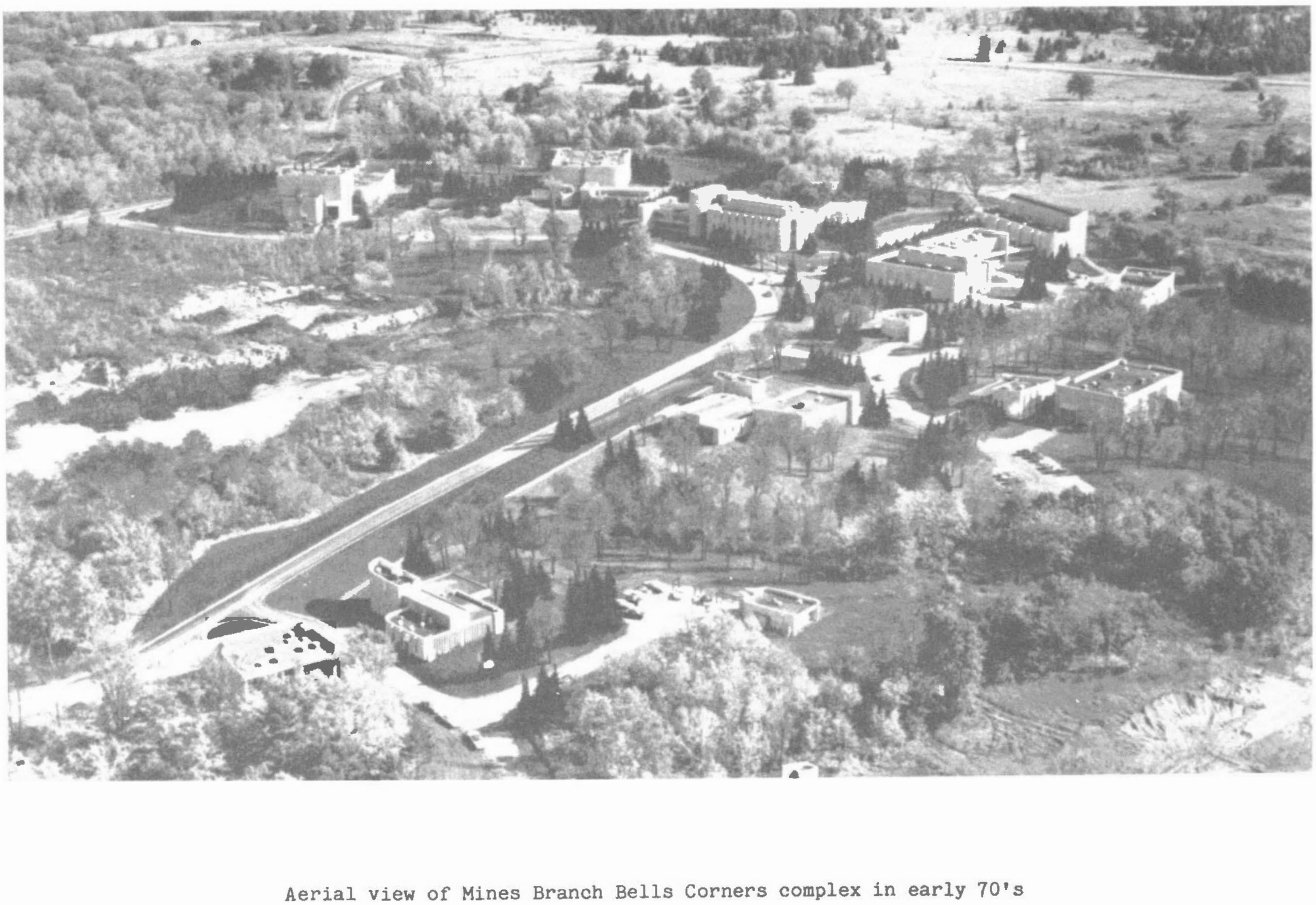
In 1955, construction of a building with four floors and basement was started in the corner block between Booth and Lebreton Streets, the first to be built on the east side of Booth Street. The new building was almost opposite 552 Booth Street, which was the site of the original peat building erected in 1910,



Aerial view of Mines Branch Booth Street complex in early 60's itself the first building in the Booth Street area. The rectangular building with frontages on Booth Street bearing the number 555 and on Lebreton Street with the number 300, with an inner court and entry from Elizabeth Street, in effect U-shaped, was the largest one constructed for the Mines Branch. The formal opening in 1957 by Minister Paul Comtois was made to coincide with the official 50th anniversary of the Mines Branch during the Sixth Commonwealth Mining and Metallurgical Congress, and a large gathering, not only of staff, but of industry representatives and the media was present. Because of difficulties with contractors, which Prince as officer-in-charge had to resolve, the building had not been finished until 1958, when it was first occupied by technical groups mostly from the Mineral Dressing and Process Metallurgy Division as well as from the Radioactivity Division. In addition, administration of the branch was transferred from the Physical Metallurgy Division building at 568 Booth Street and the Library was moved from 40 Lydia Street. Space was provided for the Inspectors of Explosives.

In 1956, at the suggestion of the Alberta Research Council, the small group working on coal preparation and beneficiation in Calgary was transferred to the newly built Research Council laboratories on the University of Alberta campus, moving again in 1966 to the Council's extension laboratories for large-scale experimental work at Clover Bar on the eastern outskirts of Edmonton, where it presently exists as an enlarged unit known as the Western Regional Laboratory. The initial field work in mining research was started in 1951 in two locations in the Crowsnest area of Alberta and British Columbia. In 1953, due to a downturn of the Western coal mining industry, H. Zorychta, stationed at Fernie, B.C., was transferred to Springhill, N.S. with an office in the Springhill Post Office Building. Cochrane, Grant and Richards returned to Ottawa at various dates until the early sixties. In the latter period they had a base office at 501 Public Building, Calgary to which Pickford was posted in the late fifties where he acted in a dual capacity of administrative officer and collector of field samples of oil and natural gas. The next development in mining research activities was the establishment of a Mining Research Laboratory at Elliot Lake, Ontario in 1964, renting space from the Rio Algom Company at the Nordic mine where operations had been discontinued. The main laboratories were housed in a building formerly used as a cafeteria in a complex of bunkhouses for single miners. This laboratory exists to this day after several renewals of the rental agreement.

Upon completion of the departmental building



Aerial view of Mines Branch Bells Corners complex in early 70's program on Booth Street and in Dartmouth, Nova Scotia, a proposal was entertained to transfer the whole of the Mines Branch to the Greenbelt area at the western outskirts of Ottawa. The site eventually chosen was on Corkstown Road near Bells Corners. Considerable time was spent overcoming Treasury Board objections arising out of escalating costs, in clearing the site, and in designing building and services for Phase 1 which affected only the Fuels and Mining Practice Division because of the acknowledged hazards in many of its activities. Provision was made for transferring the Explosives Laboratory built after the war at Uplands to the Bells Corners complex, the laboratory having joined the Mines Branch on April 1, 1959.

To maintain a high standard of safety, 16 separate functional buildings of steel and poured concrete were constructed over an area of approximately 135 acres though the "protective area" provided as a safeguard to the public increased the total area to nearly 1000 acres. Only the main laboratory and office building had three floors and a basement whereas the remainder had single floors for bench-scale laboratories and offices usually attached to pilot plant halls. There was a tendency by the architects to design buildings more suited for non-chemical research with inadequate window area and artificial ventilation. Various other difficulties arose, notably with services, because the buildings were scattered. The weight of these difficulties and their resolution was borne mostly by Dr. D.S. Montgomery, R.E. Carson and H.P. Hudson. Construction started in 1966 and was completed in 1968 with relocation and reassembly of the scaled-up plant taking another two years. This was a major operation because so much large and delicate equipment had to be moved and re-sited. Not all staff members were pleased to be uprooted but all reacted in a gracious manner. Remarkably little time was lost in the laboratories where particular urgency existed. The cost of the new facilities was close to three times the original estimate of approximately $4.5 million. Phase 2 to relocate the Mineral Processing Division with a proposed large capacity mill operation and the provision of adequate tailing and effluent disposal was under review for a couple of years but was then discontinued.

Organization and Staff of the Mines Branch

No changes in infrastructure of the Mines Branch took place following the appointment of Dr. Convey as director on November 15, 1951 until 1959 except for transfer of the Mineral Resources Division to become a headquarters unit in 1956 following the resignation of G.C. Monture. Convey was replaced as chief of the Physical Metallurgy Division in 1951 by N.C. MacPhee. Norm died in 1957, missed by many as a good foundryman, a wise and kind man. He served in the Mines Branch from 1941 to 1957. MacPhee was succeeded by S.L. Gertsman, who joined the branch in 1946 and was chief of the Physical Metallurgy Division for 18 years. Two chiefs of divisions with long total service in the Mines Branch retired: R.E. Gilmore in 1954 with more than 36 years and R.J. Traill in 1955 with nearly 40 years and they were replaced by Alex Ignatieff and Dr. K.W. Downes, an RCAF veteran, respectively. Dr. D.S. Montgomery became senior scientist of the Fuels Division, L.E. Djingheuzian became senior engineer, and Dr. Alan Prince, senior research officer of the Mineral Dressing and Process Metallurgy Division.

In 1959, following completion of the large building at 555 Booth Street-300 Lebreton Street, a reorganization took place with the Radioactivity and Industrial Minerals Divisions being discontinued and the staff merged into three newly named divisions: Mineral Processing with headquarters at 552 Booth Street and L.E. Djingheuzian as chief; Extraction Metallurgy housed in the new building with K. W. Downes as chief; and the Mineral Sciences Division housed also at 555 Booth Street with A.T. Prince as chief. The Physical Metallurgy and Fuels Divisions remained unaffected except the latter was renamed the Fuels and Mining Practice Division. The Maintenance Section was elevated to divisional status with S.J. Hayes as chief.

This infrastructure lasted until formation of the Canada Centre for Mineral and Energy Technology (CANMET) in 1975. Some names were changed in the final part of this history.

In the six years following the end of World War II in 1946, the conversion of wartime positions to permanent classified positions, particularly in the Physical Metallurgy Division, accelerated. No precise data were available until 1952, a year after Convey became director, but a reasonable estimate is that there were 400 on staff at the end of the 40's. It may be recalled that in addition to the large staff in the Physical Metallurgy Laboratories, the Radioactivity Division and another special group of physical metallurgists were created at the Atomic Energy Project in Chalk River. In any event, the 1952 figure was nearly two and a half times the 1946 figure of 215 classified positions. A breakdown of this total is as follows:

Mines Branch personnel, 1952

Professional and scientific staff	202
Skilled technicians	142
Workshops (prevailing rates)	88
Clerical and office	80
	512

In the following year, 1953, the establishment had grown to 563 and in 1958 to 588. It should be remembered that about 20 of the staff from the Atomic Energy Project resigned or transferred from Mines Branch employment to the Atomic Energy of Canada Limited. The establishment passed the 600 figure about 1959, thus in 1961 the staff that included associated personnel not in the government's employ numbered 655, with 37 seasonal positions. In 1965 the corresponding figures were 664 and 41, excluding associated personnel. In greater detail, the Mines Branch establishment at April 1, 1965, had the following composition:

Composition of Mines Branch, April 1, 1965

Division	Professionals	Non-professionals	Total
Administration	9	26	35
Physical Metallurgy	61	82	143
Fuels and Mining Practice	62	62	124
Mineral Processing	46	72	118
Extraction Metallurgy	43	41	84
Mineral Sciences	43	38	81
Technical Services	3	76	79
Total	267	397	664
Seasonals			41
Grand total			705

The foregoing data indicate that in the 14 years from 1952 to 1965 there was an average growth of about 2% per annum, whereas for the next 15 years there was no growth. Thus the staff in 1975 at the end of this narrative numbered 655.

The following list outlines the infrastructure of the Mines Branch as at April 1, 1965 in divisions, subdivisions, sections and groups. Because of space limitation, only chiefs, administration officers and heads of the sub units are given together with a full list of director's office staff, resource specialists (consultants) and Technical Services Division heads of sections all of whom served the whole branch. Other staff members who were employed for a minimum of 10 years during the period from 1901 to the end of 1975 are listed alphabetically in the Appendix. The year 1965 can be considered to represent the maximum development of the Mines Branch on purely institutional lines in the period of Canada's accelerated economic growth. Ahead was the era of programs and stricter evaluation of priorities as well as a slower national growth. The reader is reminded that when only the date of appointment is given in brackets following the name of the incumbent of the position it signifies that the individual was still on staff in the branch in 1975.

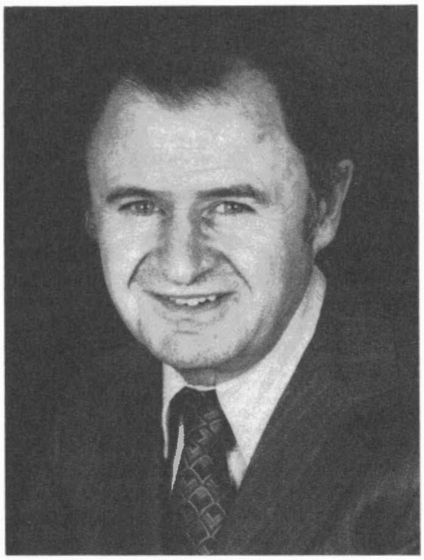
Director's Office and Administration, 555 Booth Street:
Director - Dr. John Convey (1948 - 1973)
Secretary - Nola Ferguson (1948 -)
Executive assistant - F.T. Rabbitts (1946 - 1953 and 1961 - 1974)
Special projects - Dr. T.W. Wlodek (1942 - 1970)
Special services - Patricia Stevenson (1949 - 1975)
Editor - P.E. Shannon (1929 - 1972)
Report reproduction - Marion Thompson (1955 - 1967)
Senior administration officer - T.H. Hawkins (1951 - 1970)
Assistant administration and finance officer - D.M. Livie (1947 - 1974)
Security officer - P.E. Hughes (1958 - 1975)
Personnel - Betty Hutchings (1937 - 1972)
Library - Marjorie Rice (1940 - 1968); Gloria Peckham (1963 -);
Physical Metallurgy Division branch library - Beatrice C. Cain (1953 - 1973)

Physical Metallurgy Division, 568 Booth Street:
Chief - S.L. Gertsman (1946 -)
Secretary - Betty Brabazon (1965 - 1975)
Principal scientist - Dr. R.L. Cunningham (1942 -)
Principal metallurgist - J.W. Meier (1941 - 1970)
Administrative officer - M.J.B. Bradley (1949 -)
Corrosion - Dr. G.J. Biefer (1960 -)
Engineering Physics - R.C.A. Thurston (1946 - 1975)
Ferrous Metals - Dr. G.P. Contractor (1957 - 1972)
Foundry - R.K. Buhr (1953 -)
Mechanical Testing - P.J. Todkill (1949 -)
Metal Forming - J.A. Perry (1945 - 1974)
Metal Physics - Dr. F. Weinberg (1951 - 1967)
Non-Ferrous Metals - J.O. Edwards (1948 -)

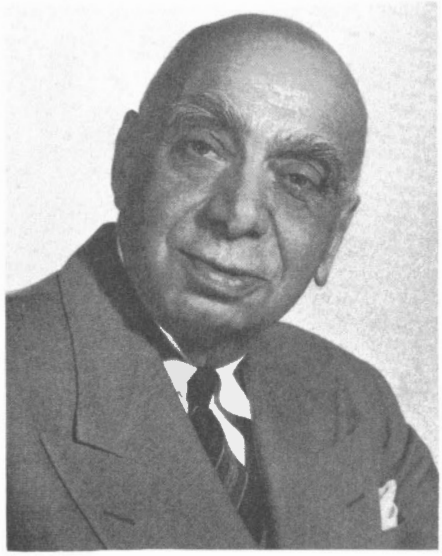
Introduction of Medicare: Front row - C.R. (Claude) Lalonde, Bernadette (Bunny) Davis O'Driscoll, John Convey, C.H. (Charlie) Glaude, Dr. W.J. Wrazej

Centre row - J.F. (Jim) Fydell, M. (Mike) Gadbois, R.B. (Rob) Huot

Back row - Dorothy Lazuk, C.A. (Charlie) Derry, H.W. (Harold) Armstrong, J.A. (John) Herbert



S.L. Gertsman



L.E. Djingheuzian (Photo - Newton)

Nuclear and Powder Metallurgy - N.S. Spence (1953 - 1975)
Non-Destructive Testing - W.E. Havercroft (1947 - 1975)
Refractory Metals - H.V. Kinsey (1942 -)
Welding - Dr. K. Winterton (1958 -)
Photographic Laboratory - Agnes Kosowan (1953 - 1970)
Glass blower - P. Hernandez (1948 -)

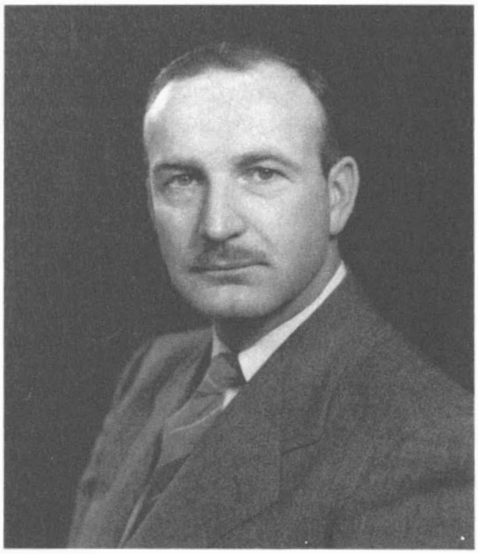
Mineral Processing Division, 40 Lydia Street and 552 Booth Street:
Chief - H.M. Woodrooffe (1946 - 1974),
- L.E. Djingheuzian (1948 - 1966)
Secretary - Lila Handford (1955 - 1965)
Administration - Madeleine Kane (1946 - 1967)
Metallic Minerals Subdivision - D.E. Pickett (1948 - 1949); (1954 - 1974)

H.M. Woodrooffe

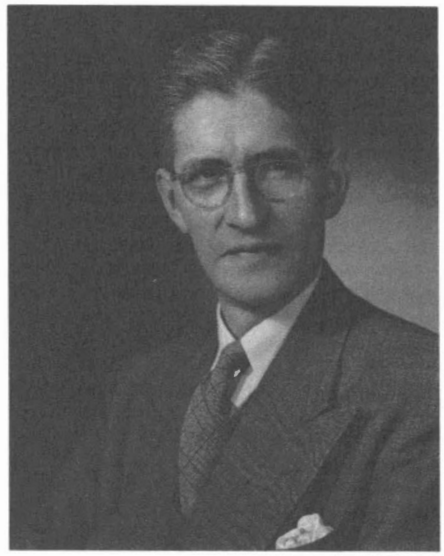
Metallic Minerals Research Laboratory - L.L. Sirois, (1961 -)
Ferrous & Less Common Minerals - G.O. Hayslip (1948 -)
Metallic Minerals Mill foreman - A.J. Boisonnault, (1948 -)
Non-Ferrous Minerals - R.W. Bruce (1948 -)
Industrial Minerals Subdivision - H.M. Woodrooffe
Ceramics - J.G. Brady (1952 -)
Special Ceramics, 555 Booth Street - I.F. Wright (1948 - 1974)
Construction Materials - N.G. Zoldners (1957 - 1974)
Industrial Minerals Milling - R.A. Wyman (1954 -)
Industrial Waters - J.F.J. Thomas (1947 - 1966)
Non-Metallic Minerals (Resource specialists) - R.K. Collings (1952 -), J.E. Reeves (1956 - 1969), C.M. Bartley (1957 - 1974), J.S. Ross (1957 - 1965), A.A. Winer (1962 -)
Ore Mineralogy - R.M. Buchanan (1955 -)
Preparation and Properties of Materials (Naval Section) 568 Booth Street - V.A. McCourt (1947 - 1972)

Extraction Metallurgy Division, 300 Lebreton Street:
Chief - Dr. K.W. Downes (1947 - 1974)
Secretary - Muriel MacCormack (1949 -)
Divisional Projects - H.W. Smith (1945 - 1974)
Industrial Liaison - C.S. Stevens (1964 - 1972)
Administration - G.W. Nolan (1948 - 1971)
Hydrometallurgy - W.A. Gow (1946 -)
Plant foreman - E.H. Devine (1948 - 1969)
Pyrometallurgy and Corrosion, 552 Booth Street - Dr. R.R. Rogers (1944 - 1969)
Research - Dr. T.R. Ingraham (1953 - 1972)
Chemical Analysis - J.C. Ingles (1949 - 1951)
Mineralogy - S. Kaiman (1946 -)

Mineral Sciences Division, 555 Booth Street:
Chief - V.A. Haw (1950 - 1959) and (1961 -)
Secretary - Victoria Nash
Administration - J.A. Hughes, Norah Doyle (1945 - 1972)
Mineralogy - Dr. M.H. Haycock (1931 - 1965)
Physical Chemistry - Dr. N.F.H. Bright (1953 - 1974)
Mineral Physics - Dr. J.D. Keys (1958 - 1967)
Physics & Electronics Group - Dr. J.L. Horwood (1947 -)



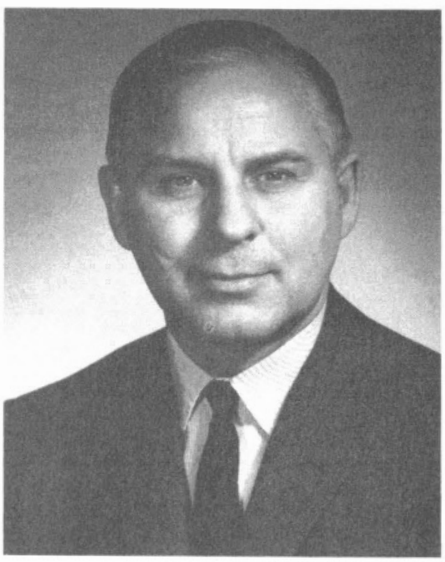
K.W. Downes (Photo - NFB)



A. Ignatieff (Photo - NFB)

Surface Chemistry Group - Dr. C.M. Lapointe (1945 - 1971)
Analytical Chemistry Laboratories - W.R. Inman (1946 - 1969)
Special Analysis and Research - G.H. Faye (1950 -)
Spectrography - Dr. A.H. Gillieson (1959 - 1975)
Metal and Mineral Analysis - W.L. Chase (1942 - 1966)

Fuels and Mining Practice Division:
Chief - A. Ignatieff (1947 - 1972)
Senior scientist - Dr. D.S. Montgomery (1948 -)
Administration officer - A.J. Reynolds (1935 - 1971)
Technical records - W.H. Harper (1927 - 1969)
Accounts - Betty Routliffe (1957 -), Phyllis Hughes (1960 -)
Fuel and Power - C.E. Baltzer (1923 - 1965)

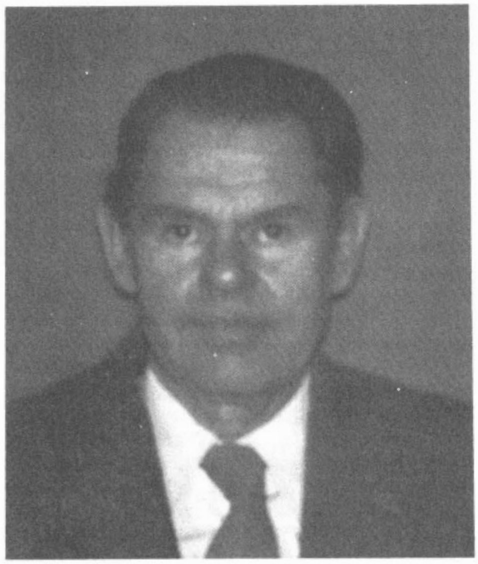


V.A. Haw

Special Projects (Bitumen and Heavy Oils) - K.W. Bowles (1931 - 1971), Dr. W.A.O. Herrmann (1956 -)
Mining advisor to director - M.A. Twidale (1958 - 1971)
Foreign information and exchanges - Dr. H. Frisch (1960 - 1970)
Coal and Peat Preparation & Surveys - T.E. Tibbetts (1952 -)
Edmonton Laboratory - Dr. J. Visman (1951 -)
Solid Fuels Laboratory - W.J. Montgomery (1948 -)
Carbonization - J.C. Botham (1948 -)
Metallurgical Fuel Engineering - Dr. J.H. Walsh (1955 - 1974)
Construction and Equipment - H.P. Hudson (1921 - 1969)
Petroleum Reservoir Engineering - Dr. R.P. Charbonnier (1954 -)
Petroleum and Gas Laboratory - R.G. Draper (1949 -)
Research on Bituminous Substances - Dr. D.S. Montgomery (1948 -)
Petroleum Process Engineering - F.L. Booth (1945 - 1975)
High Pressure Chemistry - W.H. Merrill (1947 -)
Catalysis - Dr. B.I. Parsons (1955 -)
Engineering Design - R.E. Carson (1948 -)
Plant foreman (Hydrogenation & Related Equipment) - L. Labelle (1925 - 1965)
Combustion Engineering Laboratory, 30 Lydia Street - E.R. Mitchell (1949 -)
Electric Equipment Certification Laboratory, 554 Booth Street - G.K. Brown (1948 -)
Explosives Research Laboratory (Uplands) - D.A.B. Stevenson (1951 - 1967)
Physics - 552 Booth Street (mostly rock mechanics) - Dr. W.M. Gray (1953 -)
Ottawa Research Laboratory, 30 Lydia Street - Dr. D.F. Coates (Head, Mining Research Laboratories) (1963 -)
Elliot Lake Laboratory - T.S. Cochrane (1951 -)
Glace Bay, Nova Scotia, Field Office - H. Zorychta (1951 - 1972)

Technical Services Division, 556 Booth Street:
Chief - S.J. Hayes (1941 - 1969)
Aministrative officer - H.W. Armstrong (1936 - 1972)
Electrical engineer - E.K. Swimmings (1953 -)

S.J. Hayes



E.K. Swimmings

Mechanical engineer - D.M. Norman (1961 -)
Chief electrician - P. Ferrigan (1943 - 1969)
Machine shop foreman - W.G. Robertson (1953 - 1972)
Carpentry shop foreman - M. Gadbois (1947 - 1972)
Stores - W.A. Martineau (1946 - 1970)
Transport foreman - L. Fleury (1953 - 1971)

Financial Resources

The table of annual expenditures for the period indicates the amount of funding made available to the Mines Branch.

Operating and capital (equipment) expenditures

Fiscal year ending March 31	Amount
1952	$ 2,221,755
1953	2,460,977
1954	2,622,474
1955	2,974,426
1956	3,024,814
1957	3,243,827
Calendar year	
1958	3,540,522
1959	3,690,292
1960	4,258,200
1961	4,836,584
1962	5,001,824
Fiscal year ending March 31	
1964	5,290,065
1965	5,677,414

It will be recalled there was a rapid increase in financial resources provided at the end of the last period (Chapter 5). Thus, from 1948 to 1951 expenditure rose from $0.7 million to $2 million; the foregoing table shows a somewhat slower growth except for the 1960 and 1961 increments totalling nearly $1.2 million, largely connected with the additional equipment acquired for the new building at 555 Booth Street. Thereafter the rate of increase slowed if accelerating inflation is taken into account. Furthermore, other branches, particularly the Marine Sciences, other than the Canadian Hydrographic Service, had to start from scratch. The Geological Survey had lagged behind Mines Branch in funding; thus in 1952 its expenditure was $1,437,000. In 1958 this had risen to $3.077 million, by 1962 to $6.026 million, and in the fiscal year 1964-65 to $6.955 million.

Publications

It was indicated in Chapter 5 that a new set of publications was set up to supersede the original series of Mines Branch reports going back to 1902 and the Memorandum Series to 1921.

The following remarks may be useful to avoid confusion in notations of text references.

Annual and semi-annual Reports of Investigation in type-set form were gradually phased out as follows: Mineral Resources and Mines, R 735-1932; Ceramic and Road Materials, R 726-1930/1: Fuels and Fuel Testing R 737, 1932; Ore Dressing and Metallurgy, R 797-July/Dec. 1938. No chronologically numbered reports including progress reports were henceforth published on the various projects of the divisions. Reports on completed research projects were published at irregular intervals either in the original report or Monograph Series that finally terminated with No. 874 in 1965 or in mimeograph form in the Memorandum Series that terminated with No. 137 in 1958.

During the war and for a period thereafter - in the case of uranium until the U.N. Conference on Peaceful Uses of Atomic Energy in 1955 - a very large proportion of R & D was classified to a varying degree and a small number of typewritten copies were issued with the remainder filed at the division level. There was also tacit agreement from the early days that industrial information related to work at the divisional level would not be disclosed without agreement of the enterprise concerned, and this was usually forthcoming after a time.

A Technical Paper Series was started in 1953 and was restricted to reports on the methods and results of research carried out in Mines Branch laboratories. A number described analytical methods for radioactive ores. These were reproduced by the offset method; seventeen such reports were published between 1953 and 1957.

An Information Circular (MR) Series was started in 1954 to accommodate publications of the Mineral Resources Division covering mineral commodities of topical importance, 26 reports being published between 1954 and 1957. These reports were continued as Mineral Information Bulletins after the division became a headquarters unit. Lists of operators of mines, mills and plants inaugurated in the 20's at the Mines Branch were also transferred with the division.

For clarity the old and the new series are set out below; abbreviations are used in text references:

Publication series for Mines Branch
old series

Publication	Duration	Last No. issued	Text reference
Reports and Maps (Including Monographs)	1902 to 1959	865	MB Rep
Bulletins	1909 to 1921	33	
Memorandum Series	1921 to 1958	137	
Technical Papers	1953 to 1957	17	MB TP
Information Circulars*	1954 to 1957	26	MB MR
Information Circulars**	1955 to 1956	3	MB IM

*Mineral Resources Division
**Industrial Minerals Division

New series

Publication	Start date	No. first issue	No. last issue	Date	Text ref.
Monographs	1959	866	880	1974	MB Rep
Research Reports	1958	1	282	1974	MB RR
Technical Bulletins	1959	1	196	1974	MB TB
Information Circulars	1958	102	316	1974	MB IC
Reprint Series	1965	1	132	1974	MB RS

All the above were catalogued by the Library and are included in the Government Sectional Catalogue 12, 1967. The last of the old series of Mines Branch catalogues was issued in 1946 (MB Rep 818). As in Haanel's time, Monographs provided reasonably complete coverage of a topic. Research reports represented a high proportion of original work, whether basic or applied. Technical Bulletins were reserved largely for technology. Information Circulars dealt with technical or economic subjects and reviews of research not involving descriptions of Mines Branch R & D work. An uncatalogued Mines Branch series also started in 1959: Investigation Reports designated MB IR, year and number of the report which had limited circulation as the series was largely concerned with industrial projects.

Internal or Investigation Reports also designated by the initials IR and year, including semi-annual progress reports to the director, were intended for limited circulation and were the responsibility of the divisions. The Physical Metallurgy Division published annual reviews on a restricted basis on special research projects. Reports of analyses and tests were reported at the divisional level. The divisional reports were not catalogued by the Library.

Departmental annual reports on the activities of the headquarters and branch during fiscal years ending March 31 became more impersonal and abbreviated from 1938. Naming of technical personnel engaged in research and investigations, as was the previous practice, was discontinued. The Geological Survey section of the annual report continued to name heads of field parties and projects until 1957. During the initial period of the new department from 1950 to 1956 the annual reports were supplemented by departmental reports titled: "Summary of activities for the calendar year". From 1957, the annual reports appeared on a calendar year basis and were illustrated. Towards the end of the period, from 1963 to 1965 the reports became very condensed. The first annual report of the Department of Energy, Mines and Resources for the fiscal year 1966-67 was published in 1968.

In 1961 Convey initiated an annual report titled: "Mines Memo" giving in considerable detail the research and investigations carried out during a calendar year, together with useful information on the staff, publications prepared, participation in committee work, etc. For the years 1961, 62, and 63, the dates were coincident with the year and the title, but because of delays in publication, the title date in later issues referred to the preceding year - thus "Mines Memo 1963" referred to the activities of 1963 but Mines Memo 1965" referred to 1964 activities. There was no 1964 issue.

The editorial aspect of the publication process deteriorated with time. As the department grew in size its editorial service was unable to keep up with the ever-increasing flow from the branches. It became necessary to rely on the branch's own resources for processing most of the reports with only monographs being handled by the headquarters editorial unit which included officers like D.R. Shenstone and V. McBride in the later years of the period. P.E. Shannon (1929 - 1972), drawn from the branch administration, was the only full-time editor but could not cope with the large number of branch publications. A proportion of the more urgent reports devolved on the director's executive assistants W.H. Norrish (1936 - 62) and F.T. Rabbitts who returned from the Eldorado Company in 1961, remaining in the director's office until 1972. These officers were conscientious, Rabbitts having the added advantage of a trained scientific mind, but both Norrish and Rabbitts had other responsibilities. Division reports with few exceptions were edited at the divisional level. Typing of reports for offset reproduction was a further difficulty owing to the shortage of trained staff.

Priorities

In the initial period when the Mines Branch was the prime federal agency concerned with R & D on improved analytical and treatment methods of radioactive ores and was also making an important contribution in the physical metallurgy of materials for atomic energy reactors, the Radioactivity and Physical Metallurgy Divisions were generally considered to have top priorities, although the other divisions were not overlooked. After the end of the Korean war and the transfer of metallurgical work at Chalk River to the Atomic Energy of Canada Limited, the thrust of programs became more general. The complexity of problems presented for solution by industry gradually increased as the large lower-grade deposits were opened up and increased recoveries of metals and minerals were sought. The experience with hydrometallurgical methods for treating radioactive ores was in part responsible for the formation of the Extraction Metallurgy Division. Here, following some physical pretreatment, chemical treatment was standard for various radioactive ores, essentially to make economic recoveries. The beneficiation of many lean iron ores also became a requirement as Canada was not only able to meet domestic requirements but had a large surplus for export as well.

The downturn of the coal industry became rapid after 1950, but due to the director's policy and support from the Dominion Coal Board, financial resources were provided to continue R & D activity on coal in the Fuels Division. Coal received a bigger share of staff allocation than did the petroleum group, which was involved not only in considerable scientific research but also in designing and constructing complex bench-scale and scaled-up apparatus. Additional resources were proposed but they did not materialize until the "energy crisis" of the seventies.

Mining research received priority treatment by the director, doubtless influenced by the findings of a report he prepared in collaboration with V.A. Haw to the National Productivity Council indicating that only 3% of R & D expenditures out of a total of $12.6 million per annum was allocated by industry to mining research, and only 2% of R & D expenditure out of a total of $7.5 million per annum in 1961 was spent on mining research by government agencies (95). Although most of the mining research studies in the first five or six years were concerned with the violent relief of stress in coal mines, research in hard rock mining, notably in the Wabana submarine iron mine in Newfoundland, substantially widened the scope of mining research in the Fuels Division. This was renamed "Fuels and Mining Practice Division" in 1959. An important stimulus to this trend was opening of the Mining Research Laboratory at Elliot Lake in 1964.

Industrial minerals received attention from the director in the light of the post-war growth of this segment of the mineral industry. Thus, the production value of industrial minerals in 1947 was $140 million and this increased to $844 million or by a factor of six. In spite of discontinuing Industrial Minerals as a separate division after 1959, H.M. Woodrooffe, who had been head of the Non-Metallic Minerals Section in that division, became responsible in the Non-Metallic Minerals Subdivision of the renamed "Mineral Processing Division" for nearly three times more professional staff than there had been in the Metallic Minerals Subdivision. This was understandable as metallic ores were the responsibility of the Mineral Processing Division using physical concentration and the Extraction Metallurgy Division was responsible for the hydrometallurgical R & D work on metal ore with its more costly and complex technology.

It should be emphasized that with the exception of one or two minerals such as asbestos and potash that enjoyed a sizable export trade, most industrial minerals were exploited by relatively small Canadian companies not possessing the resources for research and development of the larger multinational companies. Their markets were specialized and these low-priced minerals required various degrees of purification at minimum cost. It is therefore not surprising that these companies looked to centres like the Mines Branch for advice on their processing problems.

Problem Solving

Historically the Mines Branch has been an institution that has had to find solutions to problems, large and small. Most of the large problems were connected with self-generated programs offering alternatives to the importation of better quality mineral resources like coal and some industrial minerals by encouraging the use of domestic resources. This was for the purpose of developing economic upgrading processes, to improve their ability to compete with imports. Smaller problems arose from such industry or user inquiries as analytical difficulties, poor recovery in processing, impurity of products, metal failure, etc. There has been the mistaken view, even recently, that Canada, having attained a high standard of living, possesses all necessary skills for achieving economic prosperity. Unfortunately this is untrue - although there are many skills there are also gaps. Numerous private consultants offer specialized services but most cannot afford to operate research laboratories. Few commercial laboratories were prepared to undertake a research investigation of the scope performed by organizations like the Battelle Institute or the many R & D foundations attached to the U.S.A. universities. Canadian universities also conduct considerable research, but such projects have to be integrated with graduate studies. On the other hand, mineral processing in Canada was becoming better served by commercial laboratories. Until the "energy crisis" in 1973, fossil fuels however were not so well served. There was little formal training or research at the universities and there was a very limited number of independent specialists and laboratories concerned with fossil fuels and energy in general outside government and public utility laboratories. There were oil companies and thermal equipment manufacturers who derived much of their expertise from parent organizations abroad.

Because of the new performance evaluation program for research scientists, some of the Mines Branch staff recognized by industry and users as the most knowledgeable in their fields were placed in the difficult position of justifying their time spent on solving problems that would benefit Canadian industry in general.

Physical metallurgy was a good example of "trouble shooting", much of it done for the defence services who were major supporters and users of the Physical Metallurgy Division's facilities and knowledge.

The reason that the Physical Metallurgy Division achieved a priority position in the Mines Branch after the war was largely because of the versatile experience and knowledge gained by the then comparatively small - for the size of the country - but vigorous group of scientists and engineers in that division. They had to meet exacting demands not only on the properties of metals and alloys but also in utilizing a wide variety of fabrication techniques for rugged warfare conditions on land, sea and in the air. It is not surprising that the division became a repository of much classified knowledge during the war, and hence, the staff were inevitably drawn into problem solving. This is possibly not so much the case today because various industries and the users themselves are very much better informed. The following examples are typical of the investigations carried out in the first ten years of the Physical Metallurgy Division after it was formed in 1949:

(a) Maximum tolerances of various stray elements in scrap iron were determined as a guide to the steel industry, e.g., tin in quantities over 0.05% had deleterious effects on properties of wrought and cast steel.
(b) An investigation of hot impact extrusion of shells found this process could give a substantial saving of steel which was then in short supply.
(c) In connection with post-war naval shipbuilding, the division recommended procedures in producing the first naval steam rotor forged in Canada and supervised inspection and testing.
(d) Two Canadian clays were investigated to determine their use as bonding agents for foundry moulding sand and both were found to be more suitable than imported varieties; a similar investigation involved the testing of waste sulphite liquor as a core bonding agent and determined best core mixtures.
(e) Inadequate ductility in plain carbon, low alloy and austenitic manganese cast steels presented a constantly recurring problem to steel foundrymen; during 1953, the division investigated 11 such cases for Canadian industry and its recommendations enabled the producer to meet the specified ductility requirements.
(f) An investigation was carried out at the request of industry on pig iron electrically smelted from pyrrhotite tailings from the Sullivan mine in British Columbia and showed that steel produced from this iron compared favourably in mechanical properties with good commercial-grade structural steel and led to the construction of a smelter.
(g) The effect of boron and rare earth additions on the mechanical properties of a low-carbon cast steel originally developed in the United Kingdom for wrought products was investigated. The boron addition was found to increase the yield strength by about 50% without loss of ductility. Rare earth additions had no effect on the tensile properties of the steel but partly restored the impact values which were lowered by the boron additions.
(h) A number of stress analyses were carried out under static and dynamic conditions. A large magnesium alloy loading ramp, a "cobalt 60" beam therapy unit, and a 2 1/2-ton army truck were typical of the structures studied. The major stresses were determined under actual operating conditions, and where found to be excessive, corrective design changes were recommended.
(i) The branch was consulted by the St. Lawrence Seaway Authority on the welding, casting, forming and designing of various units such as lock gates, stop logs, lifting booms, segmental cast steel girders and steel for barges. Plants manufacturing some of these fabrications were visited and advised on production problems.
(j) The Department of National Defence was assisted in determining the effectiveness of leak-preventing seals for special bronze parts in the manufacture of aircraft propellers.
(k) Engineers of the Physical Metallurgy Division made a critical comparison for the Canadian railways of the steel made by the basic oxygen process with that by the open hearth process and found them equal.

Recipients of the Coronation (HM Queen Elizabeth II) Medal in 1954; not in this picture are Capt. W.R. Inman RCNR and Com. V.A. McCourt, RCNR who crossed the Atlantic on the HMS Magnificent for the Occasion and Dr. Maurice Lavigne (Head of Mines Research Lab, Chalk River)

Sitting: Emile Chartrand (1913 - 1956), M.S. Ralph (1919 - 1956) (Explosives and Mines Branch), Archie Rogers (1924 - 1956)

Standing - Lawrence Lutes (1916 - 1967), Walter Kritsch (1913 - 1956), George Renaud (1914 - 1956), Wilbert Norrish (1912 - 1962) (Dept of Interior and Mines Branch), Hector Picher (1917 -1954), Norm MacPhee (1941 - 1957), Cam Fresque (1912 - 1960)

METALS

The three metals that received priority attention in the Mines Branch during the fifties were uranium, titanium and iron. The production of uranium and iron experienced exponential increases from low production levels despite having to face ore treatment problems. The objective of producing titanium metal in Canada was not attained.

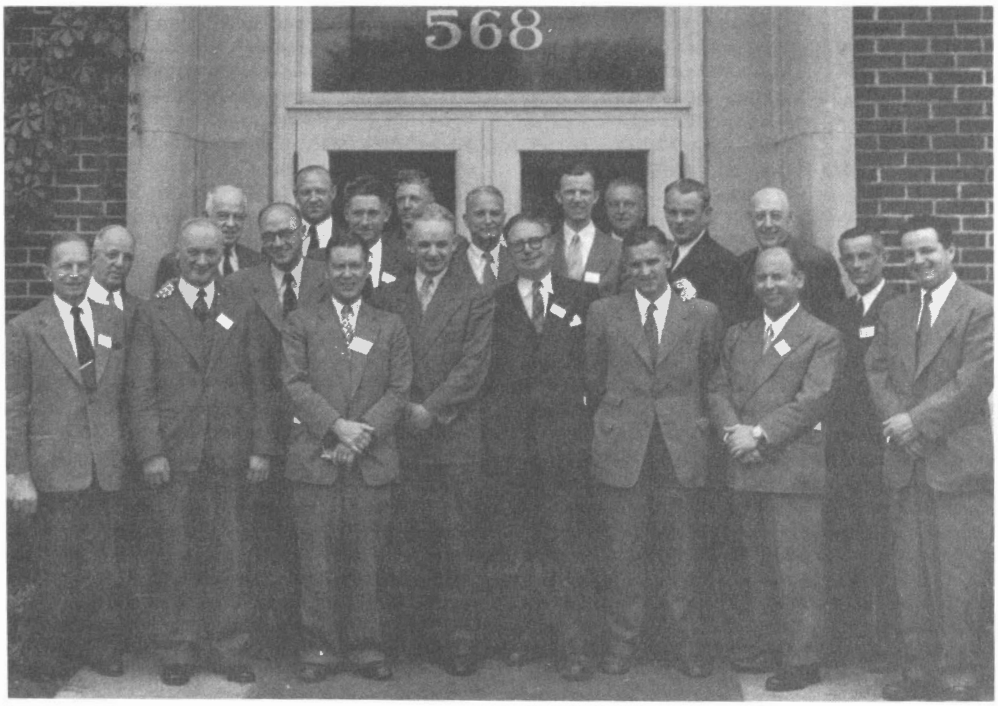
Uranium

A Challenge

Research achievement in scaling up uranium extractive metallurgy plants is a story of Canadian endeavour involving both the public and private sectors of the mineral economy. It was remarkable for coordination and execution, demonstrating again that humans can rise to the occasion when challenged to attain a well defined goal.

The story started with the 1929 uraninite discovery in Ontario and more particularly with the 1930 discovery of high-grade pitchblende by Gilbert Labine in the Northwest Territories, culminating with a virtual "crash" program from 1948 to 1957. In this ten-year period a major Canadian uranium industry was developed almost from scratch with a handful of dedicated persons who produced industrially feasible methods of analysis and treatment for a complex and hazardous group of mineral resources. The period straddled the succession of the directorship from Parsons to Convey. In the Parsons period as mentioned in Chapter 5, the program was under security wraps and the only technical reports disclosed were on methods of analysis starting with the first annual report of the Department of Mines and Technical Surveys for the fiscal year ending March 31, 1950.

The association of the Mines Branch with Eldorado Gold Mines Limited will be recalled from Chapter 4. The ores of the Port Radium mine were high-grade pitchblende-silver-lead with a uranium oxide (U_3O_8) content of 30 to 55% and a silver content of 4 to 360 ounces per ton. Milling commenced in 1933 recovering a gravity concentrate of pitchblende, and silver. The concentrate was shipped to the Port Hope refinery in Ontario for the recovery of radium and silver. The mine closed in 1941, re-opening the following year to become the sole Canadian producer of uranium, the



Organization for European Economic Cooperation (predecessor of OECD) 1952

1st row - (l. to r.): J. Fischer (France); D.T. Flood (Ireland); G. Heberlein (Switzerland); John Convey (Mines and Technical Surveys); G.R. Delbart (France); J. Knox (Great Britain); F. Savioli (Italy); R.A. Bowman (U.S.A.);
2nd row - (l. to r.): R.E. Gilmore (M.&T.S.); N.C. MacPhee (M.&T.S.); C.F. Kearton (Great Britain); J. Hennenhoffer (Germany); R. Gadeau (France); A. Thunaes (M.&.T.S.); H. Speicher (Germany); R. Major (Norway); M.F. Goudge (M.&T.S.); K. Zierold (Germany); R.J. Traill (M.&T.S.); M. Prettre (France)

"parent" radioactive element for the "Manhattan" project.

The Eldorado company became a crown corporation with the name of Eldorado Mining and Refining Company (1944) Limited, renamed Eldorado Nuclear Limited in 1966. In 1948, the crown corporation was given the responsibility at its Port Hope refinery, established by the private company, of refining all uranium oxide concentrates produced in Canada, a policy still in force.

The association of the Mines Branch with the private Eldorado company continued throughout the pre-World War II period, mostly by visits to the Port Hope refinery where the gravity concentrated mine product was chemically treated following Traill's hydrometallurgical research work of the early thirties in the Mines Branch. Improved recovery of radium remained a desideratum during this period.

After takeover of the private Eldorado company by the crown corporation, the association became even closer. The first tasks undertaken by the group formed by Parsons in 1945, known as the "Eldorado group" until formation of the Radioactivity Division in 1948 as told in Chapter 5, were to find a solution for the persistent problem of low overall recovery of uranium at the Port Radium operation and improved physical and chemical analytical methods for accurate determination of uranium in low-grade ores and concentrates. The Geological Survey of Canada played an important part in determining the wide-spread occurrence of radioactive ores. In this connection it should be recalled that radioactivity was detected during the survey of mineral waters by Satterly and Elworthy in the early part of World War I (Chapter 3). In 1953, E.A. Brown presented a paper on activities of the Radioactivity Division to the Annual General Meeting of The Canadian Institute of Mining and Metallurgy in Edmonton.

In a contribution to this paper, Parsons spoke on the question of whether physical methods could have been used to improve the gravity circuit at the Eldorado mine. He assigned J.S. Godard who had been with the Ore Dressing staff of the Mines Branch from 1922 to 1931, and W.T. Turrall who was with the Industrial Minerals Division from 1941 to 1949, to determine definitively by a thorough study of the physical nature of the ore whether physical concentration could achieve improved recovery. The conclusion was that physical means did not hold much promise. Parsons commented that he had already formed the opinion that only a chemical leaching method would achieve the goal of optimum recovery and gave credit to Professor Gaudin's "enthusiasm" for the first real progress made. Both Parsons and Brown referred to the difficulty of making physical and chemical analyses, which became particularly important after the 1948 government decision for private industry to resume large-scale exploration and development of uranium ore deposits. There were few trained chemists and assayers knowledgeable in radioactive ores at that time. Considerable and persevering R & D work was required to perfect analytical, and particularly chemical methods of analyzing low-grade ores. Analytical procedures for control analysis had to be tailored to various process steps and products. Coordination with U.S. and U.K. agencies increased as the Canadian effort was being recognized. When a method was considered reliable, the division made it public though a report or scientific paper. The Mines Branch also trained staff for industry in the Ottawa laboratories or sometimes on site.

In his CIM paper, Brown indicated the Radioactivity Division staff distribution by section in 1953, as follows: Mineralogy, 3; Analytical Chemistry, 24; Physics and Electronics, 9; Ore Treatment, 18; Supervision and Administration, 6; total, 60, of whom 33 were involved in analysis (96). At the peak of activities in 1954-55, staff numbered 65, with about another 30 Eldorado and private industry personnel.

The first major project undertaken by the division in 1948 in conjunction with the Eldorado company was in developing an acid-leach process for the complex ore of the Port Radium mine. Preliminary mineralogical and chemical research was followed by a pilot plant investigation in Ottawa, and then by a large-scale experimental plant in 1950 at Port Radium, in which the Mines Branch staff participated. In 1951 the old gravity plant burned down and a new one was immediately built incorporating revisions to the flowsheet suggested by the Mines Branch staff. An acid-leach plant was commissioned in May 1952 and soon thereafter the recovery of U_3O_8 increased by about 30%. The plant was also used for treating old dump tailings. The paper "Development of the Port Radium leaching process for recovery of uranium", (MB TP 13), was prepared by the staff of the Radioactivity Division in 1955, and was reprinted in 1956. Arvid Thunaes, chief of the Radioactivity Division, regarded the Port Radium acid leach plant as a pioneering step in Canadian milling of uranium ores as the various process steps and equipment set a pattern for most of the later plants (97). The recovery of uranium from the solution, or pregnant liquor, was effected by reduction with aluminum powder, the tetravalent uranium combining with arsenates and phosphates leached from the ore to precipitate the insoluble uranous compounds; these were then converted to metal-grade uranium trioxide in the Port Hope refinery.

Pitchblende ores of a lower grade than those of Port Radium were found in northern Saskatchewan near the border with the Northwest Territories, in the Lake Athabasca area. In 1951, the second large R & D project was started on ores from this area, one ore being from the Ace property, a pitchblende associated with carbonate minerals occurring on Eldorado's claims in the Beaverlodge area, and the other an ore in a granite environment from the Charlebois Lake area. Initial acid leaching of the Eldorado Ace ore was changed to sodium carbonate leaching because of high acid consumption caused by the carbonate minerals. Both pressure and atmospheric alkaline leaching methods were developed for this ore. Pilot plant tests were carried out initially at Booth Street using pressure leaching. Simultaneously, a full-scale, 500-tpd plant employing autoclaves was being installed at Beaverlodge. Eldorado staff recruited for the Beaverlodge mill was trained at the Mines Branch for several months. The Beaverlodge mill started production in 1953 and in the same year Eldorado built a larger experimental atmospheric pressure leaching plant in rented premises on Carling Avenue, testing the process for some five months in participation with the Radioactivity Division. This work was translated to a second leaching circuit in the Beaverlodge mill in which pachuka tanks 34 ft high were used in lieu of autoclaves, raising mill capacity to 750 tpd. At that time Eldorado served as a custom plant for treating ores from small privately owned mines in the neighbourhood. In 1955, Eldorado decided to enlarge the Beaverlodge mill to

2,000 tpd using the atmospheric sodium carbonate leach cycle enabling ore from the new Verna mine to be treated as well.

In 1953, Thunaes accepted a position as manager of the Research and Development Division of the Eldorado Mining and Refining Company, and was joined by Rabbitts in the newly set up R & D group. E. Brown became chief of the Radioactivity Division with H.W. Smith as his deputy. J.C. Ingles replaced Rabbitts as chief chemist. A cordial relationship continued between the Mines Branch and the Eldorado company, but as the latter was developing its own research organization the Mines Branch was able to attend to progressively increasing demands from private industry.

In 1953, the first private company - Gunnar Mines Limited - with a property on Lake Athabasca in northwestern Saskatchewan close to the common border with the Northwest Territories and Alberta, applied for a complete preliminary mineralogical, chemical and physical treatment investigation to be followed by a pilot plant run. The ore was less complex than that of Port Radium and acid leaching followed by ion exchange recovery of U_3O_8 was recommended. The investigation was carried out between August and October 1953, when mill design commenced together with ordering of equipment, this being completed in one year. The plant was commissioned in 1955 (98).

The Gunnar investigation was followed by a period of intensive investigation for a large number of prospective mines that sprang up in the Blind River-Elliot Lake and Bancroft areas of Ontario. This activity eventually increased Canadian uranium ore reserves substantially although these ores were of low grade. All the ores were amenable to acid leaching and ion exchange recovery of U_3O_8.

A standard procedure was evolved at the Mines Branch that included making mineralogical and chemical analyses and evaluating samples by a bench-scale acid-leach process. This procedure determined process variables such as size of grind, acid and oxidizer requirements, temperature, contact time, acidity - all of these data serving to guide the design of the initial pilot plant run. Alterations in process variables in subsequent pilot plant operations were introduced from run to run as necessary. The pregnant liquor was then treated in ion exchange columns followed by elution and precipitation to produce the solid uranium concentrate.

E. Brown

The first Eastern ore to be tested was from Pronto Uranium Mines Limited, Blind River. Altogether 8 acid leach and 7 ion exchange pilot plant runs were completed and reported on during 1954. In addition 17 reports - mineralogical, small-scale tests, trial precipitations and summary reports - were prepared over the period from 1953 to 1955, as well as a total of 32 special reports in the classified series.

The principal staff involved in this R & D work and authors of the reports were: mineralogy - S. Kaiman (1946 -); preliminary laboratory tests and leaching runs - R.P. Ehrlich, R.M. Ennis, J. Brannen (1948 - 1962), E.G. Joe (1952 - 1955 and 1972 -), and H.H. McCreedy (1954 -); uranium extraction from the leach liquor - V.F. Harrison (1947 - 1978), R. Simard (1948 - 1962), A.J. Gilmore (1948 -), and K.D. Hester (1949 - 1954).

It should be noted that Ehrlich and Ennis were from Mine Consultants Limited of Toronto. Ennis became mill superintendent at Pronto, and Ehrlich and Hester both joined the Rio Tinto management team during development of that company's several properties in the Elliot Lake area (99). Shortly after the closure of Pronto on expiry of its uranium sales contract, Ennis joined the Mines Branch as industrial advisor in the newly created Extraction Metallurgy Division in 1959. He died suddenly in 1963. Overall responsibility and guidance were provided by E. Brown, chief (1948 - 1958), his deputy, H. Smith (1945 - 1974), and W. Gow (1946 -), head of the Ore Treatment Section. There were also D.K. Presgrave and A.D. Smith on secondment from CSIRO in Australia as in the case of Kelsall earlier. The Pronto mill was commissioned in October 1955. It is appropriate to give an extract from a speech by F.B. Joubin, managing director of Pronto, on the occasion of the opening:

"It gives me great pleasure to add some observations and some names to the record of accomplishment that is the Pronto Mine....

"But before we could have a mill or even know if our uranium was commercially extractable we had to understand the metallurgy. For this task we selected Reini Ehrlich. His only qualifications were that he was young, ambitious and did not scare easily. This last was very important because with the Pronto ore we were working with a uranium mineral called brannerite that had never before in the world been commercially exploited. Ehrlich picked a small team of able and ambitious research men including Ron Ennis, Ken Hester and others. With the talent and cooperation of some of Dr. John Convey's staff in Ottawa including Dr. Ernie Brown, H.W. Smith and Sol Kaiman, Ehrlich and his team developed a highly efficient technique that may now become universal for the treatment of brannerite ores."

The first of the Elliot Lake ores to be evaluated was from the Quirke mine of Rio Algom, requiring 23 Special Reports of the classified series during the period from 1954 to 1955. The authors involved were: W.R. Bull, (1952 - 1956), R.M. Ennis, A.J. Gilmore, V.F. Harrison, K.D. Hester, W.R. Honeywell (1948 - 1973); M.R. Hughson (1952 -), E.G. Joe, (1952 - 1955, 1972 -) G.D. Lutwick (1954 - 1956), V.M. McNamara (1954 -), J.A. Poulin (1949 -), and R. Simard (1958 -

1962). Subsequent ores did not require as lengthy investigations because of their similarity, particularly those in the Blind River and Elliot Lake areas, and because the staff acquired the ability to predict. In 1956, the Algom Quirke mine at a rated capacity of 3,000 tpd became the first producer in the Elliot Lake area, the largest in Canada up to that date, and Bicroft became the first in the Bancroft area at a capacity of 1,200 tpd. By 1956, the daily production of uranium ore in Canada amounted to some 7,500 tons. A comprehensive account of the status of the uranium industry was published in the Canadian Mining Journal in the June issue of 1956 covering geology, mining, and milling and for which D. Keyes head of AECL wrote a special article "Our future sources of power" (100).

Considerable laboratory-scale investigation of small-diameter drill core samples was carried out for several companies at Elliot Lake to obtain data for plant design enabling mill construction to begin to be ready to receive ore by the time shafts were sunk 2,000 ft or more to reach the orebodies. Included in this group were Northspan Uranium, Can Met Exploration, Milliken Lake, Stanleigh and Stanrock. In 1957, Consolidated Denison, the Nordic mine of the Algom company, Northspan, (Buckles and Lacnor mines) and Can Met Exploration at Elliot Lake, Faraday in the Bancroft area, Lorado in the Beaverlodge area, and Rayrock in the Northwest Territories all started production. Each of these companies used the acid leach and ion exchange methods pioneered by the Mines Branch, for which five patents were granted. The foregoing names do not exhaust the list of mines whose ores were initially evaluated at the Mines Branch. By 1958 some 19 uranium mines in Canada were producing about 40,000 tons of ore per day, about 75% from the Blind River-Elliot Lake area, 10% from the Bancroft area and 15% from Beaverlodge and the Northwest Territories. Most mills had one or two staff members who had received some training at the Mines Branch laboratories.

Metallurgists working in industry were responsible for making many improvements, both in the unit processes and in mill equipment, by introducing new and more efficient flocculants for settling and filtering leach pulp, as well as better autoclaves, heat exchangers, and corrosion-resistant milling equipment. A spin-off from the uranium industry was that precision control instrumentation was introduced to a much greater degree in cyanidation and leaching circuits in other metal mines. Undoubtedly the recovery of metals from low-grade ores in general benefited from the research and development as well as operational experience of the 1950's on uranium ores in Canada and other uranium-producing countries.

It may be appropriate at this point to describe briefly the complex nature of the ores and the chemistry involved in the extraction of uranium.

Mineralogical Analysis

Mineralogical evaluation was an important tool in the light of the variety of minerals associated with uranium ores. Although of primary igneous origin, uranium was largely deposited as ores from magmatic or intrusive emanations in various host rock environments. The largest Canadian reserves were, and at this writing are, in the Blind River-Elliot Lake area. To these more recently have been added ores in the adjoining Agnew Lake area to the east. The deposits are in a sedimentary environment - a pyritic quartz pebble conglomerate not unlike the "Banket" of the Witwatersrand - the principal uranium source being a titanate of uranium or brannerite, some uraninite, and also small amounts of thorite. The Bancroft ores occur in pegmatite dykes in metamorphic rocks with uraninite and uranothorite as the principal minerals, thorium content being much higher than in most other Canadian ores. Most other ores in the pioneering days of the 1950's included the northern ores at Beaverlodge in Saskatchewan and in the Northwest Territories. These were of the vein type, broadly described as of hydrothermal origin, the principal uranium mineral being pitchblende with little or no thorium. A secondary oxidized mineral, uranophane, was identified in the Gunnar mine. A high proportion of ores, particularly those in the east were of low grade - under 1% U_3O_8 - and were associated with many undesirable minerals including metal traces that had to be removed to meet impurity limits for acceptable refinery feeds.

Chemical Treatment

With the exception of ores associated with basic minerals like calcite in the Beaverlodge area, which were large acid consumers, most Canadian uranium minerals at that time were easily dissolved by a relatively weak acid solution at normal temperatures although brannerite usually required solutions that were both stronger and hotter.

Ion exchange recovery of U_3O_8 from the pregnant liquor was by preferential adsorption of uranium ions on a bed of ion exchange resins, thereby avoiding the simultaneous precipitation of unwanted impurities such as iron. A further advantage of this process was that a volume of eluting solution smaller than the original volume of the leach liquor was required in washing the preferentially adsorbed U_3O_8. The eluting solution was sulphuric acid and common salt from which the U_3O_8 was precipitated with magnesia. Later, some industrial plants adopted sulphuric acid and ammonium nitrate for elution, and a two-stage precipitation with lime followed by sodium hydroxide to produce a higher-grade concentrate.

The dried concentrates were sent to Eldorado's Port Hope refinery, where purification was based on digestion in nitric acid followed by solvent extraction using a weak solution of an organophosphate (tri-butyl phosphate) in kerosene. This was followed by stripping of the solvent to extract uranium as uranyl nitrate. A reactor-grade uranium trioxide was produced by evaporation and denitration. All the nitrate in solid or vapour form was recovered in this process which was introduced at Port Hope in 1955.

In the initial urgent period of 1948 to 1955, ion exchange concentration was found to suit the majority of mines without primary preconcentration by gravity methods. This was particularly the case for most mines located in the Blind River-Elliot Lake area. The process was reasonably cheap and a further consideration was that the Eldorado refinery accepted concentrates in the range of 50 to 85% U_3O_8, with prescribed limits of impurities.

In solvent extraction, the ion exchange resin which preferentially traps the uranium ions was replaced by an organic solvent with similar selectivity. The rich liquor had to be "unloaded" or "stripped" of the uranium ions which were then precipitated in the final recovery of the high-grade product.

In 1955, probably related to the decision by Eldorado to install a solvent extraction plant at Port Radium, a study was started on the evaluation of organophosphates and amines as solvents and of stripping agents. These studies were conducted by R. Simard and A. Bellingham (CSIRO, Australia), who spent a considerable time in 1956 at Port Radium to assist in the setting up and operation of a pilot plant. A full-scale solvent extraction plant, the first in Canada, was commissioned in 1958. In general, tertiary amines gave the best extraction results. The studies were continued into 1957 and included the use of magnesium stripping of the uranium-loaded amine solvent, but the results were not entirely satisfactory because of losses of the organic reagents.

These, and somewhat later solvent extraction studies in 1958 and 1959 led to the concept of treating ion exchange eluates at the mills to produce high-grade uranium products both for reactor use as well as for isotope manufacture. Simard, Gilmore, McNamara and later H.W. Parsons (1959 -) and H.W. Smith were involved in this work and issued several internal reports before preparing a final publication in 1961 (101).

Because a considerable amount of thorium from the Bancroft mills was going to waste, studies were undertaken in 1957 to investigate the possibility of recovering thorium by solvent extraction. Preliminary studies of ion exchange solutions from the Bancroft and Faraday mills were made in Ottawa followed by operation of a pilot plant at Faraday treating 10-15 tpd of solution. The solvent was an amine in kerosene, and both sodium carbonate and sodium chloride were used as stripping agents. The final product was 98% pure thorium oxide. Simard was assisted by Mines Branch technicians A. Poulin and R. Warner (102).

The peak year for the Radioactivity Division was 1955. An indication of the extent of its activities may be seen from records for the fiscal year ending March 31, 1956: 35 mineralogical examinations; 96 samples treated of which 38 were from Ontario, 35 from Saskatchewan, 9 from each of the Northwest Territories and Quebec, 2 from British Columbia, and 3 from Australia; and 18,149 assays were made on 13,053 samples requiring 22,591 determinations. In the crowded conditions of the Quonset huts for both humans and equipment, this represented a remarkable achievement - obviously the staff did not watch the clock! Yet there were no accidents. Pilot plant runs were of several weeks' duration, seven days a week, 24 hours a day; however no one was affected by radiation.

It was demonstrated by the uranium program that, provided the sample was representative of the ore, a very large scale-up factor between pilot and industrial plant could be relied upon using chemical treatment. The pilot plant treated about half a ton per day whereas an industrial plant treated a thousand or more, yet the operating data from the plants after commissioning checked closely with data from the pilot plant. Thus cost estimates based on the experimental data could be used with a high degree of confidence for designing the full-scale plant (103).

A striking feature of the program was the rapidity with which it was carried out, probably the fastest in Canadian mining history. The whole "critical path" operation was completed in a period of two to three years from the time a private enterprise decided to bring in a mine at the prospect stage. This included testing of samples for preliminary and pilot plant evaluation, plant design, equipment acquisition, and mill construction and commissioning. This performance surely bespeaks of a high degree of cooperation and teamwork.

There was considerable liaison and exchange of information as well as of visits to R & D establishments in U.S.A. and elsewhere. Three Canadian universities were involved in the research program - British Columbia in particular, with Prof. Forward's pressure leaching method related to the Rexpar mine in B.C., Alberta and Queen's - all of which had research grants from the Atomic Energy Control Board.

Chemical Analysis

The importance of analysis for both assay and control purposes cannot be over-emphasized, as indicated earlier by staff requirements and work volume that grew from the early beginnings in 1946 to a peak in 1955. Continuous research and analysis was carried on by the need for accuracy in dealing with the increasing volume of not only low-grade and complex uranium ores (Chapter 5) but with uranium concentrates. Two new methods of analyzing concentrates evolved: a fluorometric method which was almost free of interference from other elements but limited in its basic precision "The determination of uranium in concentrates by the fluorophotometric method" by J.B. Zimmerman, F.T. Rabbitts and E.D. Kornelsen (MB TP 6, 1953) and a colorimetric method which was occasionally subject to interference but had higher inherent precision "The determination of uranium in uranium concentrates using ethyl acetate" by R.J. Guest and Z.B. Zimmerman (MB TP 8, 1954).

In the early period up to 1955, the main preoccupation was to perfect analytical methods for accurate quantification of the large number of metallic compounds associated with uranium and thorium ores, such as copper, aluminum, molybdenum, niobium, tantalum, etc. Thus two analytical methods for copper and aluminum were reported in 1953 - "The colorimetric determination of copper with 2,2-diquinolyl in minerals and ores" by R.J. Guest (MB TP 3, 1953); and "The determination of aluminum by the fluorophotometric method" by J.B. Zimmerman (MB TP 4, 1953).

After 1957 and the early part of 1958 when all of the mills had been commissioned, more attention was given to new analytical methods for uranium and thorium that might be applied in the mill. Research on solvent extraction methods of recovering uranium underlined the need for better methods of detecting traces of chemicals in solution. Considerable success was achieved in developing recovery methods for all solvents and inert diluents used in the work. The Chemical Analysis Section worked on joint projects with officers of the ore treatment group.

Several reports in the new series of Research Reports were issued at that time as follows:

- "Effect on reagent consumption of recycling solutions in the weak acid leaching of a uranium ore" by V.M. McNamara and W.A. Gow (MB RR 28, 1958);

- "Some solubility studies in the system: thorium carbonate-sodium carbonate-sodium bicarbonate-sodium sulphate-water" by J.C. Ingles and F.J. Kelly (MB RR 32, 1958);
- "Recovery of uranium from an acid leach liquor, using an ion exchange resin and sodium carbonate and bicarbonate as eluting agents" by E. Kornelsen, V.M. McNamara and J.C. Ingles (MB RR 33, 1959);
- "'Thorin' colorimetric method for thorium determination: effect of some common ions and methods for overcoming interferences" by J.A.F. Bouvier and R.J. Guest (MB RR-34, 1958);
- "Elution with carbonate solution of an ion exchange resin loaded with uranyl sulphate" by V.M. McNamara and W.A. Gow (MB RR 43, 1959);
- "Some analytical applications of solvent extraction from sulphate solution with long chain alkyl amines" by R.J. Guest and J.A.F. Bouvier (MB RR 43, 1959).

A resin-life testing apparatus was set up to evaluate ion exchange resins and research was undertaken on the separation of rare earths from thorium minerals; it was reported in "Studies in the separation of the rare earths from thorium in sulphate solutions using cation exchange resins" by D.C. Lewis (1957-58) and J.C. Ingles (MB RR 31, 1958).

The demand for accuracy of analysis in the complex and wide range of ore and concentrate grades was crowned with success and certainly advanced the knowledge and skill of analytical chemistry.

The chemistry laboratory of the Radioactivity Division acted as umpire between Eldorado and private companies for the concentrates delivered to Port Hope for refining.

Throughout this period there was considerable training of external personnel and exchange visits between industry and the Mines Branch. Cooperation with industry was close, even to the extent of setting up fluorometric analysis in their laboratories. A complete manual for the analytical control of uranium milling processes in three parts was prepared by Ingles in loose leaf binder form and was catalogued in the Monograph series in 1959 (104).

Physics and Electronics

This section was responsible for all radiometric assaying of ores which included not only laboratory but also field testing. The peak was reached in the fiscal year ending March 31, 1951 when 2,433 assays were made. In addition, considerable research and development effort was devoted to designing radiation detectors and monitors as well as complete instrument assemblies that involved intricate electronic circuitry.

Dr. C.M. Lapointe (1945 - 1971), professor at Laval, was hired for the "Eldorado Group" to start measuring radioactivity of uranium ores. Dr. F.E. Senftle was head of the section for the first two years and was succeeded by R.D. Wilmot (1947 - 1952) as acting head until Dr. G.G. Eichholz (1948 - 1963) took over in 1951.

Lapointe became resident physicist at Port Radium from 1946 to 1953, being responsible for all radiometric assaying and its improvement. It should be noted that uranium and thorium ores emit three kinds of radiation - alpha, beta and gamma. In the early period, Geiger counters and simple ionization counters assayed ores by beta radiation. It became apparent there were losses of radiation. Some of the radioactive "daughter" elements of the uranium series escaped during physical treatment like grinding and gravity concentration resulting in a reduction in counts and alteration in distribution of the emission of alpha, beta and gamma radiation. Simultaneous presence of both the uranium and thorium series also presented a problem in estimating uranium content by radiometric counting. In 1948, Lapointe and W.R. Williamson of Eldorado proposed a beta-gamma method known as the equilibrium method - "The use of Geiger-Mueller tubes for the determination of the state of equilibrium of the radioelements in uranium ore" (Radioactivity Division Topical Report 2, 1948, declassified version 1952). Eichholz, assisted by C. McMahon and J.W. Hilborne, a student, improved sensitivity of the method to gamma radiation by using a scintillation detector as a gamma detector to increase its accuracy for low-grade uranium ore assaying. Most mines in Canada as well as in South Africa and Australia adopted the Mines Branch system described in a report published early in 1953 - "The equilibrium counter assembly" by G.G. Eichholz (Radioactivity Division Topical Report 107-53).

Other methods of radiometric assaying were investigated including a scintillation detector method considered to be fast and reliable for radiometric assaying of thorium ores - "Measurement of thorium in ores by the thorium emanation method" by J.B. Zimmerman and J.A.F. Bouvier (1951-) (MB TP 14, 1955).

The scintillation counter was discovered in 1947 and opened up a wide field of application for detecting alpha, beta and gamma radiation by using fluorescent substances known as scintillators or phosphors. A study of mixed organic liquids as bulk detectors was made during 1951 to 1953. A companion investigation was the development of plastic scintillators containing mixed organic compounds in a polystyrene matrix. A procedure for pressure moulding such scintillators was developed and patented, and was described in "Preparation of plastic scintillation phosphors" by G.G. Eichholz and J.L. Horwood (Rev Sci Instr; vol 23, p 305; 1952).

Another analytical activity undertaken by the Radiation Laboratory was activation assaying and related work. This method uses a neutron source. A radium-beryllium source was loaned by the NRC that enabled the laboratory, in its first attempt, to assay tantalum ore in the presence of niobium without having to make the usual difficult chemical separation. This was described in "Activation assaying for tantalum ores" by G.G. Eichholz (Nucleonics; vol 10, No. 12; 1952). Other activation assays studied were for calcium, copper and indium. Considerable work was done on tungsten ores but there were some unexplained interferences.

A byproduct of this research work was the accurate determination of the half lives - the time to reach half the initial radiation intensity - for certain isotopes for which there were conflicting data in the literature. The isotopes studied were tantalum-182, described in "The half-life of tantalum-182" by G.G. Eichholz and L.A. Ficko (Phys. Rev; vol 86, pp 794-795; 1952); tungsten-187 in "The half-life of W 187" by G.G. Eichholz (Phys. Rev; vol 89, pp 525-526; 1953); and of mercury-203 in "The half life of mercury 203" by G.G. Eichholz and J.V. Krzyzewski (Can Phys; vol 34, pp 1167-1168; 1956). A gamma-ray spectrometer was set up and some identification of trace impurities in activated metal samples was undertaken.

Another R & D function of the section was to develop specialized equipment for mines and mills making use of the radiation properties of uranium and thorium ores. Thus Lapointe invented the electronic picker belt to produce a high-grade preconcentrate. The picker consisted of several Geiger tubes mounted over a conveyor belt which actuated a pneumatic ram to push high-grade ore off the belt, leaving the waste ore to continue on. The covering report was "Electronic concentration of radioactive ores with the Lapointe Picker Belt" by C.M. Lapointe and R.D. Wilmot (MB Memorandum Series 123, 1952). This device was patented, but, as its use was limited to high-grade ores, a new system was developed with a more sensitive scintillation detector under the belt and a swinging gate instead of a ram. This equipment was applied to the much leaner ores at Beaverlodge and Blind River and was described in "Electronic concentration of low grade ores with the Lapointe Picker" by A.H. Bettens and C.M. Lapointe (MB TP 10, 1955). The pickers did not have a wide use because of their low capacity and their being limited to coarse sizes above 1 1/2 inches.

Monitors were developed for various purposes in the mill and the mine, particularly for the Eldorado company. These included a Geiger detector suspended over a cobbing belt to check radioactivity of doubtful ore pieces selected by hand, monitors for recording grades of mill feed and waste, and a special unit for locating ore at the bottom of Great Bear Lake.

Compact, transistorized, portable, directional counters were an important application for underground assaying as detailed in "Portable directional Geiger counters" by A.H. Bettens, C.M. Lapointe and G.G. Eichholz (Radioactivity Division Topical Report 122; 1954).

All these developments took place in the early part of the so-called electronics age and were created by skilled personnel capable of designing electronic circuits and constructing a variety of instruments. In time, a large demand was created both inside and outside the branch for a "trouble locating and advice" service. Eichholz paid tribute to the senior technical personnel, some being co-authors of reports. Those who are still with the branch are: W.E. Havercroft (1947 - 1975), P.E. Bélanger (1949 -), L.A. Ficko (1948 - 1960 and 1967 -); J.M. Lefebvre (1950 -); G.E. Alexander (1951 -); A.H. Bettens (1951 -); J.A.F. Bouvier (1951 -); J.V. Krzyzewski (1954 -).

The use of radioactive tracers in industry was a natural development of detecting and measuring radioactivity by the application of radioactive isotopes. A laboratory was set up at 568 Booth Street pending new accommodation at 555. Application of tracers in ore dressing and hyrometallurgical operations were demonstrated. A series of tests was done to investigate various aspects of the flow of mineral particles and reagents in the flotation circuit at the mixed metal sulphide plant of the Quemont Mining Corporation Limited, Noranda. These were recorded in "Radioactive trace investigations in the flotation circuit" by G.G. Eichholz and W.B. Muir, Radioactivity Division, and M.J.S. Bennett, J.D. Wild, C. Lawton and S. Mostowy of Quemont (Trans CIM; vol 60, pp 63-69; 1957).

Tests were made on contact times in pilot acid leach plant agitators (Radioactivity Division Topical Report 24, 1954, by J.C. Turgeon) and on the residence time of slurries in an aerator tank (MB RR 18 by E.C. Gibson and G.G. Eichholz, 1958). The loss of kerosene in the solvent extraction of a leach liquor was determined (MB RR 25, by C.M. Lapointe, 1958).

In pyrometallurgy, radioactive tracer tests were made during an arc furnace pilot run (Division Internal Report 58-127, by G.G. Eichholz; 1958). Tests were also made on the measurement of kiln residence time by means of radioactive tracers (Division Internal Report 59-25, by G.G. Eichholz; 1959).

In physical metallurgy, tracer tests started with experiments on segregation in zirconium alloy billets in 1954. Assistance was given to Dr. Hurwitz of the Physical Metallurgy Division in calibration tests carried out to compare the relative sensitivities of photographic emulsions used in autoradiography. More fundamental problems in physical metallurgy, seemingly amenable to the use of radioactive isotopes as markers or tracers were studied. Such problems included the oxidation of titanium metal (Division Internal Report 59-10, by J.C. Turgeon; 1956; revised 1957) and studies on surface exchange kinetics between cobalt, zirconium, zinc and silver metals and their salts in solution. Grain boundary effects were investigated and some diffusion measurements made. Another unusual effect studied was the "Haeffner effect" where some isotopic segregation was observed in pure liquid metals when current passed through them. It was published as "The Haeffner effect in mercury" by G.G. Eichholz (Abstract in Phys Rev; vol 99, p 1635; 1955).

Other uses of radioactive isotopes may be mentioned: marking of dynamite to detect misfires; design of a system to provide automatic inspection of ammunition primers; and marking dials of an aircraft navigation unit to make automatic aerial photography possible at predetermined locations.

The function of the radiation laboratory during the period from 1947 to 1959 was described by Eichholz (105).

Organization of Radioactivity Division, 1959

Ernie Brown died suddenly in 1958. This was a great loss to the team of his associates and to the branch, as aside from being a very able research scientist, he possessed the rare quality of unobtrusive and helpful leadership at a time when he and his associates were under considerable stress to "deliver", which they did without acclaim. He was succeeded by Harold Smith as acting chief until 1959, when the Ore Treatment and Chemical Sections of the Radioactivity Division joined the newly formed Extraction Metallurgy Division under K.W. Downes, and the Physics and Electronics Section joined the Mineral Sciences Division under A.T. Prince.

The human side of this saga of the first years of endeavour and achievement is related in "Quonset huts gave birth to uranium industry" by Patricia Stevenson (1949 - 1975), information officer of the Mines Branch (Canadian Nuclear Technology, Spring 1962 issue).

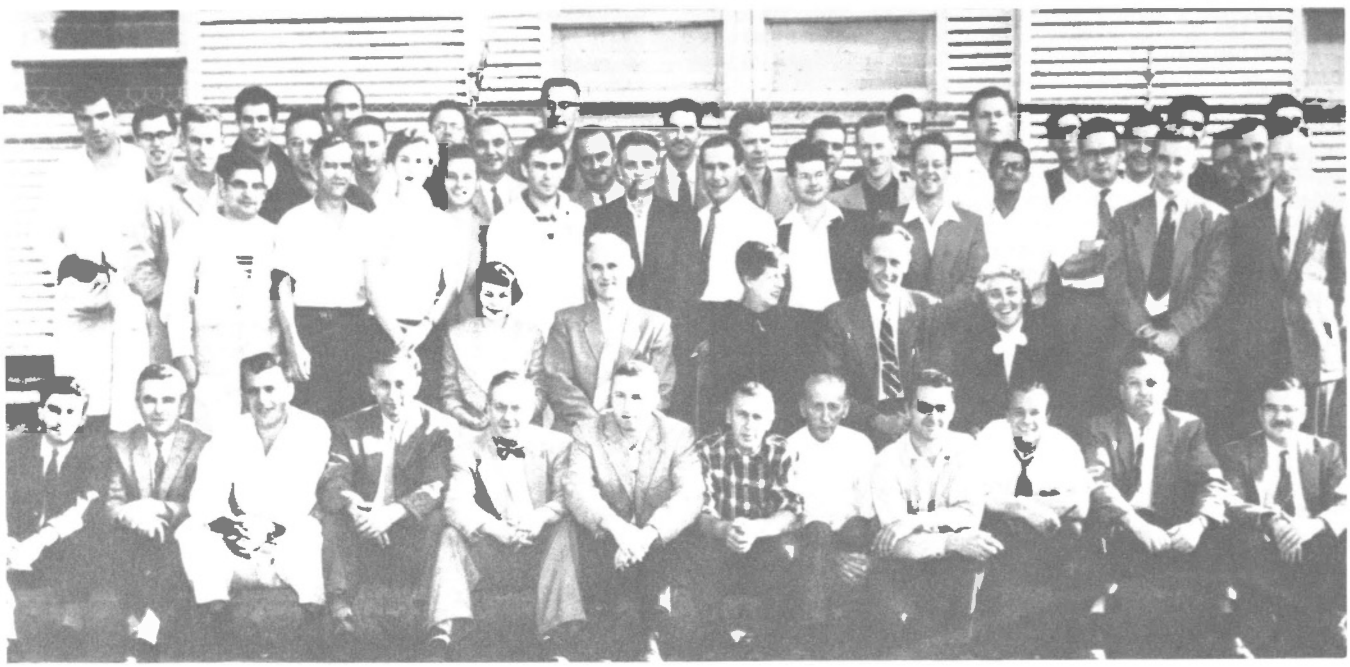
The principal staff of the Radioactivity Division immediately before it was merged with the Extraction

Metallurgy and Mineral Sciences Division is listed below:
Acting chief - H.W. Smith
Secretary - Norah Doyle
Administration - G. Meihm,
Mineralogy - S. Kaiman, M.R. Hughson
Ore Treatment - W.A. Gow, R. Simard, V.F. Harrison, W.R. Honeywell, A.J. Gilmore, V.M. McNamara, H.H. McCreedy, E.H. Devine
Analytical Chemistry - J.C. Ingles, F.P. Roloson, J.B. Zimmerman (appointed radiation safety officer in 1957), R.J. Guest, A. Hitchen, G.A. Hunt, E.D. Kornelsen
Physics & Electronics - Dr. G.G. Eichholz, Dr. C.M. Lapointe, Dr. J.L. Horwood, Dr. J.D. Keys, Dr. H.P. Dibbs, A.H. Bettens, J.M. Lefebvre, C.A. Josling, G.E. Alexander, A.F. Seeley, J.V. Krzyzewski

Before resuming the uranium narrative during the period of 1959 to 1966, it may be appropriate to reflect on the organizational change that occurred in 1959 coincident with completion of the new building at 555 Booth Street. When planned, this building was designated with good reason for occupation by Administration and by the Radioactivity Division and the principal chemical laboratories of the branch, both technical groups having been the most poorly housed.

The abrupt downturn in the uranium industry was one of the causes of the reorganization. Unquestionably the expertise developed in the Radioactivity Division gave a substantial stimulus to hydrometallurgy in general, and the Extraction Metallurgy Division was a logical successor for the wide application which has grown and will continue growing in importance as low-grade metallic ores have to be exploited. The reformed Mineral Processing Division which included the merged Industrial Minerals Division represented the activity of upgrading bulk minerals at the lowest possible cost, and that meant by physical means including flotation.

The Mineral Sciences Division was formed apparently to use the "material science" approach in study-



Radioactivity Division staff, September 1958

Front row, left to right - Steve Sandor (PDF), Charlie McMahon, Elwood Murray, Bernie Zimmerman, Gerry Murphy, Dave King, Paul Bélanger, Don Kelly, John Lefebvre, Gary Meihm, Al Gilmore, Jack Ingles;

Second row - Doreen McConnell (later Vezina), Harold Smith, Norah Doyle, Geoff Eichholz, Evelyn Waterman;

Rear row - Hauldain "Moose" Boyer, Dale Wyatt, Jack Brannen, Bob Warner, Dave Sheldrick, Louis Shaheen, John Keys, George Shanks, Art Coote, Barbara Moore (later Owens), Jack Horwood, Claude Lalonde, Arsène Bettens, Bob Lachaine, Vern McNamara, Chris Lapointe, Mickey Devine (E.H.), Bill Honeywell, Sol Kaiman, Joe Krzyzewski, Al Hitchen, Gordon Alexander, Gerry Hunt, Leo Desjardins, Vic Harrison, Jim Atkinson, Romeo Pugliese, Orville O'Hara, Dave Lister, Neil Roberts, Bob Guest, Al Seeley, Florent Bouvier, Cliff Josling, Jim Quinn (top of head), Ernie Kornelsen ing the constitutionally variable minerals. This concept was probably inspired by the metal physics studies of fundamental properties of metals whose structure was more homogeneous than that of naturally occurring minerals. Moreover the then general opinion favoured the expenditure of research funds on basic science.

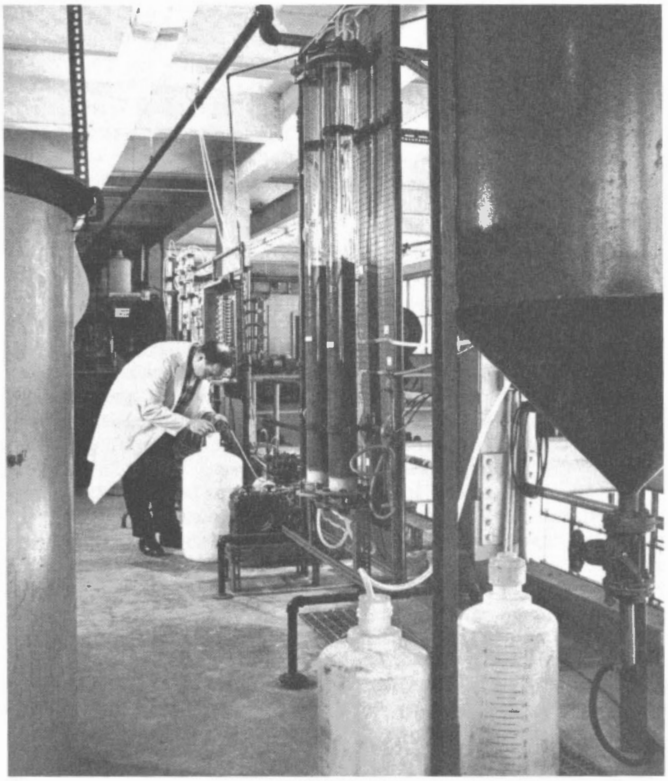
The uranium "boom" was short, the government announcing that applications for contracts at special prices would terminate at March 31, 1956. Prospecting, which had been vigorously pursued for nearly ten years with discoveries being made all over Canada, particularly in the North, declined that year. The total value of original contracts to be completed by 1963 was worth $1.7 billion, exclusive of the U.K. contract of 1962 for 12,000 tons and the Canadian Government stockpile contracts. To avoid more serious recession in the industry, the government negotiated a stretch-out program with the U.S.A. and U.K. By 1959, the 19 mills referred to earlier had a productive capacity of 45,200 tpd, with some of the mines increasing their mill capacity. The largest mine was Denison at 6,000 tpd. By the end of 1961 only Nordic, Denison, Milliken Lake and Stanrock were working in the Elliot Lake area, Bicroft and Faraday in the Bancroft area, and Eldorado and Gunnar in the Beaverlodge area. The famous Eldorado mine at Port Radium closed down in September 1960 (106).

During the last two-year period of the Radioactivity Division and the first full year of Extraction Metallurgy, R & D work was mostly concerned with studies on potential improvements and cost reduction of various aspects of uranium ore treatment. Mines Branch maintained contact with the industry through the Canadian Uranium Producers' Metallurgical Committee that included representatives of Eldorado and the Mines Branch.

As noted earlier, most mines in Canada did not preconcentrate the acid leach feed; however, acid-soluble silicates like chlorite and serpentine were consumers of acid which was a principal cost item. Flotation studies were made with selective fatty acids indicating a possible substantial reduction of sulphuric acid consumption for Elliot Lake ores. This was reported in "Flotation of uranium ores from the Elliot Lake area, Ontario" by W.R. Honeywell (MB TB 2, 1959). When this technique was applied to Bancroft ores the saving in sulphuric acid was much less. On the other hand, if a second flotation of uranium minerals following a first flotation of acid-consuming minerals were made, an overall reduction of sulphuric acid was almost equivalent to that for the Elliot Lake ores. Actually, uranothorite, if ground was easily separated by flotation.

Another approach for reducing sulphuric acid consumption in leaching operations was the pressure leaching study based on sulphur in the associated sulphide minerals. In this technique, ground ore mixed with water at 60-70% solids was heated to 150°C in a pressure vessel, air being blown through the pulp at a pressure of about 200 psi. The metal sulphides were oxidized to sulphate, generating sulphuric acid. A 95% extraction of uranium in the ore in not more than six hours was achieved compared with the 70 hours by conventional sulphuric acid leaching techniques (107).

After 1960, further work was halted on uranium until about 1966 when the outlook improved for uranium use in the energy industry, as there were indications that atomic energy could become competitive with fossil fuels.



L. Shaheen in ion-exchange pilot plant of Extraction Metallurgy Division (Former Radioactivity Division, Lebreton St. Photo - George Hunter)

During the period from 1955 to 1959 the physical chemistry group under A.T. Prince of the Mineral Dressing and Process Metallurgy Division worked out a method for preparing sintered uranium dioxide compacts as fuel for atomic energy reactors. This work was turned over to the Chalk River laboratories of Atomic Energy of Canada Limited in 1959 (108). This process was adopted for all reactors using ceramic fuel and is still in use today.

Dr. R.R. Rogers, head of the Pyrometallurgy and Corrosion Section of the Extraction Metallurgy Division, and I.I. Tingley of the Physical Metallurgy Division made a study of corrosion in the processing of uranium ores which was recorded in "Corrosion study in processing uranium ore" by I.I. Tingley and R.R. Rogers (MB RR 65, 1960).

Physics and Radiotracer Subdivision of Mineral Sciences Division

In 1959, when the Mineral Sciences Division was formed, the former physics and electronics group was transferred as a whole to the new division which was composed of the following groups with their principal officers:

Chief - Dr. A.T. Prince
Mineralogy, head - M.H. Haycock, ex Mineral Dressing and Process Metallurgy Division
Physical Chemistry, head - N.F.H. Bright, ex Mineral Dressing and Process Metallurgy Division
Analytical Chemistry, head - W.R. Inman, ex Mineral Dressing and Process Metallurgy Division
Physics and Radiotracers, head - G.G. Eichholz, ex Radioactivity Division; this subdivision was composed of two sections: Physics and Electronics - J.D. Keys (1958 - 1967) Radiotracers - C.M. Lapointe.

During the period when Eichholz was in charge of the subdivision, its activities may be summarized as follows - radiometric R & D, radiochemical research with radiotracers in relation to analytical and surface chemistry, development of radiotracers in industry, and control instrumentation development.

An extensive joint project started in 1959 was carried out by Dr. J.L. Horwood and Dr. A.F. Gregory of the Geological Survey on the degradation and change observed in the gamma-ray spectra from radiation sources in their passage through air. Field tests were carried out on a 200-ft tall radio tower with an elevator on which a detector and a "kick sorter" (pulse height analyzer) could travel. Radiation sources were pitchblende and thorium concentrates. A laboratory study was also done on "synthetic" ores to obtain data on self absorption and detector parameters. The results were published in "A laboratory study of gamma-ray spectra at the surface of rocks" by A.F. Gregory and J.L. Horwood (MB RR 85, 1961). The field study represented an exhaustive study of the factors involved in evaluating aerial survey results as described in "A spectrometric study of the attenuation in air of gamma rays from mineral sources" by A.F. Gregory and J.L. Horwood; (MB RR 110, 1963).

The Eichholz group actively participated in radiometric R & D in acquiring, installing and inaugural testing of such apparatus as a gamma-ray activation facility for beryllium ores. This consisted of two units employing a strontium-124 source for analyzing coarse and powdered samples of beryllium ores and

A.T. Prince (Photo NFB)

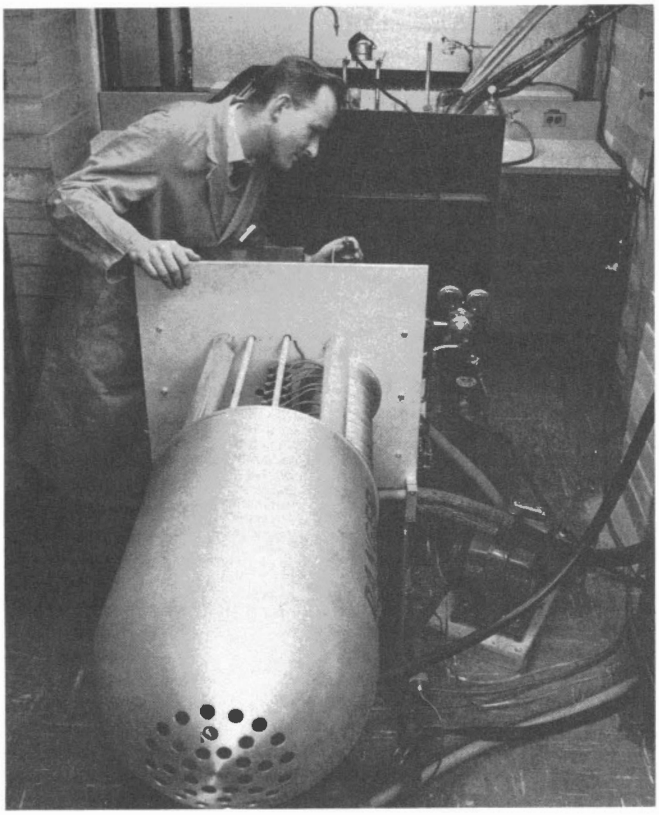
concentrates, and was installed in 1961. The relevant report describing it was "Determination of beryllium by gamma-ray activation" by H.P. Dibbs (MB TB 33, 1962). The subdivision was also involved in uranium analysis of metal alloys including trace impurity determinations which will be referred to later in the section on uranium alloys.

A Texas Neutron Corporation generator for activation analysis was also acquired in 1961 and installed in the basement with special shielding designed by the group. It proved to be a useful research tool for rapid and accurate determination of many elements present in trace amounts and was particularly useful in determining small amounts of oxygen in minerals and metals as described in "Activation analysis with a neutron generator" by H.P. Dibbs (MB RR 155, 1965).

The radiochemical work was directed to the use of radiotracers to indicate the strength and nature of adsorption as surface phenomena as well as their use in analytical chemistry to provide quantitative information on the yield and extraction rates of separation processes. Dealing first with surface chemistry, the simplest tracer application was in measuring surface areas of fine metal and mineral particles, e.g., magnesium powders described in "Surface area determination of magnesium powder with chromium-51 tracer solution" by H.P. Dibbs (Journal Appl Chem; vol 10, pp 372-377; 1960). A project was carried out by Dr. J.E. Sandor, an NRC Fellow, on the kinetics of adsorption of ions in solution on metal surfaces. Two reports were published - "Exchange reactions between zinc and its ions" (MB RR 58, 1959), and "Surface exchange reactions of silver and its ions" (MB RR 62, 1960) both by J.E. Sandor).

The adsorption of flotation reagents on minerals was a project of interest to the mining industry. Because of difficulties encountered in the separation of hematite and quartz by flotation, the research concentrated on the adsorption of oleic acid on these two minerals. This was published in "Competitive adsorption of C^{14}-labelled oleic acid by quartz and hematite in flotation processes" by C.M. Lapointe (MB RR 108, 1963). A surface chemistry project not involving tracers related to catalysis was undertaken by Dr. M. Donato, another NRC Fellow, who studied the effect of neutron irradiation of zinc oxide and chromium oxide catalysts in the thermal dissociation of ethyl alcohol. This was described in "Radiation effects on p- and n-type catalysts used in the thermal dissociation of ethyl alcohol" by M. Donato (MB RR 105, 1962). Eichholtz was enthusiastic about the employment of NRC post doctorate fellows and summer students who were given considerable freedom in selecting research projects. He acknowledged that some of the research was marginally related to the program of the subdivision but he considered that there was a mutual advantage in broadening the horizons of new scientific ideas and approaches.

Eichholz believed that improved means of controlling and measuring process variables could be applied more widely in the mining industry but few instruments were commercially developed. Accordingly his group devoted some effort in developing monitors and probes that could be used by that industry. One of the more important instruments developed had a rugged conductivity probe for acid and alkaline mill pulps with dense slurries and abrasive particles as described in "Conductimetric measurement and control of acid concentra-



H.P. Dibbs checks installation of neutron generator for activation analysis in shield enclosure (Photo - George Hunter)

tion in leach pulps" by G.G. Eichholz and A.H. Bettens; Reprint from Trans CIM, 63, pp 626-632; 1960 (MB TB 17; 1960) and in "Conductimetric control of alkaline leach liquors" by G.G. Eichholz and T.R. Flint (MB TB 27; 1961).

Eichholz was responsive to the observations made by staff. One example of this was the report "Some findings on the fluorescence of anion exchange resins under ultraviolet light at various anion loadings" by A.J. Gilmore (Extraction Met Div Rep EMT 60-8, 1960). This was followed up by a study of fluorescence phenomena of ion exchange resins and it was shown for certain ions that observation of fluorescence emission was closely linked with loading and elution, possibly providing a basis for rapid automatic control, especially in the elution cycle. A report covering this was "Fluorescence effects in ion exchange resins" by T.R. Flint and G.G. Eichholz (MB RR 91; 1961).

Eichholz promoted the use of tracers in industry generally - "Industrial tracer techniques in Canada" by G.G. Eichholz (Nucleonics; vol 18, No 10; 1960). A large number of tracer tests during the period from 1959 to 1963 was concerned with the residence time of roasting or sintering in kilns and furnaces both in industry, e.g., a test in the kiln at Quebec Iron & Titanium Corporation, Sorel, Quebec and in a shaft furnace at the Iron Ore Company of Canada, Quebec, as well as in Mines Branch work on industry projects.

Another tracer application was the tagging of a heat of steel that was used for casting grinding balls described in "Radioactive marking of steel balls for grinding tests" by G.G. Eichholz (MB TB 12, 1959). The purpose was to test the balls for relative wear properties under actual operating conditions as indicated in "Measurement of the wear rate of cast grinding balls using radioactive tracers" by J.D. Keys and G.G. Eichholz (MB TB 18, 1960).

An interesting project requiring considerable effort was the tracing of underground water seepage at Steep Rock Iron Mines at Atikokan, Ontario. A large number of samples had to be treated, and because of the low concentrations, special methods of preconcentration and counting of the tracers had to be evolved. The results were published in "Use of tritium to trace underground water" by C.M. Lapointe (Trans of the Canadian Nuclear Assoc Conf on Heavy Water, vol 1, No 4, 1962).

Before resigning in 1963, Eichholz prepared a companion booklet to the one published in 1959 (109).

Uranium Alloys

In view of the cutback in uranium production in Canada, a program was jointly sponsored by Eldorado from 1959 and by the Canadian Uranium Research Foundation from 1961 with the Mines Branch to find uses for uranium in both ferrous and non-ferrous metallurgy.

Plain carbon steels were first examined as their wide use offered the largest potential comsumption of uranium in ferrous metallurgy. The first results indicated improvement in stress corrosion and fatigue as well as in high temperature properties of ferritic steels for which patents were granted in Canada and other countries. Other patents were obtained as the studies progressed. An interim report was published in 1962 as "Influence of uranium additions to ferrous alloys: an interim review" edited by R.F. Knight and D.K. Faurschou (MB RR 95; 1962).

The program developed into a major effort that involved various types of alloy steels with studies in the distribution of uranium between the oxide, carbide and intermetallic phases as well as on corrosion, welding and mechanical properties.

Additions of uranium to non-ferrous metals and alloys were also studied. Both copper and nickel were investigated in "Uranium in non-ferrous metals" by R. Thomson and J.O. Edwards (MB RR 97; 1962).

By the end of 1963 some applications in ferrous metallurgy for which uranium additions may have beneficial results were identified as: (1) change in the sulphide form to provide better transverse ductility, (2) improvement in stress corrosion characteristics of steels, (3) beneficial effect on the static fatigue of low alloy steels, and (4) scavenging of impurities in steels.

In the non-ferrous field it was found that brass alloyed with uranium commonly contaminated with traces of lead markedly improved the hot rolling properties of the alloy.

In relation to stainless steels, studies confirmed some of the above findings. Thus the corrosion behaviour of Type 416 and 430F (resulphurized chromium stainless steels) showed that the corrosion resistance was high in relation to nitric acid but not to sulphuric acid, hydrochloric acid, or ferric chloride. This was reported in "Corrosion behaviour of uranium-bearing resulphurized chromium stainless steels" by G.J. Biefer and W.M. Crawford (MB RR 166; 1965). A companion study of transverse ductility and cold formability on the same steels showed improvement of these characteristics. Forgeability tests were not conclusive. The study confirmed that uranium additions produced globular rather than the stringer type sulphides. This is significant in the improvement of transverse tensile ductility of uranium alloyed steels.

The early studies on plain carbon steels were rushed and essentially oriented to discover large effects from small additions of uranium to avoid raising the cost of the steels as uranium is expensive. The studies were under-designed for uncovering marginal effects, and as D.K. Faurschou (1951-), the author of both the earlier studies and of the later study stated "...Fate capriciously tested investigation with initially promising results". These earlier "ad hoc" studies of uranium in the carbon steel series were complemented and clarified by statistically designed and analyzed tests. The results indicated that uranium had a limited usefulness as an alloying element in ferrous metallurgy but had more potential as a scavenger and sulphide "former". This was explained in "Study of as-rolled carbon steels over ranges of uranium, sulphur and carbon contents" by D.K. Faurschou (MB RR 178, 1966).

C.E. Makepeace of Eldorado carried out a statistically designed study of high-strength alloy steel plate and low alloy hardenable steel sheet, and the results indicated that an addition of less than half of one per cent uranium reduced susceptibility to hot cracking in alloy steel sheets: "Uranium in alloy steels" by C.E. Makepeace (MB RR 129; 1964).

Corrosion studies were also made with low sulphur chromium 430 stainless steels with uranium additions: "The effect of uranium additions on the corrosion behaviour of AISI 430 stainless steel" by G.J. Biefer (MB TB 58, 1964) followed by a companion study for comparison with alternative additions of uranium and molybdenum. The latter study showed that for maximum corrosion resistance with acids the uranium content should be 0.5% or less, whereas molybdenum provided better corrosion resistance but the content of molybdenum had to be higher at 1.02%: "Comparison of the effects of uranium and molybdenum alloying additions on the corrosion resistance of AISI Type 430 stainless steel" by G.J. Biefer and J.G. Garrison (MB TB 74, 1965).

For analytical and radiometric procedures, assistance was given by the Mineral Sciences and Extraction Metallurgy Divisions. Methods were described in two publications: "Radiometric analysis of uranium-bearing steels" by J.L. Horwood (MB TB 25, 1961) and "Analytical determination of uranium in iron and steel alloys" by J.C. Ingles, J.B. Zimmerman and J.L. Horwood (MB IC 134, 1961).

Precautions in the handling of uranium alloys were outlined in a publication by Eichholz in 1961: "Notes on the safe handling of uranium alloys in industry" by G.G. Eichholz (MB IC 125, 1961).

Mineral Sciences Division

The narrative of this division's activities is resumed at this point because of the special role it played in the mineralogy, chemistry and physics of radioactive minerals and metals since its formation in 1959 following dissolution of the Radioactivity Division. It was discipline- and not commodity-oriented. It might appear at first glance that it was formed merely to support R & D in the other divisions but it was, in effect, a research centre for physics and chemistry, the basic sciences of mineral technology. Prince was the branch representative on the building project committee responsible for the design and construction of the composite building at 555 Booth Street and 300 Lebreton Street.

By the end of the fifties it was becoming evident to most mineral resource engineers and scientists that a major part of the national mineral wealth would have to be derived from low-grade resources. The experience with low-grade radioactive ores during the fifties developed confidence in chemical extraction methods and showed them to be feasible technically and in many cases economically. However, the principal barrier to the economic exploitation of low-grade ores would be the complex association of economic minerals with unwanted impurities, often in an intergrown matrix of gangue (rock) minerals. The constitution and properties of naturally occurring minerals would have to be better understood for the appropriate separation and concentration treatment to yield optimum results. In any event, the scientific approach was in accord with the then developing policy for the department to become a scientific institution. Downes, who was a principal proponent of this policy of encouraging well designed scientific research, formed a special research group in his own Extraction Metallurgy Division under Dr. T.R. Ingraham.

When the research scientist classification for the professional staff was adopted at the end of the period under review, as noted earlier, all the scientific research staff in the branch profited from the criteria of this classification provided they could produce evidence of publication in external papers. A colloquial expression "publish or perish", frequently used in the scientific circles of the world, was much in evidence in this period. In this regard the professional scientific staff of the Mineral Sciences Division other than mineral and metal analytical chemists were classified as research scientists. Chemical analysts, who were busily engaged with their heavy workload, or engineers working on design and construction of equipment or solving industrial problems were usually not as fortunate in the career advancement they deserved. The director and some of his associates, who shared the view that a broader interpretation of the criteria of this classification should be applied in interdisciplinary institutions by demonstrating creative capability "on the job", argued this point with some success at the departmental evaluating sessions.

The strength of this division in chemistry was illustrated by the fact that some 80% of the professional staff were chemists.

Analytical Chemistry

The Analytical Chemistry Subdivision was composed of three sections - Mineral and Metal Analysis: W.L. Chase (1942 - 1966); Spectrography: Dr. A.H. Gillieson (1959 - 1975); Special Analysis and Research: G.H.

Faye (1950 -). Head of the whole group was W.R. Inman (1946 - 1969).

These laboratories dealt with a wide variety of materials by wet methods as well as by spectroscopic, flame and spectrophotometric and fire assay methods: metallic and non-metallic minerals and ores and concentrates, furnace products, ferrous and non-ferrous metals and alloys including precious metals. Considerable emphasis was directed to the assaying of the platinum group of precious metals. Fossil fuels were excluded as this group of minerals was analyzed in the Fuels Division. The Extraction Metallurgy Division was equipped with chemical analysis facilities including those for uranium and its ores to avoid the largely chemical R & D work being help up in that division.

Most of the samples originated in the branch but many were from external sources for which branch expertise was required to solve problems of an analyt-

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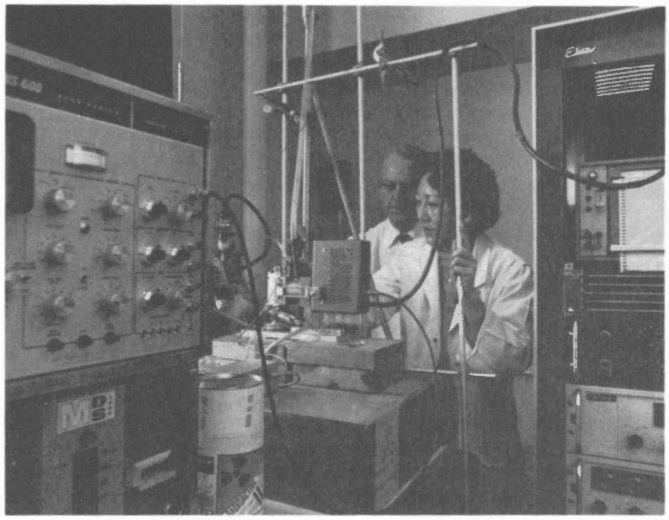

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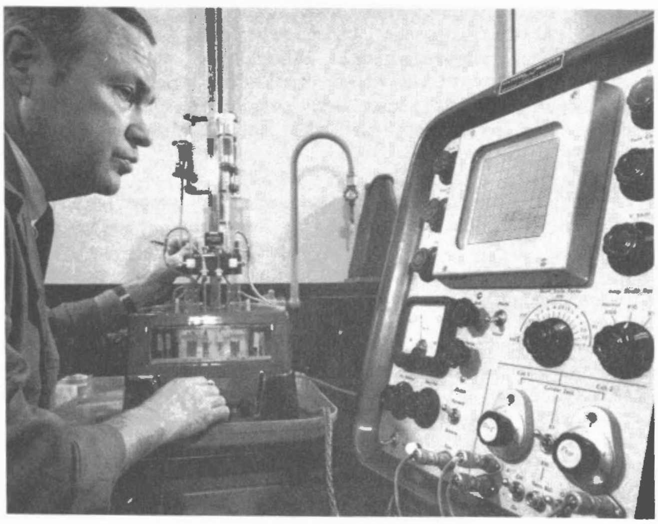

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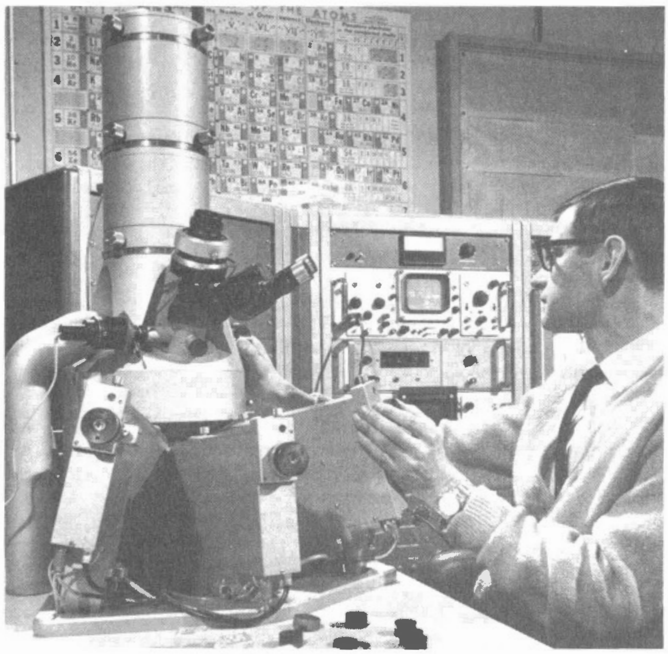

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Examples of more recent analytical methods and equipment

1 - atomic absorption spectrophotometer (Gwen Patton); 2 - on-stream analysis of iron ore concentrates using radiometric method (A. Gillieson, Evelyn Mark,); 3 - differential cathode ray polarograph used for trace analysis of metals (C.H. McMaster); 4 - electron microprobe installed in 1968 for nondestructive rapid analysis of elements in minerals (D.C. Harris) (Photos - George Hunter)

ical character. A substantial number of external samples were in connection with referee and specification matters. Emission and X-ray spectrography were developed as useful analytical tools, particularly in determining traces of elements in metals and in mineralogical analysis. Spectrographic analysis was used not only for quantitative determinations but for rapid qualitative evaluations. The laboratories were progressively equipped with the up-to-date apparatus that advanced not only the chemical analysis group but other research groups of the division.

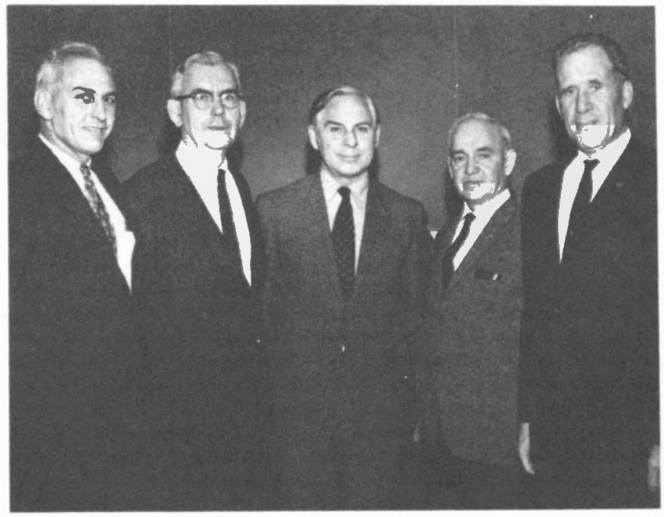
The analytical load, particularly in the early period of the division, was heavy with approximately 10,000 samples and some 40,000 determinations made per annum as recounted in "Chemical aspects of the work at the Mines Branch", by A.T. Prince (Chem in Can, pp 84,86,88, April 1960). The laboratories participated in the work of standardization with the appropriate agencies in Canada and abroad involving considerable experimentation with proposed standards, some of which were suggested by the Mines Branch laboratories; the organizations were Canadian Standards Association, International Standards Organization, American Society for Testing and Materials, and the U.S. National Bureau of Standards. The division acted as a distributing agent for standards as and when they were certified.

The laboratories were continuously investigating improved and rapid techniques of analysis to solve the problems of complex mineral assemblages and impurities. Some examples are given in the two succeeding paragraphs.

Because of Canada's NATO commitments, the laboratories worked closely with the Materials Panel of the Advisory Group on Aeronautical Research and Development that was dealing with high purity molybdenum, niobium, tantalum and tungsten. A method of determining the iron content in these refractory metal powders was evolved as described in the paper: "Extraction and determination of iron as the bathophenanthroline complex in high-purity niobium, tantalum, molybdenum and tungsten metals" by E. M. Penner and W.R. Inman (Talanta; vol 9, pp 1027 to 1036; 1962). A further and similar project was the determination of copper in these metals described in "Determination of copper in high-purity niobium, tantalum, molybdenum and tungsten metals with bathocuproine" by E.M. Penner and W.R. Inman (Talanta; vol 10; pp 407-412; 1963 reproduced in MB RR 111, 1963)

Because of analytical difficulties associated with assaying of the platinum group of precious metals, research on this continued over several years. A comprehensive scheme was developed for determining platinum, palladium, rhodium, iridium, osmium and ruthenium based on thermal fusion and collection of the precious metals in a tin button. This button was treated by distillation, precipitation, liquid-liquid exchange and ion exchange to separate the individual elements which were then determined by spectrophotometry. The above scheme provides for the determination of any associated gold as explained in "Tin-collection scheme for the determination of the platinum-group metals and gold" by G.H. Faye (MB RR 154; 1965).

The other three groups of the division were all oriented to long-term scientific research: Mineralogy, Physical Chemistry, and Physics and Radio-tracer sections. The latter was renamed Mineral Physics after Eichholz left the branch in 1963, when Keys became head. The division in effect assumed more of a "material" science function as mentioned earlier.



Presentation of 25-year pin, left to right: George Wills, James Fydell, Vic Haw, Roy Buckmaster, Darcy Charette

Mineralogy

Narrating in order, the mineralogical group organized at the inauguration of the division included Maurice Haycock (1931 - 65), Dr. E.H. Nickel (1953 - 1971) and Dr. W. Petruk (1960 -). A valuable tool in mineralogy was provided by X-ray diffraction as it reduced requirements for the number of polished sections, particularly of thin sections used in microscopy. The mineralogical laboratory was also well equipped with various other apparatus including excellent lapidary facilities and separation apparatus for minerals of different as well as of similar specific gravities.

Less common mineral occurrences were examined. One such was the Bernic Lake, Manitoba complex zoned pegmatite deposit which contained a wide variety of minerals of which the principal ones of potential economic significance for contained metals were pollucite (cesium), spodumene (lithium), and stanniferous tantalite (tantalum and tin). Other metallic minerals were rubidium and beryllium. Many of the metallic minerals were intergrown with rock minerals. In the late sixties the deposit became the source of the first tantalum produced in Canada and one of the few in the world. This is an example of the complexity of some Canadian ores with the implication of difficulty in processing: "Mineralogy of the Bernic Lake pegmatite, southeastern Manitoba" by E.H. Nickel (MB TB 20; 1961).

The complex niobium ore at Oka was studied. This was composed of two niobium minerals - pyrochlore and niobium perovskite in association with titanium, iron, magnesium, manganese, calcium, sodium and radioactive elements. Niobium pentoxide content was variable: "Compositional variations in pyrochlore and niobium perovskite from a niobium deposit in the Oka district of Quebec" by E.H. Nickel (MB TB 31; 1962).

Beryllium-niobium ore from Sea Lake, Labrador, one of the unusual deposits in the world was also examined. A brown micaceous silicate mineral was identified as a niobium analogue of the mineral astrophyllite. The name "niobophyllite" was proposed for this new mineral species which contains about 15% of niobium pentoxide as a replacement of most of the titanium oxide found in astrophyllite.

The mineralogy of a complex low-grade tin ore in New Brunswick was evaluated as described in "Mineralogy of the Mount Pleasant tin deposit in New Brunswick" by W. Petruk (MB TB 56; 1964). Due to an increase in the price of silver, there was a revival of interest in the Cobalt-Gowganda silver district in Ontario resulting in a request by the producers for mineralogical studies to be carried out: "Preliminary mineralogical study of the silver deposits in the Cobalt area, Ontario" by W. Petruk (MB IC 179; 1966).

In 1965, the X-ray diffraction facilities of the Physical Chemistry and Mineralogical sections were merged into one laboratory.

E.H. Nickel became head of the mineralogical group following Maurice Haycock's retirement in 1965 after 34 years of service in the Mines Branch, having started as the pioneer of the mineragraphic laboratory in 1931. The first spectrograph was built under Haycock's supervision by the then senior instrument maker, J.G. (Jim) Williams, who served the Mines Branch in the Fuels Division from 1913 to 1946, the father of Dr. A.J. (Al) Williams of the Physical Metallurgy Division. Maurice, besides his professional skills, was a person of many talents that included being a "radioham" and a renowned Canadian painter specializing in arctic scenes, an art which he practises today. Two of Al's treasures are the inherited pictures painted and donated by Maurice to Jim Williams on the occasions of completion of the spectrograph and Jim's retirement. Maurice prepared the designs in the entrance lobby of 555 Booth Street and his paintings hang in the department today.

Physical Chemistry

This group originated from Parsons' period in his desire to encourage scientific research in the high temperature field of refractory materials. It will be recalled that in 1946 Prince was appointed head of the Ceramics Section, later renamed as the Crystal and Physics Section of the Mineral Dressing and Metallurgy Division. In 1959 the head of this group was Dr. N.F.H. Bright (1953 - 1974), who first came to the Mines Branch as an NRC postdoctoral Fellow in 1951. His professional associates were J.F. Rowland (1949 -), Dr. A. Jongejan (1957 -) and Dr. A.H. Webster (1957 -).

The iron-titanium-oxygen system was studied at temperatures up to 1200°C under low oxygen pressures in connection with the branch program on titanium that started in the early '50s. This research was in reference to the smelting of the Quebec ilmenite ore. Two research reports were published prior to formation of the Mineral Sciences Division - "Compound CaO: Ti_2O_3" by N.F.H. Bright, J.F. Rowland and J.G. Wurm (MB RR 4; 1958), and "Some new fluoride complexes of trivalent titanium" by N.F.H. Bright and J.G. Wurm MB RR 7; 1958). A third report was published in 1961: "The system irontitanium-oxygen at 1200°C and oxygen partial pressures between 1 atmosphere and $2x10^{-14}$ atmospheres" by A.H. Webster and N.F.H. Bright (Journal of the American Ceramic Society; vol 44, No. 3, pp 110-116, 1961); (MB RR 76, 1961). Because of the industrial importance of niobium, the complexity of niobium deposits and the geological interest in their genesis, compounds of lime and silica with niobium were studied during a period of some years: "Crystallography of compounds in the calcium oxide-niobium pentoxide system" by J.F. Rowland, N.F.H. Bright and A. Jongejan (MB RR 48; 1959), and the two-part report: I - "The binary system Nb_2O_5-SiO_2" by Mohammad Ibrahim and N.F.H. Bright, and II - "The binary system CaO-Nb_2O_5 by Mohammad Ibrahim, N.F.H. Bright and J.F. Rowland, reprinted from Journal Am Cer Soc; vol 45; pp 221-221 and 329- 334, 1962 (MB RR 101; 1962).

In later years the study of liquid-solid and solid-solid equilibria at elevated temperatures was an important part of the section's activity. The systems studied were related either to divisional projects on mineral association, composition or structure, or to materials of industrial importance such as electronic ceramics, magnetic ceramics and refractories. Experimental techniques involved the use of high-temperature furnaces with close control of temperature and, if necessary, of atmospheres. X-ray diffraction petrographic microscopy that included a hot-stage microscope (with temperatures up to 1800°C) was used to identify the products of furnace treatments. The techniques of differential thermal analysis and thermogravimetric analysis were applied to problems encountered in the branch and by outside agencies and industry.

Research was done on the kinetics of thermal decomposition of pyrite employing polycrystalline cylinders of pyrite heated in a flowing argon atmosphere. This research was part of the major sulphide program of the division and was described in the paper "The kinetics of the thermal decomposition of pyrite" by A.W. Coats and N.F.H. Bright (Can Journal Chem; vol 44, pp 1191-1195; 1966).

In 1960 Bright started a series of Information Circulars entitled "Bibliography of high temperature condensed states research in Canada and elsewhere", starting with IC 122 and concluding with IC 296 in 1972. Some issues included data on laboratories in the U.S.A. and U.K. where this research was conducted. The high temperature phase equilibrium work was discontinued as a research project in 1971. Norm Bright retired in 1974 with 21 years' service; he died tragically shortly after.

Mineral Physics

This group from 1963, under John Keys moved away from tracer and radiometric apparatus development. One reason for discontinuing the development of tracer application and industrial control instrumentation was establishment of the Commercial Products Division of Atomic Energy of Canada Limited.

Before describing the sulphide program which preoccupied the Mineral Sciences Division after 1964, other activities of the mineral physics group should be noted. Keys commenced a project on semiconductors in 1960, selecting bismuth telluride, a compound of particular interest for its thermal electric properties. A horizontal zone melting furnace technique was evolved for growing single crystals. Experiments were conducted on the diffusion of silver in a direction at right angles to the cleavage planes; Ag-110 was used as a tracer. Later, the experiments were repeated with gold "Diffusion and solid solubility of silver in single-crystal bismuth telluride" by J.D. Keys and H.M. Dutton (Journal of Physical Chemistry of Solids; vol 24, p 563; 1963) and "Diffusion and solid solubility of gold in single-crystal bismuth telluride" by J.D. Keys and H.M. Dutton (Journal of Applied Physics; vol 34, p 1830; 1963). A long-term ion drift experiment was carried out which showed, for drift parallel to the cleavage planes, that copper, silver and gold migrate in a bi-polar direction simultaneously, namely to the anode and cathode (Int Rep, MS 66-107; by H.P. Dibbs and J.D. Keys; 1966).

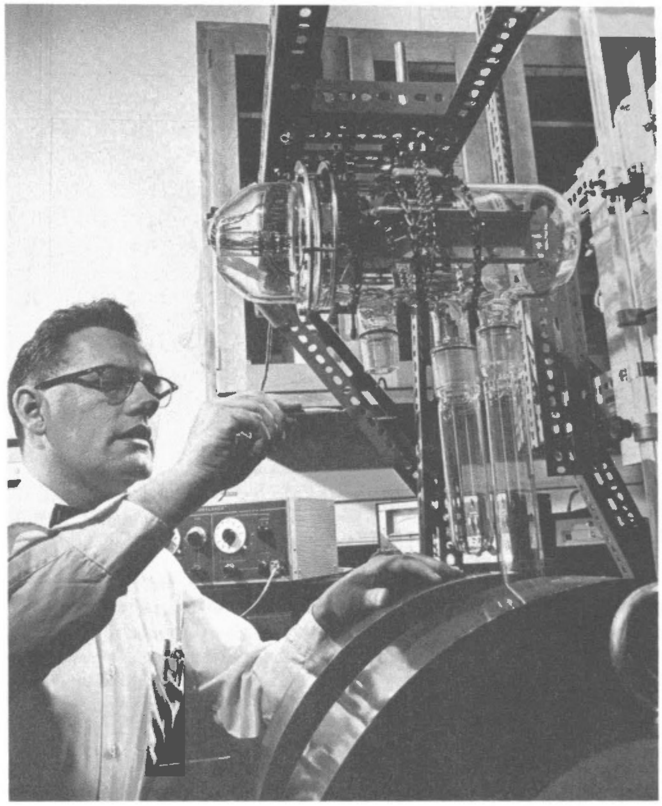
A carefully engineered and executed radiotracer experiment made at the Noranda copper smelter showed that 93% of the copper from converter slag was recovered. This information was obtained through the use of approximately one gram of radioactive copper-64 added to the transfer ladle of slag and admixed with about 1600 tons of slag and matte in a reverberatory furnace. It was recorded in "Radiotracer test at the Noranda smelter, July 15-18, 1963" by J.L. Horwood and H.P. Dibbs (MB TB 52; 1964).

Two devices of possible industrial application were developed during the period. One was a laboratory model of an ore-sorting system based on the detection of characteristic X-rays emanating from ore bombarded with electrons from radioactive strontium-90 source and was described in"Excited X-rays identify minerals as ore moves down conveyer belt" by R.H. Goodman, A.H. Bettens, C.A. Josling (Can Electronics Engineering; vol 43; MB RS 7, reprinted June 1966). The second was a prototype instrument for automatically scanning konimeter slides used for dust sampling in mines and constructed under the auspices of the Mines Accident Prevention Association of Ontario. It was described in "Progress report on electronic konimeter slide counters" by T.R. Flint (MB IR 62-72; 1962). This instrument combined closed circuit television techniques with pulse height analysis. At the end of the review period in 1966, one version of this instrument had been in field service for two years.

Sulphide Program

A major reason for undertaking this integrated "material science" program was the realization that a substantial proportion of Canada's mineral wealth was in base metals contained in sulphides which were often complex and lean. The Mineral Physics and the Mineralogy sections were the major contributors to this program, the former allocating about 50% of its effort from 1964 to the end of the period: "A proposal for a sulphide research programme in the Mineral Sciences Division of the Mines Branch" by A. T. Prince (Int Rep MS 64-43, June 1964).

The scientific aim behind this program was to study the mineral substance to determine inter-atomic bonding, electron energies and other fundamental properties of its crystal lattice. This would require a considerable number of chemical, crystallographic, optical, electrical and magnetic measurements. Surface properties of minerals would also be part of the program as the creation of new surface is a feature of mineral comminution and surface energies play an important part in mineral processes such as dissolution and flotation. Sphalerite (zinc sulphide) was selected



J. Horwood determines magnetic susceptibility of minerals using microbalance and electromagnet (Photo - George Hunter)

for the initial studies. As background information, a review of the properties of sphalerite was made by E.H. Nickel (MB IC 170; 1965). Natural crystals of sphalerite were obtained and chemical crystallographic optical absorption spectra and magnetic susceptibility measurements were made. A major project in this program was to study iron atom bonding in pyrites, a mineral prevalent to varying degrees in all mixed sulphides, using Mössbauer effect technique: "The Mössbauer effect" by R.H. Goodman (Chem Can; pp 31-36, April 1966). This effect can be related to the electrons surrounding the nucleus; in many cases these are bonding electrons and this effect was studied in the fields adjacent to the iron nuclei in pyrite, chalcopyrite, arsenopyrite and iron containing zinc sulphide. A record was provided in "Iron impurity states in cubic zinc sulphide" by R.H. Goodman (Int Rep MS 66-22; 1966). Pyrite as predicted showed no signs of ferromagnetic coupling between iron atoms. Low-temperature experiments were to be carried out and some anomalies and ambiguities were expected to be resolved. The most successful results were from optical absorption spectra discussed in "Absorption spectra of Fe_{III} in octahedral sites in sphalerite" by P.G. Manning (Int Rep MS 66-24; 1966).

The general conclusion at the end of the period under review was that it was not possible to characterize a mineral compound by measuring the properties of a natural specimen and that synthetic mineral crystals of known composition must first be studied. A synthetic crystal laboratory was set up for this purpose.

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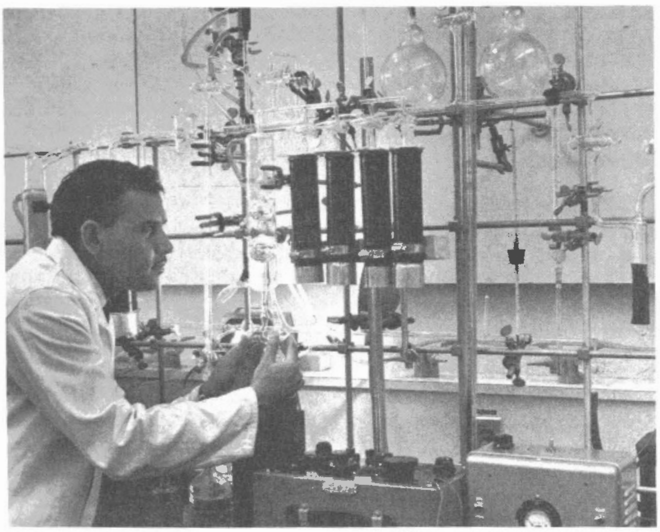

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Sulphide mineral studies:
1 - E. Gabe working on four-circle X-ray diffractometer; 2 - J.F. Rowland carries out X-ray diffraction studies using goniometer and recording equipment; 3 - S. Ahmed measures surface areas of mineral powders (Photos - George Hunter)

An important contribution was made to speed up measurements by the installation of an on-line computer (PDP-8) operating on a time-shared basis with the Mössbauer effect experiment and an automated four-circle X-ray diffractometer as detailed in "Use of 'on-line' computer for Mössbauer experiments" (Rev Sci Instrum; vol 37, pp 283-286; 1966).

With regard to surface properties, work continued on the nature of the adsorption of oleic acid on hematite and magnetite as well as on cassiterite. Radioactive tracers were used to follow the effect of the concentration of oleic acid. A study was started to obtain basic information of the double layer at mineral surfaces. The behaviour of this layer and the extent to which specific ion adsorption occurs on oxide mineral (silica, zirconia and thoria) surfaces were investigated extensively and this research was to be extended to the interaction on sulphide mineral surfaces as recorded in "Studies of the dissociation of oxide surfaces at the liquid-solid interface" by S.M. Ahmed (Can Journal Chem; vol 44, pp 1663-1670; 1966 and Erratum: ibid., p 2769).

In 1967 Keys published a companion booklet to the two authored by Eichholz on the Radiation Laboratory from 1947 to 1959, (IC 113), and on the Physics and Radiotracer Subdivision from 1959 to 1963, (IC 150) (110). J.D. Keys transferred to the Inland Waters Branch in 1967.

Prince resigned in 1965 to become director of the Inland Waters Research Branch of the Department of Mines and Technical Surveys, transferring in 1967 to the Department of Environment with the name changed to Inland Waters Branch. V.A. Haw was appointed chief of the Mineral Sciences Division in 1965. He had joined the Mines Branch in 1950 and been appointed to the Industrial Minerals Division. He left to take up an appointment in the mining industry in 1959 and returned to the branch in 1961 when he worked in the director's office on a number of projects including the preparation of reports in connection with the director's membership on the National Productivity Council and other projects.

Titanium

A major program was carried out in the Mines Branch between 1951 and 1959 on titanium, which was described at the time as a "wonder metal", with the view of developing a titanium metal industry in Canada. Titanium possesses a high strength-to-weight ratio when compared with steel and has high corrosion resistance. These properties were attractive to the aircraft engine and frame industries and to the Navy. On the other hand, titanium was not an easy metal to produce, suffering loss of ductility if even small amounts of impurities, particularly oxygen, were present, requiring the employment of a vacuum or inert gas atmosphere in heat processing.

The program received financial support in grants totalling about $250,000 from the Defence Research Board, which also supported related university research. A research project was undertaken at the University of Toronto by Dr. T.R. Ingraham under Prof. L.M. Pidgeon on the iodide preparation of titanium metal free from oxygen. Ingraham joined the Mines Branch in 1953. A related research project under Prof. B. Chalmers was undertaken by Dr. J.N. Pratt on the mechanism of embrittlement of titanium by oxygen. At the University of British Columbia, research was done on phase transformations in titanium-base alloys by Dr. J.G. Parr under Prof. Frank Forward. Later, in connection with the Shawinigan titanium sponge program, Laval University was given a grant to elucidate the composition of complex salts formed during the electrolysis of titanium compounds in molten baths containing sodium or potassium fluoride. University research is mentioned in this narrative as it was coordinated by the Mines Branch under H.V. Kinsey, head of the Refractory Metals Section in the Physical Metallurgy Division.

The task set by Canada was difficult from the outset. Several countries possessed titanium resources either in the purest natural form of titanium dioxide as the mineral rutile, mainly in beach sands in Australia, or in the more plentiful ilmenite which consists of strongly combined oxides of titanium and iron. World rutile concentrate production was about 75,000 short tons in 1955, mostly from Australia with a small amount from the United States. About 1.4 million short tons of ilmenite concentrates were also produced of which 580,000 were from the United States, 301,000 from India, 174,000 from Norway, and 164,000 from Canada (with a higher content of 70% in the TiO_2 slag). The Canadian deposits at Allard Lake in Quebec were considered to be the largest in the world which was probably the main incentive for the R & D program aimed at developing domestic resources up to the end use.

However, the Canadian ore required costly processing before it could be converted to metal. The largest producer of titania slag at that time was the Quebec Iron and Titanium Corporation (QIT) which in 1955 produced about 300,000 tons of slag containing 70% titanium from 400,000 tons of ore grading 35% Ti and 8% Fe. The conversion from ore to slag was accomplished at Sorel, Quebec after shipping ore by a 27-mile rail line from the mine to Havre St. Pierre followed by a water haul of 570 miles. Initially, after crushing, the ore was mixed with anthracite and fed into an electric arc furnace to produce slag. Intermediate beneficiation steps were introduced for upgrading the ore in 1956. This was done first by gravity concentrating the coarse fraction using heavy media Dutch State Mine cyclones and the fine fraction using Humphrey spirals followed by calcining the concentrate to reduce the sulphur content derived from the pyrites in the ore. The upgraded product was then mixed with powdered anthracite and electrically smelted to produce molten iron and 70-72% pigment-grade titania slag. These beneficiation steps were first tried out in the Mines Branch. The program for upgrading titaniferous ores from various parts of the country continued into the late 60's. Up to 1959 the investigations were the responsibility of the Mineral Dressing and Process Metallurgy Division and thereafter of the Mineral Processing Division. The principal officers concerned with these investigations were W.S. Jenkins, J.D. Johnston, R.A. Elliott, T.F. Berry, D.E. Pickett, R.S. Kinasevich and D. Raicevic. The latter prepared a review of mineralogical and ore dressing investigations carried out in the Mines Branch from 1950 to 1975 with an evaluation of results (111).

The titania slag produced by QIT was mostly exported although a proportion was sold domestically for pigment manufacture. Expansion took place in succeeding years, capacity reaching about 400,000 tons of slag per annum by the end of the 50's and 800,000 tons by the end of the 60's. At this time Dominion Magnesium Company was the only producer of titanium metal in Canada, importing refined titanium dioxide from the United States and converting a small quantity into titanium metal by a two-stage thermal reduction process designed by Prof. Pidgeon using magnesium and calcium as reducing agents. Domag Titanium was the principal supply of titanium metal for the R & D work in the Physical Metallurgy Division, but the metal was somewhat brittle because of the impurities still present. In 1955 the company developed methods for producing homogeneous alloy powders of titanium with molybdenum, vanadium, manganese, chromium and aluminum, and claimed to be sufficiently low in impurities for it to be used in alloy billet production.

The foregoing was the industrial setting at this time. The Mines Branch program had two components directed to the treatment of ore or slag, the first leading to the production of titanium metal and carried out in the Mineral Dressing and Process Metallurgy Division; the second was directed to melting, casting, forming and fabricating methods in a study of titanium metal and titanium alloys, carried out in the Physical Metallurgy Division.

Treatment Research

The treatment research was headed by Downes and the laboratory work was carried out by Dr. B.J.P. Whalley (1950 -) assisted by T.F. Berry (1948 -). A pressure leaching process was developed consisting of treating the ore with dilute sulphuric acid in an autoclave at 250°C. This step produced ferrous sulphate and undissolved titanium dioxide with siliceous matter. A second step to digest titanium dioxide with concentrated sulphuric acid resulted in the formation of titanyl sulphate which was heated to precipitate the titanium dioxide. The recovered filtrate was used to leach fresh ore. On the iron side the ferrous sulphate was converted to ferric oxide and the sulphuric acid could be almost entirely reused except for the small amount consumed by the gangue minerals; later the richer titania slag was also tried successfully at lower temperatures and pressures (Res Rep MD 176, 1955). Pressure leaching was considered cheaper than atmospheric leaching because of the high consumption of strong sulphuric acid in the latter. Downes gave Whalley full credit for the work in the latter's exclusive authorship of a Canadian patent in 1960. In a co-authored presentation, this ilmenite leaching process was reported by Downes and Whalley at the 5th Congress of the Chemical Engineering Division of the Chemical Institute of Canada in March 1955.

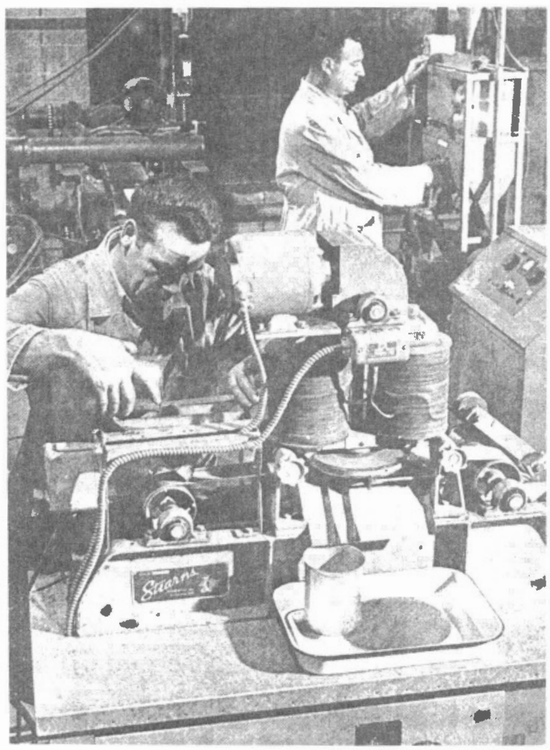
In the Chemical Metallurgy Laboratory under Dr. R.R. Rogers, attempts were made to produce titanium metal by the thermal reduction of titanium dioxide. In 1953, a 250-kVA electric arc furnace was installed and a series of tests over a period of several months was carried out on Lake Allard ilmenite. A high-grade titanium slag assaying 85% titanium dioxide with only 1.2% iron oxide was produced and was considered as a highly satisfactory material for the pigment industry. However, the production of titanium metal was not considered successful as it was impossible, even after repeated efforts, to strip the metal of undesirable impurities which made it brittle.

These impurities included not only gases like oxygen, nitrogen and hydrogen but non-metallic elements like carbon, sulphur, calcium, phosphorus, and silica, all of which above certain levels had a deleterious effect on the properties of titanium and titanium alloys. The Chemical Laboratory in the Mineral Dressing and Process Metallury Division made a special effort to develop analytical procedures for the accurate determination of these impurities, and their work was crowned with success.

In the Physical and Crystal Chemistry Section led by A.T. Prince, petrographic and X-ray diffraction examinations were made on samples of titania slag to evaluate the constituents. Later, phase equilibria studies to explain the intimate association of titanium and iron were carried out by Bright to provide guidance in the smelting process and to ensure the best quality product either as a dioxide or possibly as a metal. This study sought to determine the necessary thermodynamic conditions for effecting a reduction of contained iron oxide to metal which subsequently could be removed by acid leaching or by magnetic concentration (MB RR 76, 1961).

In 1954, an agreement was made with the Minister of Defence Production for the Shawinigan Water and Power Company of Montreal to undertake an R & D study in a pilot-scale demonstration plant on the production of titanium metal. The method was to chloridize titanium slag to yield titanium tetrachloride which was then fed into a molten sodium chloride bath for electrolysis under an argon blanket. The titanium was produced at the cathode and was periodically removed and leached to make a titanium sponge. The estimated production cost was $2.50 per pound, which was competitive with the Kroll titanium chloride or magnesium reduction process used in the United States. At first the results appeared promising but contamination from oxygen, nitrogen, sodium and other impurities could not be eliminated. After two years of experimentation and an expenditure of about $500,000 in grants from Defence Production the project was abandoned.

With the increasing application of electrowinning and electro-refining of metals in molten salt electrolysis stimulated by the titanium metal program, a project was undertaken in the Extractive Metallurgy Section of the Mineral Dressing and Process Metallurgy Division led by Dr. T.A. Ingraham to develop more fundamental knowledge of the molten salt electrode process. Standard electrode potentials were measured for various metals and the thermodynamic properties of the cell reactions calculated. This research was reported in "Voltaic cells in fused salts" by S.N. Flengas (1958 - 1960) and T.R. Ingraham in 5 parts (MB RR 16, 17, 19, 20, 29, 1958). In a later study, solubility of titanium tetrachloride in fused chloride mixtures and the electrode potentials of titanium chlorides were measured. The covering report was "Solubilities of $TiCl_4$ in mixtures of KCl-MgCl and the electrode potentials of the titanium chlorides in 1:1 (mole) KCl-NaCl solutions" by S.N. Flengas (MB RR 50, 1960, reprint from Ann N.Y. Acad Sci, 79, Art 11, Jan. 30, 1960).



Concentration of titanium ore. In the rear H. Renaud is at the infrasizer and in the foreground J. Banks is operating the high-intensity magnetic separators

Physical Metallurgy Research

The physical metallurgy aspect of the Mines Branch program was pursued simultaneously with the foregoing extraction research. Much of Kinsey's time in his coordinating capacity was taken up in providing liaison between industry and government departments. In fact, he could have been described as the "anchor man" to the Canadian Titanium Committee which was composed of government and industry representatives with Convey as chairman. At this point it should be said that there was considerable Canadian and foreign industrial interest from about 1953 for the next three or four years in potential Canadian metal production from the metal products end of the metallurgical industry, in particular, from Atlas Steels which was the most heavily involved. The company kept in close touch with the government in general and with the Mines Branch in particular. In 1956, Atlas Titanium Limited was formed jointly by Atlas Steel Limited and Mallory Sharon Titanium Corporation of Ohio to produce titanium metal and alloy ingots from titanium sponge. This was derived from titanium tetrachloride in the U.S.A. Some Shawinigan sponge was melted into alloy ingots at the Ohio plant but the results were reported as being erratic due to contaminants. This may have been the principal reason for stopping the titanium metal production by Shawinigan. Later, the downturn in Canadian aircraft manufacture, notably the cancellation of the "Arrow" plane program, no doubt contributed also to the demise of a nascent titanium metal production capability in this country.

The initial Physical Metallurgy Division team was headed by J.W. Meier with Dr. W.D. Bennett (1951 - 1955) responsible for the scientific aspects, O.Z. Rylski (1947 - 1956) and J.J. Sebisty (1951 -) for melting and casting, Dr. Y.L. Yao (1950 -) and K.S. Milliken (1950 -) for oxygen analysis, and John Perry for metal forming.

The preliminary work included the selection, adaptation, acquisition and construction of melting furnaces and auxiliaries including the casting equipment. The initial melting and casting facility was on a bench scale, comprising a DC arc furnace of 300-gram capacity operating in an argon atmosphere in which 95 melts were made. This was followed by melts of 2,000 grams in a vacuum high frequency induction furnace. One of the casting units was continuous. Twenty-five melts were produced. The titanium metal mostly used was Dominion Magnesium Company's "Domal". The initial classified Research Reports of the Physical Metallurgy Division covering the early work were designated PM 100 to PM 107 by O.Z. Rylski, PM 110 and 113 by W.D. Bennett, PM 114 by O.Z. Rylski and J.J. Sebisty, and "Bibliography on titanium metal and alloys (1946 to 1950), - properties, fabrication and uses" by J.W. Meier (Memorandum 303) - "Bibliography on refractory melting including some references on vacuum technology (1946 to 1950)" by J.W. Meier (Memorandum 304).

The R & D facilities were later scaled up to produce billets up to 6 in. in diameter and between 10 and 25 pounds. The melting furnace that gave the best results was a water-cooled copper crucible type using an arc struck from a consumable tungsten or titanium electrode. The oxygen content of the Domal titanium was too high, causing the metal to be brittle. Nevertheless, the metal forming processes carried out by John Perry and his group produced forgings of reasonable quality as well as hot-rolled and some cold-rolled sheet. Kinsey in 1953 presented a summary paper on titanium with emphasis on the physical metallurgy aspect to the annual general meeting of the Canadian Institute of Mining and Metallurgy in Edmonton (112).

The R & D in the laboratories of the Physical Metallurgy Division (PMRL) embraced considerable work on titanium alloys which was continued throughout the period. Alpha titanium alloys in the lower temperature range and beta in the higher temperature range were investigated. Dr. A.J. Williams, who joined the branch in 1954, carried out research work in this area for several years. A ternary alloy of titanium, aluminum and molybdenum was selected for study, and the constitution diagrams of the titanium-rich corner of the ternary system was investigated for the purpose of designing an alloy for the optimum heat-treated properties. Two research reports by A.J. Williams were published in 1958 and 1964 - "Design of heat-treatable titanium alloys" (MB RR 11; 1958), and "Study of the constitution of the titanium-rich corner of the titanium-aluminum-molybdenum system" (MB RR 132; 1964). In addition, Williams was concerned with development of the consumable electrode arc furnace and embrittlement of titanium by hydrogen, the latter being described in the report PM 203.

Process influences in relation to magnetic properties of titanium alloys were described in the report "Effects of cold work and quenching on the magnetic susceptibility of a commercial titanium alloy" by Y.L. Yao reprinted from American Society for Metals; vol 51, pp 862-870, 1959 (MB RR 35; 1958).

The welding characteristics of titanium and titanium alloys were investigated by Dr. K. Winterton, who joined the Mines Branch in 1958 and who wrote "Weldability of titanium and titanium alloys" by K. Winterton (MB TB 71; 1965). In an overall review in 1966, Kinsey published a survey of the application, processing and manufacturing technology of titanium alloys (113). The largest use for titanium is in the pigment industry. Use of ferro-titanium decreased in Canada from 198 short tons (titanium content) in 1961 to 34 tons in 1964.

H.V. Kinsey

Dr. A.J. Williams

PRECIOUS METALS

Gold

Research in cyanide chemistry with a view to improving the process in the gold mining industry was renewed in 1948 but was interrupted in 1950 by projects in titanium and iron ore. The pooling of the hydrometallurgical and chemical expertise inherited from the former Mineral Dressing and Process Metallurgy and Radioactivity Divisions was utilized by Downes in launching a project in 1961 to improve the cyanidation process. The international gold price fixed at U.S. $35 some 30 years earlier was still in effect, hence there was an incentive to improve recovery at the mills. The project was well received by industry. The various mills were visited and improvements were suggested after on-site study and experimentation in the Ottawa laboratories. This survey indicated the abundant association of sulphide minerals with Canadian gold ores. It was found that pyrrhotite in particular was sensitive to alkalinity, and if the cyanide solution exceeded the pH value of 11.2 the pyrrhotite was dissolved at an appreciable rate.

A standard test for measuring the dissolving power of a cyanide solution for gold by the timed dissolution of a gold leaf was developed to indicate the amount of possible discard of barren cyanide solution and the make-up of fresh solution to obtain optimum concentration and alkalinity in the mill circuit. Another innovation was a rapid method of determining oxygen in solutions and pulps; oxygen being necessary for the dissolution of gold but must be in a dissolved form and controlled to avoid oxidation of sulphide minerals.

Field studies had shown considerable variation in operating conditions of the cyanide process within each plant and also between different plants treating similar ores. As a result, a pilot plant was set up in the Extraction Metallurgy mill laboratory, consisting initially of a grinding unit to measure and control circuit variables for maintaining predetermined conditions of grind and alkalinity.

In January 1962, some 20 gold mill superintendents attended a two-day technical meeting at the Mines Branch to review progress of investigations and to discuss operation of their gold mills. This meeting was deemed a success and led to the formation in 1963 of the Canadian Gold Metallurgists Committee with annual winter meetings taking place at the Mines Branch with the main objective of promoting the exchange of scientific and technological information concerning gold metallurgy. The group was broadened in 1968 to include all mineral processing and its name was changed to Canadian Mineral Processors.

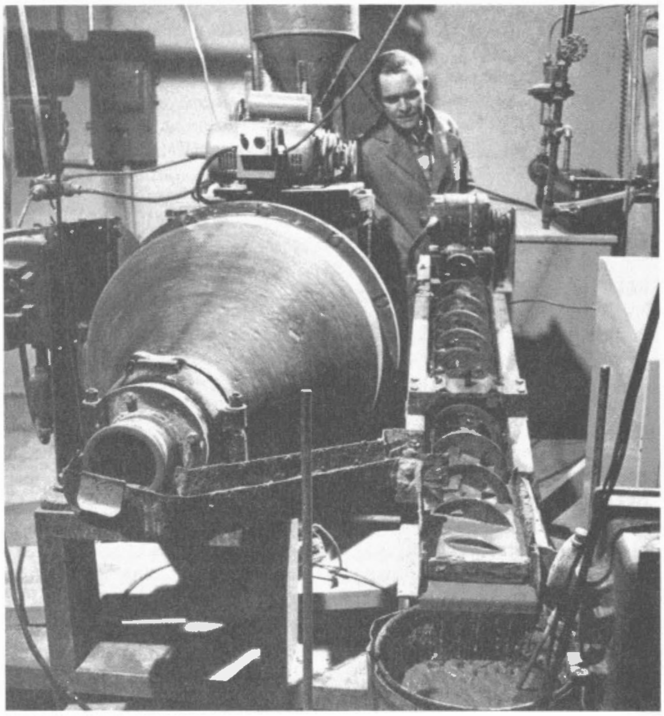
The committee requested the division to develop standard test methods so that data from different laboratories could be compared when testing gold ores in response to varying conditions. The procedure adopted was to cyanide a typical gold ore in which the pulp was agitated by end-over-end tumbling in closed bottles, by rolling in open bottles, by mechanical high-speed stirring in an open beaker, or by air in a pachuca-type vessel. The pulp density was maintained at 10% solids by weight in all these tests. The dilute pulp provided a large excess of reagents - cyanide, lime and oxygen - over that necessary for the chemical reactions taking place. The leaching solution was thereby kept constant and it was not necessary to readjust the concentration during the test. The most reliable tests were obtained from the closed bottle tests, although the gold extraction rate was essentially the same for all the other agitation methods. The results of the earlier program of the effect of sulphur compounds on the dissolution rate as determined by the gold leaf tests was confirmed using typical gold ores and a dilute leach technique.

A series of monitors and other apparatus for the measurement and control of process variables were designed for the laboratory and field studies. Thus a gold dissolution monitor was designed with the assistance of the Eichholz group and described in "Semi-automatic monitor of cyanide solution strength for gold ore dissolution" by G.G. Eichholz and C.A. Josling (MB TB 43, 1963). An electronic system was designed for the pilot plant grinding circuit that controlled the ore and water feed to give maximum output consistent with a sustained quality of final product. Control was actuated by selected frequencies of the noise generated by the grinding mill and modified by continuous measurement of the pulp density of the final slurry. Alkalinity or control of lime reagent additions to the cyanide solution was provided by the conductivity probe developed by the Mineral Sciences group (MB TB 27, 1961). An automatic titration unit was developed for monitoring cyanide concentration of leach solutions. "Measurement of free cyanide concentration by continuous potentiometric titration" by J.C. Ingles (MB RR 127, 1964).

These control and measurement devices were tried out in a number of mills for varying periods of time, resulting in certain cases in better circuit operation. In 1966, with the advent of computer technology, the Extraction Metallurgy Division turned to the study of mathematical simulation of hydrometallurgical processes as a means of evaluating optimum process conditions. The first simulation studies were done on uranium and gold leaching but no reports were published.

Throughout the 50's there was considerable activity in prospecting for gold, particularly in Ontario. There were periods when requests for investigations by the Mines Branch rose to the same level as in the pre World War II "rush". Thus in 1955, 12 ores were treated and flowsheets established.

After 1959 in the Mineral Processing Division as in the Mineral Dressing and Process Metallurgy Division, there was a steady flow of requests from industry for treatment of gold ores mainly of those asso-



F. Kelly observes automatic control of feed rate to grinding circuit by sound from ball mill (Photo - George Hunter)

ciated with other metals thus requiring more complex concentration methods, e.g., Red Lake, Ontario ores. Selective flotation played an important part in such ores, at times requiring a second pass after cyanidation.

In spite of the fixed price of gold, production rose unevenly from a low in 1945 of 2,696,727 troy ounces to a peak in 1960 of 4,628,911 ounces. Production then started to slide again and by 1970 was only 2,357,620 ounces and, by 1975, 1,674,000 ounces. The proportion of the 1970 production that originated from lode mines was 78%. Ontario accounted for 48.5% and Quebec for 29% of the total output.

The average price of gold in 1970 in Canada was $36.57 per fine ounce in Canadian funds. The Canadian dollar was pegged at $0.925 U.S. plus or minus 1% in 1962, but it was allowed to float in 1970. In 1975 the price of gold in U.S. funds per troy ounce fluctuated widely between $130 and $185.00. Many mines were finding the lower price of $130 unprofitable, indicating the degree of the rise in costs which had taken place in the five-year period from 1970.

A research project sponsored by the Canadian Metal Mining Association was carried out in 1959 and 1960 in the Physical Metallurgy Division to explore new industrial applications of gold. A literature study for the ten-year period from 1950 to 1959 was undertaken by L. Badone of the Canadian Metal Mining Association and N.S. Spence (MB IC 116, 1960). Another study was made on the properties of gold and gold alloys by the same authors (MB IC 129, 1961). Various metals, both ferrous and non-ferrous, were tried with small additions of gold and tested for their effects on properties of metals but results were either inconclusive or negative.

Some research was carried out between 1966 and 1968 using gold as a barrier to entry of hydrogen in steel in the electroplating process. This was an Air Canada-sponsored project to produce a sound gold coating prior to cadmium plating.

Silver

Silver production in Canada in the 60's surpassed the previous peak production of 33 million troy ounces in 1910, the heyday of the Cobalt silver rush, to over 40 million ounces in 1968. Thereafter silver followed gold in a decreasing production curve.

The revival of silver production can be accounted for by the increased output of base metal ores, which was responsible for about 90% of the silver produced, and by the revival of the Gowganda-Cobalt area of Ontario due to the overriding factor of increased silver prices.

In 1961 the Mineral Processing Division was asked for assistance in obtaining more advantageous returns from the custom smelter operated by Kam-Kotia Porcupine Mines Ltd. For this purpose an officer of the division spent some time in the field, resulting in a better return to the producers for the silver values from the custom smelter.

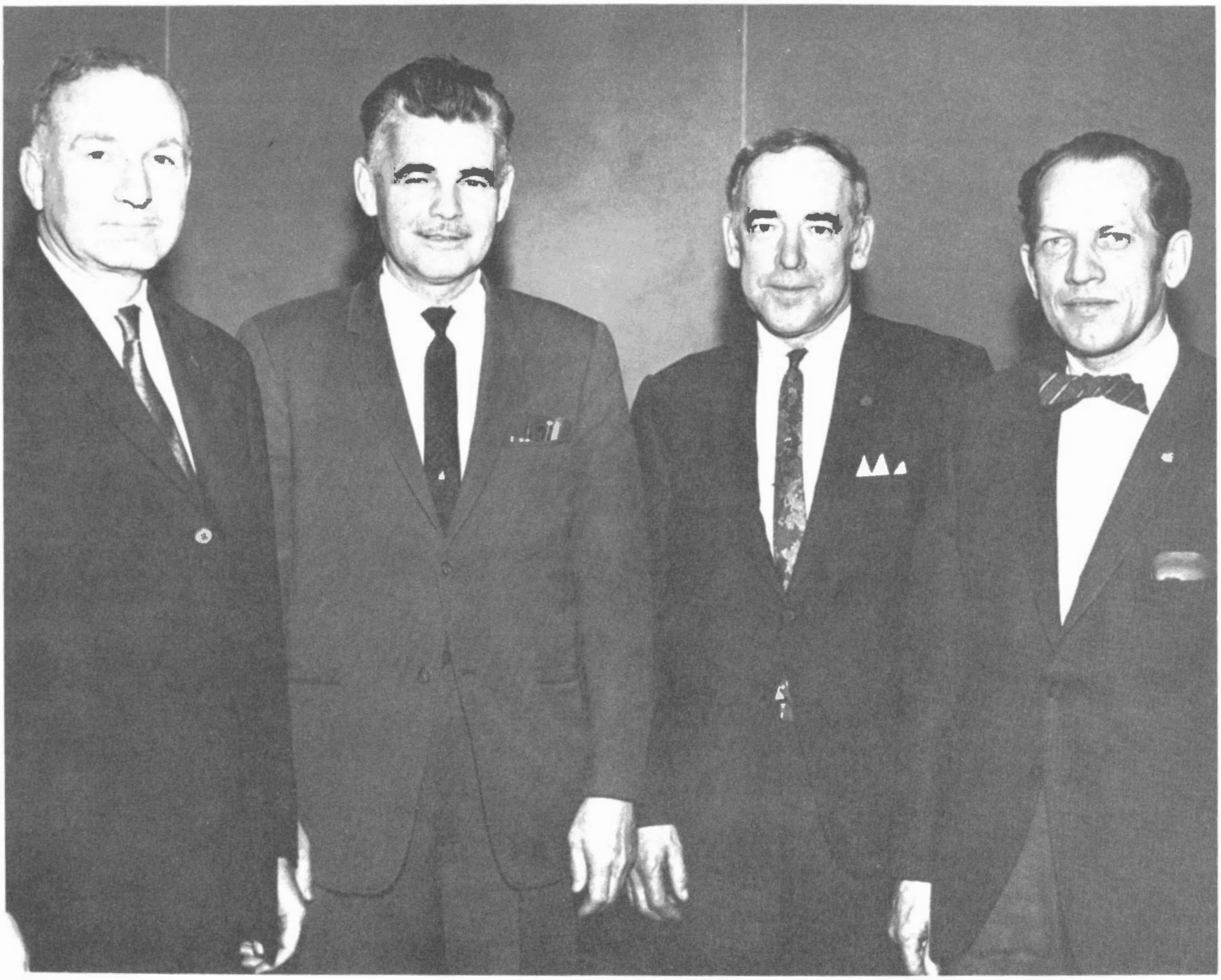
In spite of a good silver recovery ranging from 90 to 95%, the Temiskaming Mine Operators Association requested the Mines Branch in 1964 to further reduce tailing losses. A mineralogical study of mill products was made and various plants were visited. Fine grinding and flotation eventually recovered about two thirds of the silver left in the tailings. Often the recovery of silver or of other required metals was vitiated by the interference of an unwanted mineral. A good example came from the Ontario Red Lake area known for its complex ores where a gold-silver ore assaying 1.06 ounces of gold and 4.5 ounces of silver yielded a silver recovery of only about 80%. It was found that the ore contained a small amount of silver telluride, and a technique employing bromo-cyanidation was proposed for a flowsheet that incorporated jigging, amalgamation and cyanidation with the addition of bromo-cyanide. This method gave a recovery of 99% gold and 98.4% silver.

Platinum Group

Canada was the third largest producer of the platinoids after South Africa and U.S.S.R. at close to one-half million troy ounces per year from the middle sixties, or almost double the 1942 peak. This group of metals was derived as a byproduct from the nickel-copper ores of the Sudbury Basin. After 1970 there was production from the Shebandowan district of Ontario and the Thompson-Wabowden and Bird River districts of Manitoba. However, Canadian production of platinoids after the new mines were commissioned did not increase because of the cutback in overall base metal production; moreover, platinum and palladium prices were falling.

During the early sixties, the Mineral Processing Division investigated on behalf of independent entrepreneurs, a number of non-ferrous ores that contained one or more of the platinoids. These ores occurred outside the Ontario and Manitoba nickel-copper belts, but none of these projects resulted in established mines.

As mentioned earlier, the Mineral Sciences Division conducted considerable research in evolving accurate analytical procedures for the platinoids. It earned the group recognition as the national reference laboratory and this resulted in many requests for analysis or check analysis from applicants other than principal producers.



Recipients of the 25-year service pins, left to right: K.W. (Ken) Dowles, G.W. (Tim) Nolan, L.J. (Bill) Quinn, W.A. (Bill) Gow

Extraction Metallurgy Division

The formation of a largely chemistry-based division at the time of an abrupt downturn of the uranium industry created both a challenge and difficulties for the division as explained below. As in the case of the Mineral Sciences Division, it is appropriate to outline briefly the organization of the Extraction Metallurgy Division with its strong emphasis on chemistry.

Virtually the whole of the chemistry and mineralogy staff of the Radioactivity Division was transferred in 1959 to the new division. This formed the Hydrometallurgical, Chemical Analysis and Mineralogy sections which were joined with the Research Section (formerly Extractive Metallurgy) and the Pyrometallurgy and Corrosion Sections (formerly Chemical Metallurgy) from the former Mineral Dressing and Process Metallurgy Division.

There was no question of the potential importance of continuing the development of appropriate treatment methods for the extraction of economic minerals from the more abundant low-grade and complex ores by a staff which had demonstrated its expertise so successfully in dealing with low-grade radioactive ores. On the other hand, the mineral industry with the exception of the uranium component, was enjoying "boom" circumstances, and broadly speaking would only use the chemical route where the economics were strictly favourable. The new Mineral Processing Division assumed the major role in dealing with mineral dressing requests from industry.

As mentioned earlier, Downes and his associates selected the project to assist gold mining in improving recovery by the cyanidation process. The gold industry as a whole showed confidence in him and his associates by agreeing to support the formation of the Canadian Gold Metallurgists Committee and its successor the Canadian Mineral Processors, and by participating in open dialogue on their problems at annual meetings of the group; its meetings continue to be well attended by industry representatives. Ron Ennis joined the Mines Branch in 1959 and was particularly helpful in this project until his untimely death in 1964.

The division kept in close touch with industry through its engineering staff mainly in the Hydrometallurgical Section as well as through men like R.M Ennis and C.S. Stevens, appointed as industrial liaison officers. The approach to projects on ore treatment which usually involved the three sections mentioned was on the basis of perceived need by the industry as a whole related to a given commodity rather than on requests from specific enterprises, though of course there were exceptions. Principal contributions of the division to the chemical treatment of minerals is scattered throughout this narrative where specific commodities are described.

Much of the mineralogical and chemical analysis was concerned with bench and pilot plant R & D work related to ore treatment, but research on devising new or improved methods was pursued not only for divisional but also for industrial needs particularly related to the objective of improving process control at the mills. An example of development work on the analysis of less common metals was the determination of bismuth by chelatometric titration by A. Hitchen and G. Zechan-

Formal opening of Extraction Metallurgy Division, 300 Lebreton St., May 1, 1957. K.W. Downes, John Convey, H.W. Smith

owitsch (MB TB 173, 1973). Another example was a complete analytical procedure for analysis of electric furnace slags with particular reference to ilmenite titanium bearing slags (114).

Organization of Extraction Metallurgy Division, 1965

At the formation of the Extraction Metallurgy Division in 1959, W.A. Gow, J.C. Ingles and S. Kaiman were heads of the Hydrometallurgical, Chemical Analysis and Mineralogical Sections respectively of the Radioactivity division. In 1965 the professional staff of the three sections were:

Hydrometallurgy Section:
Head - W.A. Gow, head (1946 -)
V.F. Harrison (1947 -)
A.J. Gilmore (1948 -)
W.R. Honeywell (1948 - 1973)
H.H. McCreedy (1954 -)
V.M. McNamara (1954 -)
B.H. Lucas (1958 -)
F.J. Kelly (1959 -)
H.W. Parsons (1959 -)
J.A. Vezina (1960 - 1973)
Mill foreman: E.H. Devine (1948 - 1969)

Mineralogy Section:
Head - S. Kaiman, (1946 -)
M.R. Hughson (1952 -)

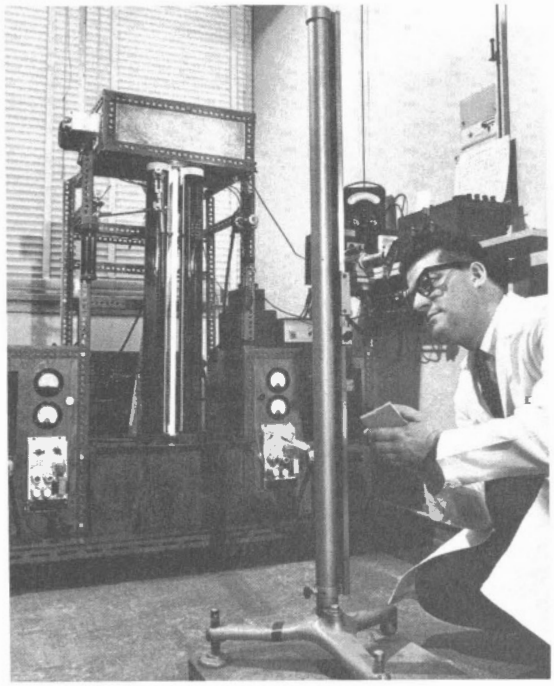
Chemical Analysis Section:
Head - J.C. Ingles, (1949 - 1951) and (1952 -)
J.B. Zimmerman (1947 -)
E.D. Kornelsen (1948 - 1968)
F.P. Roloson (1948 - 1970)
R.J. Guest (1948 -)
A.D. King (1949 -)
A. Hitchen (1952 -)
G.A. Hunt (1952 -)
J.E. Atkinson (1953 -)
D.J. Barkley (1953 -)

Hal Smith was acting chief of the Radioactivity Division after Brown's death and in the new division was appointed as special assistant to Downes, a position he occupied until his retirement in 1974. He was concerned with industrial liaison, particularly with the uranium industry technical feasibility studies, program planning, and with technical information. C.S. Stevens, appointed to replace Ron Ennis in 1964, served as industrial liaison officer until his death in 1972. In 1971 Gow was appointed assistant chief of the division. In 1972 the Hydrometallurgical Section was divided into Ore Treatment - head, H.H. McCreedy with K.A. Bragg (1971 - 1973), F.J. Kelly, H.W. Parsons, R.F. Pilgrim (1948 -) and J.A. Vezina - and Solution Treatment - head, G.M. Ritcey (1952 and 1967 -), A.J. Gilmore, B.H Lucas and V.M. McNamara. Gordon Ritcey worked as a student with the Radioactivity Division in 1952; he then joined Eldorado Nuclear Ltd. for 11 years where he developed a number (some patented) of solvent extraction and other hydrometallurgical techniques. He contributed to development of the high purity zirconium metal production now used by the sole Canadian zirconium producer.

The Research Section under Dr. T.R. Ingraham in the newly-formed division was concerned with some research related to the projects of the division mentioned under the relevant commodities described. There were other projects described in such reports as: "Measurement of dissolved air in alkaline solutions from uranium mills and from gold mills" by G. Thomas and T.R. Ingraham (MB RR 71, 1960); and "Operating variables of a small hydrocyclone" by R.F. Pilgrim and T.R. Ingraham (MB RR 103, 1962, reprint from Can Journal Chem Eng).

A large proportion of research was conducted for advancing the knowledge of kinetics and thermodynamics of chemical reactions and processes involved in dissolution, thermal decomposition, and chlorination as well as kinetic studies of metal on metal deposition (cementation) of metal compounds. Some of these studies were published in Mines Branch reports, others in the Metallurgical Quarterly published by the Mines Branch on behalf of the Canadian Institute of Mining and Metallurgy and in the Transactions of the Metallurgical Society of the AIME, New York. An example of an overall review of thermodynamics and kinetics was related to the roasting operations used in extractive metallurgy (T.R. Ingraham and R.C. Kerby, Can Metall Quarterly, vol 6, No. 2, pp 89-119, 1967).

P. Marier carries out kinetic decomposition studies using automated analytical equipment.



R. Charlebois measures decomposition pressure to establish thermodynamic properties of metallic sulphates at elevated temperatures. (Photo - George Hunter)

After formation of the Department of Energy, Mines and Resources in 1966, Ingraham redirected much of his research effort into the protection of the environment. Examples of studies were: "Kinetic and thermodynamic data from effluent gas analysis" by T.R. Ingraham (Proc Second Toronto Symposium on Thermal Analysis, pp. 21-36, 1967 - reprinted as MB RS 47); and "Role of calcium sulphite in desulphurizing gases containing sulphur dioxide" by P. Marier and T.R. Ingraham (MB RR 222, 1970). A comprehensive study was made on sulphur recovery from base metal ores related to the Mines Branch program on environmental improvement (115).

In 1965 the professional staff of the Research Section were:

Head - Dr. T.R. Ingraham (1953 - 1972)
R.F. Pilgrim (1948 -)
Dr. G. Thomas (1950 - 1967)
P. Marier (1954 - 1972)
Dr. M.C.B. Hotz (1963 - 1968)
Dr. E.A. Von Hahn (1964 - 1967)

Ingraham resigned in 1972 to join the Department of the Environment and was succeeded by Dr. A.W. Ashbrook, who joined the Mines Branch in 1970.

The Extraction Metallurgy Division became part of the Mineral Sciences Laboratories in 1975. A group picture taken in 1974 is shown overleaf.

Extraction Metallurgy Division staff, 1974

Seated: G. Carrière, H.W. Smith, J.A. Gilmore, J.C. Saiddington, W.A. Gow (assistant chief), Dr. K.W. Downes (division chief), J.C. Ingles, Mrs. I. Marion, Mrs. J. Tegano, Miss M. MacCormack, Mrs. M.B.Y. St. Germain;

2nd row: C.R. Lalonde, A. Hitchen, G. Zechanowitsch, D.J. Parkley, J.L. Beaupré, O. O'Hara, D.A. Sheldrick, F.J. Kelly, J.E. Atkinson, J.L. Fleury, R.J.C. MacDonald, J.J. Laliberté, W.J. Craigen, G.M. Ritcey, F. Bouvier, R.F. Pilgrim, G. Shanks;

3rd row: E.H. Lucas, Dr. A. Lui, R.J. Pugliese, A.D. King, R.J. Guest, G. Levine, P. Carrière, M. Joly, Dr. J.E. Dutrizac, Mrs. C. Leblanc, P. Prud'Homme, S. Kaiman, V.F. Harrison, P. Bélanger, Dr. G.R. Hoey, E. Rolia;

4th row: K.T. Price, Dr. D.J. MacKinnon, J.M. Brannen, J.R. Gordon, Dr. D.J. Francis, G.A. Hunt, L.E. Shaheen, J.B. Zimmerman, L.L. Lalande, V.M. McNamara, J.B. Kearns, C. Freeman, M.R. Hughson, W. Dingley

IRON AND STEEL

Some 40 years had to pass before fulfilment of Eugene Haanel's hopes that Canada would not have to rely so heavily on imports of iron ore as it did in his day. This transformation took place in the decade following World War II. In 1948 imported ore supplied 93% of consumption, which amounted to approximately 4 million tons. In less than 10 years, by 1956, imported ore had dropped to about 70% of consumption which had increased to 6.4 million tons; at the same time, there was an export surplus of 18 million. By 1965, imported ore declined to about 50% of consumption, which increased to 9.6 million tons with an export of 30.8 million tons. This included ore, concentrates and agglomerates as enriched feed to blast furnaces had come into demand. By 1970, imported ore was only approximately 18% of the consumption which had reached 11.5 million tons. Canada in 1970 was the fourth largest producer of iron ore in the world after U.S.S.R., U.S.A. and France. Our best customer was the U.S.A., purchasing 23.8 million tons from total exports of 38.7 million long tons (consisting of 7.7 million tons direct shipping ores, 13.5 million tons concentrates and 17.5 million tons agglomerates or pellets). Having reached a total production of about 50 million tons per annum in the seventies, the progressive growth slowed down because of the general instability of international mineral markets and the downturn in output of steel in most industrial countries.

Iron ore production, consumption, imports, and exports 1948-1970 (long tons x 10^6)

Year	Production	Consumption	Imports*	Exports
1948	1.2	4.1	93%	1.0
1956	20.0	6.4	70%	18.1
1965	35.7	9.6	50%	30.8
1970	46.7	11.5	18%	38.7

*As percentage of consumption

The impetus to the Canadian iron ore industry was undoubtedly provided by results of the prospecting in the late 40's undertaken by the Hollinger-Hanna group, a mixed Canadian-U.S.A. venture, later to become the Iron Ore Company of Canada (IOC), which delineated the reserves from an original discovery by Dr. A.P. Low of the Geological Survey of Canada many years previously in the Ungava Bay district on the border of Quebec and Labrador. A considerable investment was required in building a 350-mile railroad line from Schefferville to a new port at Sept Iles on the St. Lawrence River, making the area accessible for loading iron ore which initially was high grade direct-shipping quality. Construction was started in 1949 and the first ore was shipped in 1954. These shipments were destined for the U.S.A., which was starting to experience a decline of reserves from the famous Messabi iron ranges in Minnesota. As the foregoing Canadian import figures have shown, U.S.A. ores have continued to be available because of ownership by Canadian integrated steel companies of U.S.A. iron and coal mines.

A landmark development occurred in the early fifties in smelting of iron ores. Rapid improvements were made in blast furnace efficiency, resulting in the retention of the blast furnace as the main ironmaking unit. At the conclusion of hostilities in Europe there was considerable debate about the future of the classical high-shaft furnace with its high capital investment and requirement of high-grade feed in both ore and fuel. The newly formed Northwest European Coal and Steel Community sponsored a research project on a low-shaft furnace at a lower investment cost to evaluate the use of lower-grade feed materials. Possibilities of using an oxygen enriched blast were also investigated. There were some discussions about participation of the Mines Branch in this project, particularly in relation to the establishment of a primary iron and steel industry in the Prairie Provinces. This activity was complemented by the rapid enlargement of iron and steel research establishments in Europe, such as BISRA (British Iron and Steel Research Association) and IRSID (Institut des Recherches de la Sidérurgie Française) to which the Mines Branch staff had easy access. These centres played an important role in focussing attention on the possibilities of optimizing the blast furnace and other ferrous metallurgy operations. Similarly, in the U.S.A. the Bureau of Mines later formed an organization known as the Blast Furnace Research Incorporated which the integrated Canadian steel companies joined.

The main improvements that enabled the blast furnace to increase its productivity besides major increases in furnace size - itself made possible by improved properties - were an enriched blast using oil or natural gas and even coal through the tuyeres, better sized ore, enriched ore feed, and coke produced from selected coal blends. It is noteworthy to record that the first iron ore pellet plant in Canada started at Marmora, Ontario in 1955 for shipment of iron ore pellets to the Bethlehem Steel Company in the U.S.A. These changes over a time increased the daily production of blast furnaces from 1000 to 2000 tons or more of pig iron with the coke consumption rate almost halved. This is illustrated in the Canadian case by the following data: in 1949 there were 13 blast furnaces operating the largest number being at Algoma with five furnaces, providing an aggregate annual capacity of 2,538,760 tons of pig iron, and in 1961 there were 16 blast furnaces with a total capacity of 5,007,875 tons of pig iron per annum.

The Mines Branch contributions to primary iron production R & D were mainly in the beneficiation of ores and improvement in coke quality. There was also some research and development in direct reduction processes and non-conventional smelting. It may be recalled that research in primary iron and steel production was featured in the first thirty years of Mines Branch history, albeit on a modest scale, but the events of World War II introduced an era of physical metallurgy research on an impressive scale. During this period the activity on the primary ferrous end was virtually terminated until the post-war period. The research in the Mineral Dressing and Process Metallurgy Division, and to a lesser extent in the Fuels Division, from the middle fifties, although selective because of limited resources, was well done in the judgement of the Canadian steel and coal industries.

Resources of Canadian iron ore are very large but the quantity of high-grade or shipping ores represents the smaller proportion. The reserves of medium-grade ores of between 48% and 59% iron; of low-grade ore of less than 48% iron, and of high-grade ore of more than 59% iron, which were being mined in 1965 were estimated at between one and one and a half billion tons. In the same year, iron ore resources that were considered economically exploitable under the prevailing technological conditions amounted to some 20 billion tons.

Iron Ore Treatment

Despite the discovery of high-grade direct shipping iron ore in the Schefferville area of Labrador and Quebec, other large deposits further south in this iron ore region, as well as prospecting elsewhere in Canada, indicated that ores would have to be beneficiated. This was the conclusion arrived at by the Mines Branch in the period of Haanel's and McLeish's directorships for the much smaller area of prospected terrain, much of it delineated by magnetometer surveying in the accessible parts of Canada east from the Manitoba border to the Maritimes. Some of the iron ores came from prospects that had been evaluated in the early days of the Mines Branch such as Moose Mountain in northern Ontario and Texada Island in B.C. During the fifties several companies such as Inco, Falconbridge, Noranda and Cominco became producers of byproduct iron. In addition, iron-titanium, iron-manganese and iron-sulphur ores were submitted to the Mines Branch to evaluate beneficiation methods. With passage of time, many of the iron-bearing ores submitted by industry were not only low-grade but contained other metals requiring the development of complex flowsheets. The beneficiation requirements of the industry were reflected in the large number of iron ore investigations carried out by the Mines Branch during the period from 1950 to 1962, peaking in 1960 with 28 out of a total of 68 metal ore investigations. During this period, Downes, chief of the Mineral Dressing and Process Metallurgy Division, proposed a sulphur recovery method for the nickel-iron ores of northern Ontario. Sulphur was in short supply at that time but the position rapidly changed when large supplies were made available by the production in Western Canada of sour natural gas. Downes' method used pressure leaching on pyrrhotite, yielding an iron oxide with 5 to 10% sulphur which, after sintering, produced an acceptable grade of iron concentrate. Pyrite, of course, provided another source of iron after sintering.

Mineral Processing Division (Ferrous Ores)

Beneficiation by grinding, gravity and flotation separation, magnetic concentration and sintering were carried out in the Mineral Dressing and Process Metallurgy Division until 1959. After that date the Mineral Processing Division with L.E. Djingheuzian as chief was responsible for iron and metallic ore beneficiation investigations, but smelting and corrosion were assigned to the Extraction Metallurgy Division. A total of 149 large and small samples of iron ore from industry were investigated in the period from 1940 to 1975, with the largest proportion being submitted from 1950 to 1965 (116). About one half of the samples originated from Ontario repeating the earlier experience in Dr. Haanel's time. There was an incentive to find iron ore sources close to the iron and steel-making facilities and markets, yet the sources, though numerous, were small in extent and low in grade, and all of the ores required beneficiation.

Considerable work was done on ores from the large Quebec-Labrador deposits, the first sample being received in 1946. About 20% of the samples originated from Quebec including the Ungava area and several samples from the asbestos belt of the Eastern Townships, in the latter case the objective being the reclamation of iron and nickel from asbestos tailings. About 15% of the samples, mostly received after 1950, were from the Prairies, the Territories and British Columbia. Two samples - a low-grade ore from Alberta and a medium-grade from Baffin Island, N.W.T. - are given as contrasting examples of the R & D carried out in that period.

A siliceous oolitic ore from a large low-grade deposit in the Peace River district of Alberta was first examined in 1956. Gravity concentration was not successful. Reduction roasting followed by magnetic concentration yielded a 50% iron concentrate. Flotation of deslimed ore produced an iron concentrate of 36.5% Fe. As of this writing, further work is in progress on this ore.

Superconcentrates were produced from grab samples originating on Baffin Island, N.W.T by cobbing magnetically at 10 mesh, the concentrate being reground to 65 mesh and again concentrated yielding a product of over 69% iron with less than 2% silica. The improved beneficiation methods developed in the Mines Branch, including fine grinding followed by flotation or by high and low intensity magnetic concentration coincided with the interest to use superconcentrates with an iron content of 70% or more and a silica content of less than 2% for direct reduction processes and more particularly for the production of iron powder. There were metallurgists like Dr. J.H. Walsh who joined the branch in 1955 and predicted steel sheets would be produced from powder.

Officers who were principally concerned in these investigations were: before 1950 - A.K. Anderson (1916 - 1953), W.S. Jenkins (1930 - 1964), J.D. Johnston (1925 - 1960) and K.N. Stewart (1941 - 1943); after 1950 - Jenkins, Johnston, Bruce, G.O. Hayslip (1948), R.A. Elliott (1948 - 1952), D.E. Pickett (1954 - 1974), S. Chwastiak (1955 - 1958) and P.D.R. Maltby (1959 - 1964); after 1965 - G.O. Hayslip (1948 -), D. Raicevic (1966 -), I.B. Klymowsky (1968 -), and G.W. Riley (1964 -).

As in the past, the mill was made available to industry. Technical assistance to the resident industry personnel was given by Mines Branch staff as required. The peak year for this cooperative work was 1957 when metallurgists from 23 companies were able to take advantage of these facilities by collaborating with the branch engineers on various projects including pilot plant runs involving samples mostly up to 100 tons. In 1959 a 1500-ton sample from Ontario of high-silica ore was treated and the concentrates shipped to Niagara Falls, Ontario for smelting by the Strategic - Udy process. Also 400 tons of Quebec ore was treated and 71% iron concentrates were shipped to Trois Rivières for smelting. It should be made clear that this cooperative work included a variety of metals and minerals, more than half being base metal ores, particularly copper-nickel, which, like iron and metals in general, were experiencing a buoyant era. In the sixties the "iron ore rush" slowed down and most of the

A. Boisonnault adjusts impact crusher before treating northern Ontario iron ore

industry requests for technical assistance were more concerned with improving the grade of concentrate produced from low-grade ores with high silica, phosphorus or titanium contents to enable the enriched material in concentrate or pellet form to qualify as feed to the blast furnace or for direct iron processing, powder metallurgy and manufacture of pigments. To cater for these requirements a flotation research program was inaugurated in 1962 in the Mineral Processing Division.

Mineral Processing Research

The Metallic Minerals Research Laboratory was set up in 1963 for research in ore dressing fundamentals that included facilities for grinding, floating and filtering. A considerable proportion of ores studied by this laboratory were ferrous.

A study of flotation was undertaken of carbohydrate derivatives as depressants for iron oxides: six flotation reagents of different molecular structure were selected to determine their effect on surface tension, adsorption characteristics and influence on cationic flotation. Dodecylamine hydrochloride was found to be an effective depressant particularly for hematite. "Study of dodecylammonium chloride on a labradorite" by T. Takamori (NRC Postdoctoral fellow) and L. Sirois (Journal Mining & Metall Inst Japan, vol 83, No. 945, 1967).

The problem in floating finely ground ore was the production of excessive amounts of slimes which had to be dispersed to produce clean surfaces capable of reacting wih cationic collectors used in the flotation process. This led to the study of electrochemical phenomena of the "double layer" and establishing the zero-point-of-charge when the layer disappears. This parameter was important because any specific changes had to be brought about at the surface of a solid. Two reports were published in the period: "Experimental flotation cell" (MB RR 135, 1964) and "Simple low-rate feeder for water-insoluble flotation reagents" (MB TB 81, 1966) both by L.L. Sirois and T. Takamori.

Flotation research in this laboratory became a basic study with the objective of improving selectivity of the process to recover finely divided minerals in the 1 to 20 millimicron range. Studies were made on bubble formation and behaviour, on surface electrical characteristics of minerals and on surface-ion replacement measured by specific-ion electrodes. An automated apparatus was built which recorded the pH change when acid or base reagents were added from which surface changes on the mineral were calculated: "Development of an automated potentiometric titrator for the study of surface electrical phenomena" by L.L. Sirois, G.E. Alexander, A.P. Page and A.A. Winer (1962) (CIM Bull, pp 410-414; Apr. 1969). The study of the characteristics of bubbles dealt with the measurement of streaming potential and bubble charge showing that for fixed hydrodynamic conditions, simple electrostatic interactions between bubbles and particles played a significant role in flotation: "Role of gas bubbles in flotation of quartz" by H.P. Dibbs, L.L. Sirois and R. Bredin (1961 -), jointly published by Mineral Sciences and Mineral Processing Divisions (MB RR 248, 1972). An investigation was commenced to apply the flotation principle to gravity concentration in studying the influence of surface characteristics of minerals on their behaviour in table concentration. Research on methods to measure and control metal ion concentration in flotation pulps and the evaluation of new collector reagents was continued until the end of 1972.

Filtration to which Dr. N. Németh (1964 - 1973) was assigned, was studied with a literature review made in 1966 (MB IC 180). An experimental project was then started wherein water was continuously passed through

L. Sirois determines electrical characteristics of minerals in flotation research (Study of electrophoresis) (Photo - George Hunter) a porous bed. This showed a slight but gradual decrease in the rate of filtration approaching a constant rate. The tests were done under vacuum but the rate measurements were at atmospheric pressure. A number of factors that controlled liquid-solid separation including surface electrical properties and ultrasonic vibration were investigated. Photography was used in evolving an explanation for the reduction of the filtration rate indicating that gases evolved from solids and liquids restricted solid-liquid separation. Following laboratory tests, synthetic fibre filter cloths were selected for testing at the Iron Ore Company of Canada and at Hilton Mines over a period of several months. The results were apparently inconclusive. After some laboratory work the project was discontinued in 1972: "Role of the filter medium in continous vacuum filtration: an intralocular approach" by N. Németh and L.L. Sirois (Trans Soc of Min Eng, AIME, vol 247, pp 104-108, 1970), and "Filtration: basic mechanisms and the medium" by N. Németh (Can Min Journal, pp 71-76, June 1970).

Grinding of ores and minerals has always had the attention of the Mines Branch as it is the first and most costly step in treatment after coarse ore crushing. Innovations and improvements had always been followed. Thus after World War II in 1948 an experimental installation was made of an Aerofall dry grinding mill with an air separator feature for dealing with fines. Djingheuzian paid particular attention to grinding, for example, he investigated the influence of temperature on the efficiency of grinding (Trans CIM vol 57, p 57-168, 1954). At the request of industry, he set up a standard master set used for standardizing sieves of the mining industry (MB TP 16, 1956, by J. Brannen (1948 - 1958) and L.E. Djingheuzian). He collaborated with M.A. Twidale (1958 - 1971), mining advisor to the director, correlating the comminution procedures of drilling and blasting with that of grinding (Quarterly Colo Sch Mines, vol 54 3, pp 43-60, 1959). He also organized a forum on the non-cataracting ball mill in 1958 (Trans CIM vol 61, pp 269-278, 1958). Autogenous grinding was tested on a 154-ton sample of ore in 1958, and considerable data were analyzed showing that the mill was an efficient grinding machine.

An experimental grinding project was started in 1966 by the Metallic Minerals Research Laboratory. A 20 x 30-in. ball mill was used with a feed, first of limestone and then of quartz. The study was designed with the following variables measured in continuous open circuit grinding: kind and load of medium (ball or pebble) size distribution of medium discharge method, height of lifter bars, feed size and rate, mill speed and pulp density. Computer programs were written to handle the calculations. From the results obtained, log-size/frequency curves were drawn for ease of comparison. The studies were reported to the Canadian Mineral Processors meeting in 1968 and to the Commonwealth Mining and Metallurgical Congress in London in 1969 under the following titles: "Grinding studies to determine variables affecting size distribution" by T. Nagahama, L.L. Sirois and D.E. Pickett [Proc of 5th Annual Meeting of the Canadian Gold Metallurgists (Canadian Mineral Processors) pp. 98-114, Jan. 1968] and "Study of grinding parameters by statistical analysis" by T. Nagahama, L.L. Sirois and D.E. Pickett (Proc 9th Commonwealth Mining and Metallurgical Congress, vol 3, pp 603-630, London).

In 1969 the International Organization for Standardization established a working group in the Technical Committee 102 (Methods of chemical analysis of iron ore) on iron ore sieving standards. An intensive program was carried out by Pickett, assisted by G.W. Riley (1964 -); Pickett was appointed chairman in 1970 in the light of this work and the working group became Standardization Committee 4. Further work was done in preparation for the ISO meeting in Tokyo in 1972; four documents covering sieving machines, sieving of plus 1 in. ore, sampling of plus 1 in. ore, and characterization of "slimy" ores were presented at that meeting.

Organization of Mineral Processing Division, 1959

The original group of the Mineral Processing Division formed in 1959 from the Mineral Dressing and Process Metallurgy and the Industrial Minerals Divisions were: Chief of division - L.E. Djingheuzian (1948 - 1968); Head of Metallic Minerals Subdivision - W. Hutchings (1943 - 1964); Head of Industrial Minerals Subdivision: H.M. Woodrooffe (1946 - 1974).

The Metallic Minerals Subdivision divided into two principal sections: Ferrous and Less Common Metals, which was led by D.E. Pickett (1948 - 1949 and 1954 - 1974), and Non-Ferrous Metals, headed by R.W. Bruce (1948 -). Pickett's principal assistants in 1959 were: W.S. Jenkins (1930 - 1964), P.D.R. Maltby (1959 - 1964) and L.L Sirois (1961 -). Hutchings retired in 1964 and Maltby resigned. Pickett became head of the Metallic Minerals Subdivision, a position he retained until his retirement in 1974. Sirois was appointed head of the Metallic Minerals Research Laboratory in 1963, a position which he retained until he became activity leader in the Minerals Program on the reorganization of the Mines Branch in 1975.

Pickett, following graduation from University of Alberta, spent a short time at the end of the 40's in the Mines Branch and then joined Cominco for about five years. He had a good "feel" for and had good relations with industry. When Djingheuzian retired in 1966 after

D. Pickett

a year or so acting as consultant, Pickett took over Djingheuzian's former responsibility dating from 1953 of preparing an annual review of technical advances in milling and process metallurgy for Canadian Mining Journal's annual review issue. With retirement of W.S. Jenkins in 1964 with 34 years of service in the Mines Branch, the last of the pre-war generation of ore dressing engineers had left. The longest service engineer A.K. Anderson retired in 1953 with 37 year's service and J.D. Johnston in 1960 with 35 years. Staff of the Non Ferrous Section is given later.

Chemical and Spectrographic Research

The chemical laboratories in the Mineral Dressing and Process Metallurgy Division as the successors of the laboratories in the Metallic Minerals Division with which the original Chemistry Division had merged in 1936 were involved with a wide range of analytical work from these raw materials to vendible mineral and metals products - analysis of ores, residues, slags, etc. It should be remembered that these laboratories had also to cater for the requirements of the Industrial Minerals Division and some analyses for Fuels and Radioactivity Divisions and for other government agencies. In addition, considerable R & D was done on improving and developing new methods.

Chemist group, 1951, chief - J.A. Fournier, (1937 - 1954) R.A. Rogers (1924 - 1956), A. Sadler (1919 - 1954), J.S. McCree (1930 - 1969), S.R.M. Badger (1930 - 1966), W.L. Chase (1942 - 1966), R.C. McAdam (1945 -), D.J. Charette (1946 -), J.F. Fydell (1949 -), G.H. Faye (1950 -), R.G. Sabourin (1950 -), L.G. Ripley (1950 -),H.R. Lauder (1950 -), E.H. MacEachern (1955 -) and R.W. Buckmaster (1955 - 1972).

It will be seen from this list that the laboratories lost many long-service personnel during one of their busiest periods. In 1959, before the transfer to Mineral Sciences Division, most of the "old timers" had gone. W.R. Inman was made chief in 1956 with Chase as his first assistant.

J.A. Fournier (Photo - NFB)

With the demand for analysis from the ferrous metallurgical side, considerable work was done in increasing the accuracy and speed of analytical procedures. Improved equipment using photometry, colorimetry and polarography was introduced. Research projects were undertaken such as separating nodules in the nodular cast iron process in a technique for the determination of magnesium used in this process; the substitution of boron for scarce alloying metals in steel required an accurate determination of the element, and this was achieved by the combination of decomposition distillation and use of ion exchange resins with a final spectrophotometric determination.

In 1949 a paper was prepared, "Methods of analysis of iron and steel used at the Mines Branch" and this led to the publication of a booklet describing the analyses of 22 constituents of iron, steel and ferrous alloys. Interest was shown in this publication not only in Canada, but in other countries and a revised version was published in 1953: "Methods of analysis of iron and steel used at the Mines Branch Laboratories" by J.S. McCree (MB Memorandum Series 119, 1953). As an example of the analytical load in the fiscal year 1949/50 the laboratories analyzed some 2700 metal samples involving about 11,000 determinations and nearly 4900 samples of minerals requiring about 24,000 determinations.

The Spectrographic Laboratory was also progressing with a constantly increasing number of fully quantitative determinations. During the period to 1959 the Mineragraphic and Spectrographic Laboratories were separate but were both under the direction of Maurice Haycock. In 1959 Haycock became head of the Mineralogical Section in the Mineral Sciences Division, and Dr. A.H. Gillieson (1959 - 1975) was appointed head of the Spectrographic Laboratory. As noted earlier, both laboratories were part of the Analytical Chemistry Subdivision with W.R. Inman as chief.

It is appropriate to remark that the success of the R & D programs of the branch expanded considerably during the post-war period, depending fundamentally on support of the laboratories which themselves were undergoing up-dating in apparatus and in methods

B.J. Stallwood (1948-52) works on spectographic analysis (Photo - NFB) involving considerable research, much of it unrecorded in the scientific literature.

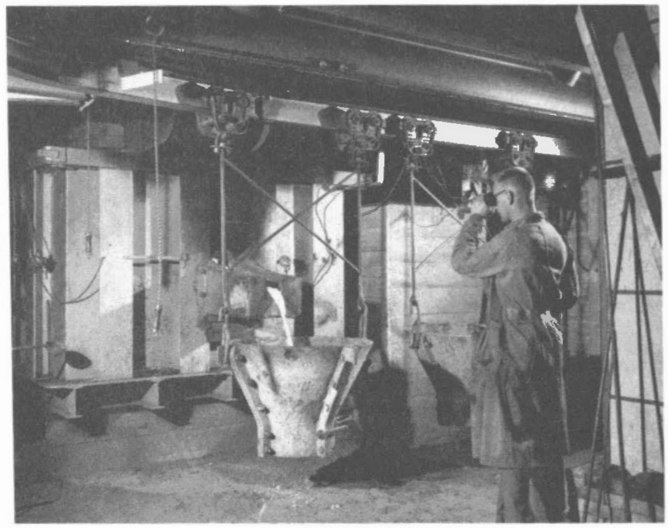
Thermal Treatment Including Electric Smelting

Thermal treatment of ores and concentrates by roasting and sintering as beneficiating steps was practised uninterruptedly in the R & D activities of the Mines Branch from World War I, but electric smelting as a principal project had been discontinued in 1913. As described in Chapter 4, Traill recommenced research on iron in 1921 as part of the more general hydrometallurgical R & D program in the extraction of iron and titanium from titaniferous ores. With the formation of the Iron and Steel Section in the Ore Dressing and Metallurgy Laboratories in 1928 and in the appointment of T.W. Hardy as its head, there was rekindled emphasis on beneficiation of iron ore by thermal methods and extension of R & D into direct iron ore reduction and smelting. A 60-kVA arc furnace was installed at that time. Unfortunately, Traill and McClelland had to be transferred to work on radioactive ores in 1931. These were the depression years and there were restrictions on hiring. Upon the resignation of Hardy in 1934 to join the Atlas Steel Company, research in the primary ferrous metallurgical field was curtailed in favour of physical metallurgical investigations largely related to metallographic and diagnostic work until the outbreak of the war, when the entire emphasis was shifted to physical metallurgy.

Rapid mining developments in the fifties of ferrous ores coupled with the polemics related to the role of blast furnaces gave rise to renewed interest in direct iron reduction methods and non-blast furnace smelting. A review of the status of direct reduction of iron ore was made in 1958 by Dr. R.R. Rogers, head of the Chemical Metallurgy Section of the Mineral Dressing and Process Metallurgy Division. He described eight processes using fluidized beds, vertical shafts, retorts or rotary kilns as process methods. Of these, the Strategic-Udy continuous kiln process was Canadian and operated on a pilot-plant scale at Niagara Falls, Ontario (MB IC 109, 1958).

Gertsman of the Physical Metallurgy Division participated in a CIM symposium on iron ore in Canada and contributed to "Smelting of iron ore" (CIM Bull, pp 221-226, Apr. 1955). The Physical Metallurgy Division carried out a project between 1959 and 1961 on direct-reduced iron produced by Strategic-Udy (chrome iron ore), Freeman Corporation and Quebec Iron and Titanium Corporation. Electric furnace melts were made from these iron samples with lower contents of residual elements than would be contained in normal scrap. In the case of the Strategic-Udy sample, a 12% chrome stainless steel was made from the chrome iron ore with no further addition of ferrochrome. Direct iron ore did not enjoy general acceptance because steel scrap was considerably cheaper. Some direct iron reduction research with emphasis on the role of coal was done in the Fuels Division and this will be reviewed under "Fuels".

Electric smelting facilities were enlarged in the chemical metallurgy section of the Mineral Dressing and Process Metallurgy Division by the installation in 1953 of a 250-kVA electric arc furnace at 552 Booth Street, already referred to under the titanium program. One of the objects of this project was to encourage the smaller producers of iron ore concentrates to smelt



N. Banks checks slag temperatures with optical pyrometer from 250-kVA arc furnace (Photo - George Hunter)

them in Canada, which was, it will be recalled from Chapter 3, one of Dr. Haanel's aims in his early work on iron. For some five or six years the furnace was used extensively in Mines Branch projects as well as by industry. This was a very busy period for Rogers and his group. Various ores and concentrates of iron, titanium, manganese, and even tailings such as from asbestos, were processed. Pig iron and several ferroalloys like ferromanganese, ferrosilicon, ferrochrome, and ferronickel were produced. By the early sixties the position of the blast furnaces as the principal iron-making unit was reasserted, and the electric furnace continued in its important function of melting.

In 1951 the Chemical Metallurgy group, which was responsible for pyrometallurgy and corrosion, was composed of R.R. Rogers (1944 - 1969), G.E. Viens (1945 -), W. Dingley (1945 -), G.V. Sirianni (1939 -), and J. Fydell (1949 -). Before this group was assigned to the Extraction Metallurgy Division in 1959 when it was renamed the Pyrometallurgy and Corrosion Section, the following were recruited: R.A. Campbell (1950 -), I.I. Tingley (1953 - 1964), G.N. Banks (1953 -), and Dr. J.H. Walsh (1955 - 1974). In the Extraction Metallurgy Division period, four further appointments were made: W. McLeod (1960 - 1974), J.C. Saiddington (1961 -), R.L. Sachdeva (1962 - 1967) and Dr. A.W. Lui (1964 -). At the request of the Fuels Division, J.H. Walsh participated in a Fuels Division smelting group formed in 1957 to examine the role of fuels in metallurgical applications, and in 1961 he transferred to Fuels and Mining Practice Division in the capacity of special adviser in process metallurgy to the director and to the division. Aspects of his own and the division's work in this area will be reviewed in the section on fuels.

After 1959 some R & D work on iron ore treatment was done by the Pyrometallurgy and Corrosion Section of the Extraction Metallurgy Division; thus, in 1961 an effort was made to increase the iron content of concentrates to 65%, a level then considered acceptable as blast furnace feed from the abundantly occurring 35% iron content siderites in northwestern Ontario. The beneficiation was carried out in a rotary kiln. The product consisted of combinations of ferric oxide combined with oxides of manganese, magnesium and alumina known as spinels which were magnetic and could not be separated. The silica was reduced to 0.6% though the content of iron in the concentrate was only 56-57%.

In 1963 a project on pelletizing iron was undertaken that included a literature study by Banks, Campbell and Viens. Some work was done on producing and evaluating standard pellets, as well as studying some of the controlling factors such as the specific surface of a pellet and binder materials to increase green pellet strength: "Iron ore pelletizing, a literature survey" by G.N. Banks, R.A. Campbell, and G.E. Viens (MB IC 152, 1963).

In the early sixties interest by the industry in electric smelting of ferrous ores died down and this allowed the Pyrometallurgy and Corrosion Section of the Extraction Metallurgy Division to embark in 1964 on an interesting long-term project which is continuing at this writing.

The concept was to combine the 250-kVA electric arc furnace with a surmounted shaft furnace whereby the downcoming feed was preheated and partially reduced by the hot off-gases from the electric furnace and from combustion of additive natural gas burning in the shaft. Progress in this project was slow because of considerable design problems such as the provision of continuous feed in the shaft, transfer and even distribution of feed in the electric furnace, and because of limited manpower. However, various campaigns using iron ore pellets demonstrated that this was an efficient conversion process in terms of both metallurgy and energy: some 20% of feed reduction was achieved in the shaft and overall throughput was nearly doubled at the maximum rating of 250-kVA of the electric arc furnace compared with operation without the shaft: "Development of a combination shaft and electric furnace" by R.A. Campbell, G.V. Sirianni, G.N. Banks, R.L. Sachdeva and G.E. Viens (CIM Bull, pp 174-178, Feb. 1968).

Physical and Crystal Chemistry

This section with its head, Dr. A.T. Prince, assisted by two professionals, Dr. S.A. Forman (1949 - 1955 and 1964 - 1966) and Dr. P.D.S. St. Pierre (1948 - 1955), was concerned initially with studies on refractories including the specific study of refractory metal oxides like silica, alumina, etc. In 1948, an X-ray diffraction laboratory had been set up by the NRC on John Street, Ottawa, for study of refractory oxides related to its atomic energy project. This was transferred in 1949 to Booth St. to assist the Mines Branch project. In 1950, differential thermal analysis DTA apparatus was installed, thus equipping the group to undertake a wide range of studies in the high-temperature inorganic chemistry field.

In 1950, two contrasting studies were commenced that were related to iron and steel. First, a cooperative project with the Geological Survey was inaugurated on the examination of shales from the Quebec-Labrador iron ranges involving the use of D.T.A. apparatus in air and nitrogen that assisted the stratigraphic correlation in structurally disturbed terrain of the iron-bearing formations: "Study of some shales from the Quebec-Labrador iron ranges" by S.A. Forman (Div. Research Report MD No. 126, 1952). The same techniques were used in aiding a large iron ore producer to develop a process for beneficiating its ore. Some research, including development of instrumentation, was undertaken to determine temperatures at which minerals in an orebody were deposited, thereby providing a geological history, so to speak, in the quest for ore. However, because of the demand made on the group by other projects, and possibly because the results were inconclusive, the project was discontinued by 1954. It should be noted that in 1949 and 1950 a project of the Mineragraphic Laboratory was a geothermometric study with apparatus designed and built in the laboratory to determine the temperatures of deposition of various hydrothermal minerals at the Eldorado mine at Port Radium; some indications on deposition sequence were obtained but no reports were published.

Second, in 1950 studies in the Physical and Crystal Chemistry Section investigating physical properties of slags were started on methods of slag control, and on factors related to removing sulphur by slag-metal reactions. Typical blast furnace and open hearth slag compositions were prepared to determine melting points and crystallization sequence. As sulphides of calcium, manganese and iron were chiefly concerned in desulphurizing reactions occurring in iron and steel, purified samples of these compounds were prepared and studies were started of rapid methods for controlling slag compositions. The chief factors in the relationship between slag composition and slag melting point were determined. In the case of basic open hearth slags, experiments aimed at showing their condition at steelmaking temperatures indicated the presence of significant amounts of undissolved slag constituents in slags that were formed late in open hearth heats. This research demonstrated that liquid metal-slag reactions occurring in the open hearth are more complex than generally assumed.

Much work was done in evaluation and improvement of slag control in open hearth heats: "Evaluation of the pH and conductivity methods of slag control" by P.D.S. St. Pierre [Trans Metals Branch of AIME, pp 41-43, vol 197, 1953 (Journal of Metals, Jan. 1953)].

In response to industry demand, a study was done of the effect of magnesium content on the properties of blast furnace slags. Experiments indicated that dolomite can substitute for limestone without raising the melting point of slag; this was important as supplies of limestone were limited, whereas on the other hand, supplies of dolomite or magnesian dolomite were plentiful.

A process for melting, casting and consolidating magnetite to give a hard, dense lump suitable for open hearth additions was worked out in the laboratory. After 1952 much of the group's attention was diverted to the titanium and uranium projects.

Physical Metallurgy R & D

A program on desulphurization of iron and steel was started in the Physical Metallurgy Division in 1954.

A project on foundry pig iron (grey iron) was carried out by using iron produced in a 500-pound acid-lined direct arc electric furnace. The object was to compare the desulphurizing properties of soda ash, caustic soda, calcium carbide and calcium cyanamide and lime used as a ladle slag. The additions were made to the tap stream of the iron at 1500°C. Sulphur reductions varied from 4% to 80%: "Five ways to desulphurize in the ladle" by D.E. Parsons and S.L. Gertsman (American Foundryman, vol 27, pp 60-65, June 1955).

An extensive project on steel continued for several years in which desulphurization of both basic and acid steel in a treatment ladle or in a 500-pound direct arc furnace was accomplished by injecting calcined lime or a mixture of lime and a 50% aluminum-50% magnesium alloy beneath the surface of the molten metal. Argon, nitrogen or carbon dioxide were used as carrier gases.

Five hundred-pound basic steel melts were desulphurized by 60% from 0.02% initial sulphur by the injection of 24 pounds per ton of calcined lime and 8 pounds of the aluminum-magnesium alloy into the metal held under a basic slag in the arc furnace immediately prior to tapping. Treatment time was two minutes. Five hundred-pound acid steel melts were desulphurized up to 40% from 0.050% initial sulphur when the furnace slag was removed prior to tapping and the metal was treated by ladle injection for periods of thirty to ninety seconds. The injection charge consisted of 18 pounds per ton of calcined lime and six pounds per ton of aluminum-magnesium alloy. Reduction of sulphur of about 20% was achieved with lime injection alone. The injection technique in desulphurization was adopted as a standard practice in the industry: "Desulphurization of steel by injection of lime and aluminum-magnesium alloy" by D.E. Parsons and S.L. Gertsman (AIME Proceedings of Electric Furnace Conference, December, vol 16, pp 283-300, 1958).

The results of this project indicated a possible saving to the Canadian steel industry of approximately $3 million on a production of 2 1/2 million tons of steel annually and a 10 to 15% increase in Canada's steel-melting capacity.

IRON AND STEEL ADDITIVES

These metals are so termed because they provide the additions to iron and particularly to steel, and to a lesser extent to non-ferrous metals, in the production of alloys of specific properties for a wide range of applications. Many of these additives have other industrial uses. High melting point metals such as chromium, molybdenum, niobium, titanium, tungsten and vanadium are known as refractory. If metals are malleable at high temperatures such as niobium, titanium, tantalum and tungsten, they are known as reactive.

During this period these metals were used in the Physical Metallurgy Division research on ferrous alloys. To retain the commodity approach these additive metals are grouped in this section of the narrative following the iron and steel section. Only those additives are described that were produced in Canada and which were the subject of R & D work, not only in the Physical Metallurgy Division but also in the ore treatment divisions of the branch. The exceptions are chromium and manganese which had been produced in Canada in the past as described in Chapters 4 and 5 and considerable R & D effort was devoted in the post-war period by the Mineral Dressing and Process Metallurgy Division to revive production by chemical treatment of these low-grade ores of these two metals.

Chromium and Manganese

During World War II the production of domestically produced chromium and manganese was less than in World War I in spite of the efforts of the War Metals Corporation to stimulate Canadian production. Furthermore, the North American continent is deficient in chromium and manganese resources and most of these are of low grade. The largest use for both metals is in ferro-alloys for steel production.

Canada relied on imports for its requirements of chromium and manganese during the entire period under review. The following data indicate the approximate magnitude of these requirements in 1969 towards the end of the rapid post-war industry growth cycle.

The acceptable grades of chromite vary from 48% plus to 35% of chromic oxide, CR_2O_3, according to use. In descending order of magnitude in 1969 these were: metallurgical, refractory, and chemical. Imports were almost 42,000 short tons of contained chromium in ores and concentrates and 25,000 tons of ferro-chromium and chemicals, mostly from the U.S.A, and South Africa for a total value of approximately $9.5 million.A large proportion of manganese ores and concentrates originating in Brazil amounted to nearly 108,000 short tons of contained manganese valued at $5.3 million and nearly 30,000 gross tons of ferro- and silico-manganese and some high manganese iron (spiegel-eisen) valued at $4 million for a total value of $9.3 million were imported. There was an export to the U.S.A. of 5,500 short tons gross weight and a domestic consumption of 166,175 short tons of metallurgical grade as well as 2,300 tons of refractory and chemical grades.

These two metals account for the largest consumption of additive metals in Canadian metallurgy other than silicon which, strictly speaking, is a non-metal, and nickel which fulfills both additive and metal base functions. The Physical Metallurgy Division used chromium and manganese extensively in alloy research. It may be noted that the chromium contents of alloy steels vary from less than 1% to 35%. Manganese is the most widely used alloying metal in the ferrous metals industry and it is also used in heavy and light non-ferrous metals.

Regarding chromium, the metallurgical industry required a chromic oxide content of 48% with a Cr to Fe ratio of 3:1. In Canada, the Bird River, Manitoba, deposits (Chapter 5) were discovered in 1942 and were estimated to contain 10 million tons. They graded 18 to 26% chromic oxide content with a Cr to Fe ratio of 1.2 to 1.5:1. During the war, water concentration tests at the Bureau of Mines produced a concentrate of 41% Cr_2O_3 content.

One of the projects that Downes undertook on joining the Bureau of Mines in 1947 was the evaluation of chemical treatment methods, two of which he developed in the laboratory. The two Mines Branch processes were:

(a) Ground chromate concentrate was pelletized with soda ash and lime and roasted at 850°C. The sodium chromate produced was leached with water, then crystallized, dried and mixed with coal and heated in a reducing atmosphere at 750°C. The chromic oxide recovery was 90% and some soda ash was also recovered. The estimated cost of treating Bird River concentrate was $15 to $20 per ton.

(b) Finely ground chromate concentrate was leached with a limited quantity of sulphuric acid at high temperature and pressure. Both chromium and iron were dissolved, the chromium being later precipitated as an insoluble basic sulphate, the iron sulphate remaining in solution. The large amount of sulphur in the residue could be removed by sintering. The chromium recovery was in excess of 95% and the estimated cost was $17.25 per ton.

Other methods developed outside the branch in industry and in the United States were investigated or reviewed by Downes and Morgan and were reported in 1951: "Utilization of low-grade domestic chromite" by K.W. Downes and D.W. Morgan (MB Memorandum Series 116, 1951, reprinted 1958).

The last year of Canadian chromite production was 1949. The country's deposits were unable to compete with the world's largest producers - the U.S.S.R. and South Africa. Raicevic published a review of ore dressing investigations of chromite ores in the period 1918-1976 (117).

Manganese was in a similar position to chromium. Most of the manganese in Canada was associated with iron but with a content usually less than 5% of the ore. A reasonably large deposit near Woodstock, New Brunswick, was reported to have a content of 11% manganese, whereas the metallurgical grade called for 46-48% manganese with a maximum iron content of 7%.

In 1954, at the request of the iron ore mining industry, research was undertaken to recover manganese from the oxides, mainly pyrolusite, associated with an Ontario ore containing 40% of iron oxide, approximately 4% of manganese oxides and 50% of silica. A beneficiation test using screening, tabling, sink-float and hydrocyclone treatment failed to produce a smelting grade of manganese concentrate from this ore. About three-quarters of the manganese that was contained in the original ore was in a fine fraction size, suggesting that leaching might be considered. Considerable research was undertaken to evolve an economically feasible method. This research produced two developments of note - first the use of a non-expensive reagent, iron pyrites, fulfilling the dual role of reduction and dissolution in an aerated aqueous medium, the reaction taking place at moderate temperature of 90°C in a pachuca tank, and second, the recovery of manganous sulphate, instead of by evaporation, by thermal precipitation in an autoclave with the stripped barren liquor returned to treat the ore. The results of this extensive research, which was completed by the end of 1956, were presented in 1957 at the Symposium on Mineral Beneficiation and Extractive Metallurgy Techniques in India and at the 7th Annual Conference of the Chemical Engineering Division of the Chemical Institute of Canada at Kingston. The Indian paper was entitled "Beneficiation, leaching and manganous sulphate recovery from pyrolusite type ore" by B.J.P. Whalley, D.E. Pickett, R.F. Pilgrim and T.R. Ingraham (Indian Mining Journal Special Issue, "Ores", pp 61-65, 68, 1957). A research report on the development and chemistry of the leaching process outlined above was published in 1958: "Leaching of manganese from pyrolusite ore by pyrite" by G. Thomas and B.J.P. Whalley (MB RR 3, 1958).

Niobium (Columbium)

The treatment of the complex niobium or columbium ores was first undertaken in 1954 by the Mineral Dressing and Process Metallurgy Division. At first it was concluded that chemical treatment would have to be used as the complex ores were low grade. Leaching followed by a liquid-liquid extraction was tried but was apparently considered too expensive.

In 1959, flotation was successfully applied as a continuous process and acceptable concentrates were produced with recoveries of about 80%. This was demonstrated on two ores totalling 145 tons. A mineralogical study of the niobium ore from Oka, Quebec, was done in 1961 as mentioned earlier under Mineral Sciences (MB TB 31). The study must have been of considerable assistance in resolving difficulties in the treatment of this complex ore. Also in 1961, pyrometallurgical studies were done on low- and high-grade concentrates containing 33% and 48% of niobium pentoxide using aluminum as a reductant. These were smelted in the 60-kVA electric furnace. Ferro-alloys containing up to 75% niobium were produced. An alternative process worked out jointly with the Physical Metallurgy Division was to use compressed pills of niobium concentrate with aluminum and ferrosilicon for addition directly to the steel melt. An improved chemical (leaching and liquid-liquid extraction) method was developed in 1962 in the Extraction Metallurgy Division on a laboratory scale yielding a product of 99.5% of niobium pentoxide at a recovery of 90%: "Production of high-purity niobium oxide from pyrochlore-perovskite concentrate" by F.J. Kelly (1959 -) and W.A. Gow (CIM Bull, pp 843-848, Aug. 1965, reprinted in RS 24).

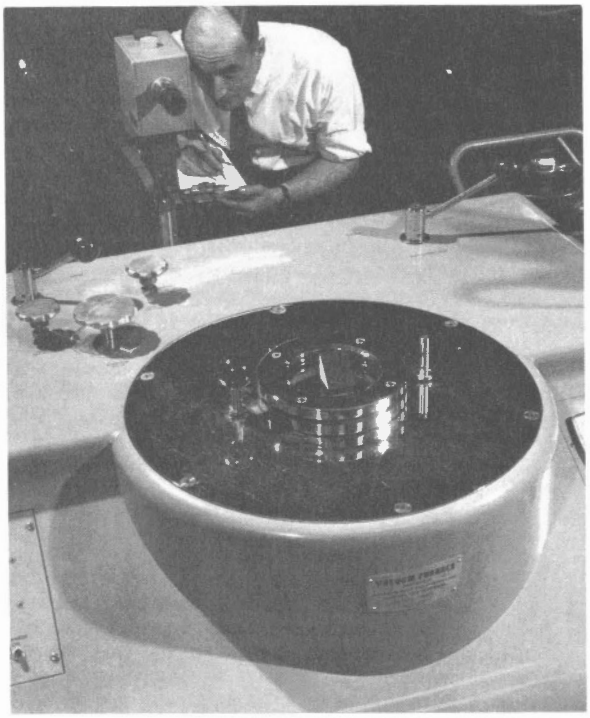
In 1963, the aluminum reduction-electric smelting of niobium ore was resumed in the 60-kVA furnace to establish the slag to metal ratio and the relative melting points of slag and alloy. A 60% ferro-niobium was produced with a low slag volume that contained only 5% niobium. The binary system of niobium pentoxide with lime and with silica were studied by Bright and associates in the Mineral Sciences Division (MB RR 101, 1962).

At this writing St. Lawrence Columbium and Metals Corporation is the only Canadian producer, starting up in 1961 with a rated annual output of about 5 million pounds. Canada is not only self-sufficient in niobium but has a sizeable export, mostly to the United States. Another producer, Niobec Inc., with a property near Chicoutimi is expected to start production in 1976.

Ferro-niobium was gaining application in the metallurgical industry as a valuable additive for the manufacture of a variety of steels and more particularly for the high-strength, low-alloy class. One of the largest applications of low-alloy niobium steels has been the growing manufacture of pipelines where the strength to weight ratio is important: "Survey of niobium alloys and their strengthening mechanisms" by D.C. Briggs (1958 -), (MB IC 153, 1963).

In the Physical Metallurgy Division, research was pursued on the addition of niobium to carbon steels for structural use at low temperatures in Northern Canada as a means of preventing brittleness and maintaining strength both in civilian and defence applications. An interesting and particularly important feature discovered during this research was that by lowering the metal forming (rolling) finishing temperature, substantially improved impact value of the steel was obtained.

It may be noted that small additions to carbon steel of elements that are chemically somewhat similar in the periodic table like vanadium and niobium, tita-



A.J. Williams vacuum heat-treating a high-strength niobium alloy (Photo - George Hunter)

nium and zirconium, and later hafnium, were used in the research. This indicated that these elements had significantly different influences on the properties of the steels.

Tantalum

Though tantalite samples were received for analysis and treatment during the war and in 1951, no action by industry developed until the sixties possibly on account of the complexities and the low grade of the ore as well as the low price for the metal. However, in 1961 a sample of tantalum ore from Bernic Lake, Manitoba was treated by gravity concentration, by the Mineral Processing Division yielding a concentrate of 41% tantalum pentoxide with a recovery of 33%. As mentioned earlier, a mineralogical study of this complex ore was done by Nickel of the Mineral Sciences Division (MB TB 20, 1961). In 1967 a further laboratory investigation was undertaken followed by a gravity concentration pilot plant run involving a sample of 75 tons. On the basis of the proposed flowsheet, a mill was designed by the Tantalum Mining Corporation of Canada. In 1969 the first concentrates containing 50% tantalum pentoxide were shipped. In 1970, the first year of full production, the company shipped in excess of 300,000 pounds of concentrates, of which the largest proportion went to the United States. This represented over 50% of U.S. imports of the metal. A further investigation carried out by the Mineral Processing Division in the early seventies by Wyman was on the recovery of lithium from complex Bernic Lake ore. A high proportion of the world use of tantalum is in the electronics field, particularly in the manufacture of capacitors, the balance being used in super alloys, corrosion-resistant equipment and carbides. In 1970 the price of tantalum oxide was $7.00 per pound, but by 1975 it had reached $15.00.

The Physical Metallurgy Division used tantalum as one of the alloying elements in research started in 1965 to study the effect of alloy additions on the corrosion of AISI-type 430, 17% chromium stainless steel. Each of the elements - silicon, vanadium, germanium, molybdenum, palladium, tantalum, tungsten, and rhenium - provided good to excellent corrosion resistance in sulphuric and hydrochloric acids and also significant solubility in ferritic iron: "Effect of single element additions to AISI-type 430 stainless steels in dip-and-dry corrosion tests" by H.M. Weld (MB TB 102, 1968). The Canadian consumption by the steel industry of ferrocolumbium and ferrotantalum-columbium was 244,000 pounds in 1969.

Vanadium

In 1963, Petrofina Canada indicated an interest in recovering vanadium from their refinery residuum of Venezuelan oils. Some of this residual product was converted to petroleum coke and burnt for plant process steam. The fly ash was recovered electrostatically and this contained a concentration of vanadium pentoxide of up to about 10% with small amounts of nickel. Following initial experimentation in the Extraction Metallurgy Division with alkaline and acid solutions, a 20% sulphuric acid leach for six hours in the temperature range of 70-100°C yielded good recovery at a low acid cost. Following leaching and filtration, the vanadium was precipitated from the sulphuric acid solution by adjusting the solution to the pH value of 2 after prior oxidation of the solution with a small amount of sodium chlorate. The nickel remained in solution, thus effecting the separation of the nickel and vanadium. The precipitation was done by ammonia, producing ammonium metavanadate; the latter was then heated and cast into flakes. The overall recovery of vanadium was 91%. The plant was designed and built with production starting in 1965: "Preparation of commercial-grade vanadium pentoxide from boiler fly ash "by J. A. Vezina and W. A. Gow (MB TB 63, 1965). The Chemical Laboratory of the division developed analytical methods for the control of this process "Analytical procedures for a vanadium recovery process" by R.J. Guest and J.C. Ingles (MB TB 79, 1966).

Vanadium is used mainly as ferro-vanadium, an additive in the ferrous metallurgy industry. Moreover, there was a fair demand by the chemical industry as well as by the petroleum industry where vanadium is used in catalytic cracking.

Some chemical research was done on the pyrolysis of ammonium metavanadate. A high-purity salt was first produced by reaction of the oxide with ammonium chloride: "Preparation of high-purity ammonium metavanadate from impure vanadium pentoxide by precipitation with ammonium chloride" by J. A. Vezina and W.A. Gow (MB TB 64, 1965). The purpose of the research was to clarify the course of the decomposition of the metavanadate as no agreement existed in the literature: "Mechanism of thermal decomposition of ammonium metavanadate" by M. Taniguchi and T.R. Ingraham (Can Chem, vol 42, pp 2467- 2473, 1964).

Vanadium is an important alloying element in high-strength alloy steels often in association with other elements. It is used in high-temperature applications with titanium-base alloys in the aircraft industry. In the Physical Metallurgy Division, vanadium was used increasingly after World War II in various high-strength alloy formulations. A good example was the naval requirement for a turbine rotor operating at a temperature of about 565°C. High-carbon steel with 1% each of chromium, molybdenum and vanadium was formulated after considerable experimentation (Phys Met Div Report IR 63-89). The Canadian consumption of imported ferrovanadium was 206 short tons of contained metal in 1969.

Molybdenum

In 1947, Canadian production of molybdenum ore ceased with the closure of the Lacorne, Quebec mine (Chapter 5). However, geological indications were such that, with the exception of Alberta, Canada possessed large molybdenum resources. Molybdenum had become an important alloying element in the production of high-strength steels, some four-fifths of the molybdenum being used in ferrous metallurgy with the post-war upturn of the iron and steel industry. The mining industry of Canada responded to the growth in demand by bringing in mines mainly in British Columbia but also some in Quebec. By 1970 there was a production of 32.8 million pounds in B.C. and 2.5 million pounds in Quebec for a total of 35.3 million pounds compared with 29.7 million pounds in 1969 that placed Canada second in the free world after the United States in molybdenum production. Canada exported 30.3 million pounds in 1970 compared with 25.7 million pounds in 1969 and imported a small amount from the United States as ferro-molybdenum and molybdic oxide. Her own requirements were in excess of 2 million pounds with ferrous and nonferrous alloys consuming some 90% of molybdenum metal; pigments, electrics and electronics accounted for the remainder.

The British Columbia production came mostly from large-tonnage open pits that were mining copper-molybdenum ores and could afford to operate with low-grade molybdenite reserves. The largest was the Endako mine, which milled an average of 27,721 tons per day in 1970 with a molybdenite grade of 0.182% at a recovery of 82.4%. The production was 162 million pounds in molybdenite concentrates and molybdic oxide as roasted product.

The Quebec grades had to be higher as the molybdenite was not associated with copper except in the operation at Murdochville.

It will be recalled from Chapters 3 and 5 that the concentrating technology for molybdenum ores was developed as early as World War I with further developments in World War II. Hence it was to be expected that more complex ores were submitted to the Mines Branch and this occurred largely from the early sixties. Selective flotation, followed if necessary by tabling and grinding, was used in the Mineral Processing Division with successful results in most cases. However, some of the ores were quite intractable. For example, in the case of a molybdenum-bismuth ore from a Preissac Township mine in northwest Quebec, talc was encountered after starting up the mill in 1964 which lowered the grade of the molybdenite concentrate and gave poor bismuth recovery. After several years of research that included acid leaching, a flotation depressant "Depramin" was found to give good separation in the Mines Branch pilot plant as well as in the field.

The Physical Metallurgy Division made use of molybdenum in quite a spectrum of steel formulations from carbon steel to high-strength steels. In the late sixties it became evident there was an excess of Canadian molybdenum production capacity. The leading producer, Endako Mines Limited, which had no facilities of its own, stationed a resident engineer in the Physical Metallurgy Division with a view to obtaining the best technical advice in efforts to develop new alloys. A new chromium-nickel-molybdenum austenitic stainless steel was evolved for use in highly corrosive chlorine and chlorine dioxide bleaching in the pulp and paper industry. A large number of melts was tried and an alloy containing as much as 9.5% of molybdenum gave good results. Later, manganese was added and indicated the superiority of the quaternary alloy.

Tungsten

From a peak of approximately 1 1/2 million pounds of 60% concentrate in 1943, Canadian production of tungsten ceased temporarily in 1948 with closure of the Emerald mine of Canadian Exploration Limited near Salmo, B.C. In 1949, Canadian consumption had fallen to some 170 short tons but it should be noted that the world production had also fallen to less than 50% of the war peak at 61,000 tons of 60% concentrates. However, by 1970 Canada was producing about 4 million pounds of tungstic oxide, or about 3.1 million pounds of metal equivalent. There was some importation of ore and concentrates and ferrotungsten amounting to a metal equivalent of about half a million pounds. The Canadian consumption of tungsten in pounds of metal in 1969 by use was: carbides 791,021; alloy steels 195,244; non-ferrous alloys, chemicals and pigments 34,035; electric and electronic 30,514, for a total of 1,050,824 pounds.

The sole Canadian producer in 1970 was Canada Tungsten Mining Corporation, operating a mine at Tungsten, N.W.T. near the Yukon border, the scheelite ore containing about 1 1/2% of tungstic oxide, at a mill recovery of about 79%. There were prospects of other mines, but in view of a depressed international market at the time of writing, Canada Tungsten remains the only producer.

Samples of tungsten ore in the form of scheelite (calcium tungstate) were submitted to the Mines Branch during the fifties and early sixties from the Northwest Territories, Quebec, New Brunswick and Newfoundland. There were also samples of gold mine tailings containing scheelite from Ontario but the grades were too low for production of commercial-grade concentrates. The Mineral Processing Division worked for several years on ore from the Canada Tungsten mine. In 1962 the final pilot plant run involving 34 tons was made on this high-sulphide scheelite ore. The gravity concentrates were upgraded by high intensity magnetic separation and the final concentrate contained 79% tungstic oxide and recovery was 70% of the tungsten. The slime fraction was treated by flotation, and after acid leaching the concentrate contained 69% tungstic oxide, representing a further 15% recovery of tungsten.

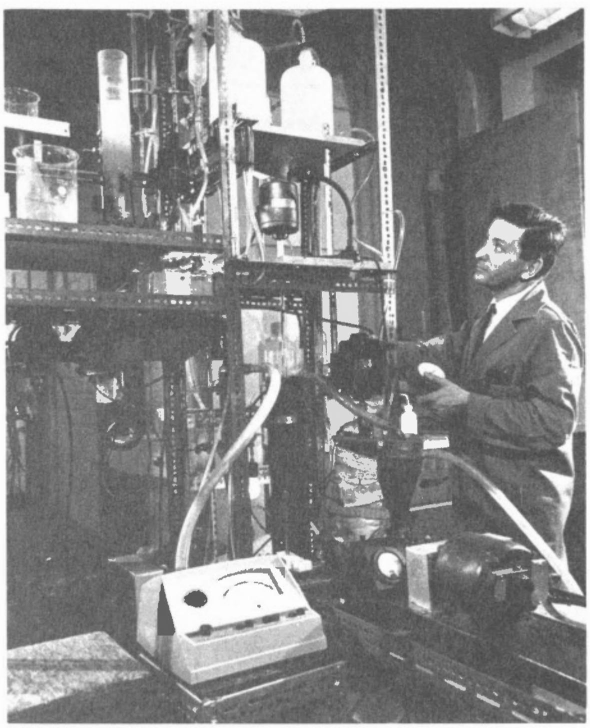
In 1965 the Extraction Metallurgy Division, recognizing that scheelite concentrates produced at the mine would not yield an intermediate product suitable for the manufacture in Canada of tungsten powder and chemicals, carried out a research investigation on the possibilities of producing a pure tungsten oxide as a basic material for these processes. An unconventional process was to produce ammonium paratungstate by decomposition of the scheelite with hydrochloric acid, followed by leaching of the acid-insoluble tungstic acid by ammoniacal solution. A process was developed wherein a sodium hydroxide leach followed by cation exchange treatment produced 96% recovery of tungsten. Higher extraction achieved by this process more than compensated for the ion exchange cost: "A process for preparing tungstic trioxide of high purity from a Canadian scheelite concentrate" by J.A. Vezina and W.A. Gow (CIM Bull, pp 1418-1422 December, 1966). No industrial high-purity tungstic oxide or paratungstate was produced because the Canadian requirements for such a product were below the economic size of plant which was considered to be 3 million pounds per annum. The U.S.A. tariff structure proved too high a barrier to Canadian competition for this product.

Tungsten was used in much of the steel alloy research in the Physical Metallurgy Division during the whole of this period.

The Chemical Laboratories of the Mineral Sciences Division published a Technical Bulletin on the analysis of tungsten in ores, concentrates and steels: (MB TB 37, 1962, by G.H. Faye, R.J. Guest and R.C. McAdam).

Silicon

It is appropriate to mention silicon which, next to carbon, is the most widely used additive not only in the iron and steel industry but also in the non-ferrous industry. It is produced from silica of 98% purity and is usually converted into a ferro-silicon. As a result of developments in alloy technology a variety of silicon alloys with elements like calcium, barium, boron, aluminum, magnesium, zirconium and titanium, mostly in a mixture with iron, have become available for high-performance iron and steel products.



J. Laliberté processing tungsten concentrates in pilot plant (Photo - George Hunter)

Silicon is considered as the most widely used deoxidizer in steel-making and one of the most economical. A large-scale application of silica (silicon oxide) in metallurgy is its use in lump form as a flux in smelting base metal ores to slag iron and other oxides as silicates. Other uses of silicon are in abrasives and chemicals.

There was a sizeable export, particularly to Britain, of Canadian produced ferrosilicon as a deoxidizer in ferrous metallurgy and to the U.S.A of silicon carbide. For use as an abrasive as well as oxidizer in ferrous metallurgy, in electronics and in the nuclear energy fields. There was also an importation of ferrosilicon. In 1969, almost 48,500 short tons of ferrosilicon and 103,500 tons of silicon carbide was exported; and 9,000 tons of ferrosilicon was imported. The value of ferrosilicon exports amounted to $5.25 million and of imports to $2 million. Silicon carbide exports were valued at $15 million hence providing a credit balance of $18 million in Canada - U.S.A. trade. There was a domestic consumption of 51,000 short tons of which nearly half was used by the steel industry. Foundry sand used in Canada amounted to about 820,000 short tons. Another large use of silica in the form of quartzitic sandstone was for flux in smelting base metal ores to slag iron and other oxides as silicates; in 1969 nearly 1 1/2 million tons was used in the process.

Zirconium

Though no domestic production of zirconium has taken place there are occurrences of zircon (ZrO_2SiO_2) in Canada and it is said that Alberta oil sands contain small quantities of zirconia. Several zircon samples were submitted to the Mines Branch for examination.

The metal which has resistance to corrosion and retains strength at high temperatures on the one hand and possesses low capacity of neutron absorption on the other hand, was selected early in the development of the nuclear energy reactor program as a suitable material in metal and alloy form for the manufacture of tubing for fuel cladding, pressure tubes and structural material for reactors. The associated metal, hafnium, is recovered as a byproduct of reactor-grade zirconium processing largely due to its capacity for high neutron absorption. Eldorado Nuclear established a zirconium producing plant at Port Hope, Ontario, for the Canadian manufacture of pressure tubes and fuel cladding tubes by a process in the development of which Ritcey, of the Extraction Metallurgy Division, participated, that averts the intermediate stage of making sponge metal, producing ingots of zirconium directly from Australian zircon sand concentrates. The Physical Metallurgy Division carried out a project for a number of years on ferrous and non-ferrous alloys using zirconium. Hafnium was also one of the additives used in the division's research. In 1969 the importation of zirconium alloys, mainly from the U.S.A. amounted to approximately 210,000 pounds valued at $4.5 million.

The consumption of ferrozirconium was reported to be 60,000 pounds gross weight.

National Productivity Council

As mentioned earlier, Dr. Convey, as a member of the Council was requested to prepare a review of expenditures on ferrous metallurgy by the iron and steel industry of Canada, including research both in ore treatment as well as in physical metallurgy. He was assisted in this by Faurschou and Walsh. Though the emphasis in this study was on industrial research, there was also information on non-industrial research. Mines Branch expenditures in 1961 in ferrous metallurgy that included R & D in mineral processing and physical metallurgy were estimated at $700,000, or nearly 15% of the branch budget for that year. This represented about one third of the R & D expenditures by the iron and steel industry. Next to the Mines Branch the largest non-industrial expenditure was made by Ontario Research Foundation and a lesser amount by the Alberta Research Council: "Report to the National Productivity Council on research and development in the Canadian primary iron and steel industry" by John Convey, D.K. Faurschou and J.H. Walsh (Applied Research Report NPC-3, Mar. 1963).

Expenditures on mineral processing R & D related to additive metals largely used in iron and steel alloys were not included in the case of the Mines Branch.

Recipients of St. Johns Ambulance Certificates

Back row: l - r: G.P. Cox (1958-1961), G.J. Noel (1955-), R.G. Olivier (1958-1965), L.A. Clement (1954-), G.E. Handy (1946-), W.H. Cere (1956-1971), M.J.B., Bradley (1949-), R.W. Buckmaster (1955-1972), L.G. Ripley (1950-), J.F. Fydell (1949-);

Middle row: L.E. Desjardins (1955-), A.H. Gillieson (1959-1975), Leveck (1960-1963 and 1974-), M. Power (Industrial Minerals and Mineral Resources), B. Staples (1958-1967), H. Fergusson (PMRL and Industrial Minerals), J.J. Donnelly (1959-1962), J.A. Herbert (1951-), R.G. Fouhse (1958-);

Front row: F.J. Kelly (1959-), R. Closs (Explosives Division), M.J. Malette (1955-), L.P. Smith, (1952-1963), John Convey (1948-1973), Commissioner Nicholson, RCMP, P.E. Hughes (1958-1975), "Bill" Bailey (Health Unit Nurse), D. Quinsey (PMRL, HQ, MOSST), W.H. Merrill (1947-)

NON-FERROUS METALS

The three principal non-ferrous metals - copper, zinc, lead - popularly known as base metals, showed a considerable upswing in Canadian production in the two decades from the fifties to the seventies. So did nickel, which in end use is associated with iron and steel and could be regarded as an important additive metal; at the resource end it is usually associated with copper and other metals.

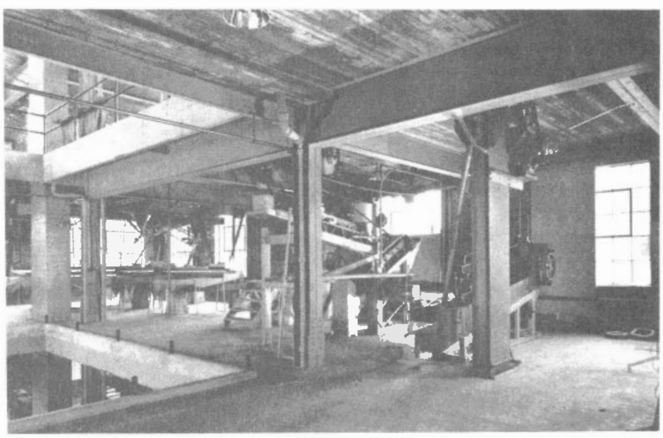
Canada in 1970, was and still is, the world's largest producer of nickel. It became leader in zinc in the sixties when the United States slipped from first place. In copper and lead, Canada was third and fifth respectively. The largest producer of nickel and copper continues to be Inco in Sudbury and Manitoba, and the largest producer of lead and zinc is Cominco, principally in British Columbia but also in several other Canadian regions.

Canadian companies like Cominco, Noranda, Hudson Bay and Sherritt Gordon were in varying degrees developing their own R & D capabilities in process metallurgy towards the end of the war, but continued to consult the Mines Branch on matters of specific interest to their companies. The small entrepreneurs had to rely on Mines Branch laboratories for the evaluation of their ores. The large nickel producers had already worldwide interests at the end of the war, and to protect their multi-metal extraction and refining technology they developed considerable self-reliance in R & D.

Provincial governments were increasingly entering the field; the first provincial research council formed was in Alberta in 1921, concentrating mostly on large fuel resources such as coal and oil sands, but attention was being paid to other minerals as well. The Ontario Research Foundation was formed in 1928 and increasingly undertook mineral processing research with a chemical orientation. After the war the B.C. Research Council, Saskatchewan Research Council and Nova Scotia Research Foundation were formed in the late forties and early fifties. Later, the New Brunswick Research and Productivity Council was formed. The Quebec Department of Natural Resources opened a mineral processing laboratory in Quebec City in 1960.

In addition, many of the universities had become interested in mineral processing research. It may be recalled that both McGill and Queen's carried out research on a contract basis for the Mines Branch in the pre-World War I period, and professors at several

J. Banks operating a Jeffrey Stephanson magnetic separator, circa 1960



Mineral Processing Laboratory, 550 Booth St. showing gravity tables, magnetic separator, and classifier

H.R. Renaud performing size analysis on ore sample using the Haultain Infrasizer, circa 1960 other universities prepared mineral commodity reports which formed part of the earlier publications of the Mines Branch. From the formation of the NRC in 1917, grants were made to universities on many subjects including mineral processing research. As it will be seen later, a grants-in-aid program to universities was started by the Mines Branch in 1961. Apart from the academic and government fields, many more commercial analytical laboratories were also being established. In 1941 the Lakefield Ore Dressing Laboratory, an independent facility but backed by Falconbridge, was started.

Ore Treatment

The facilities at the Mines Branch for conducting mineral dressing research were updated after the war; there were improvements in unit processes: comminution, gravity and magnetic separation and flotation, as well as in hydrometallurgical and pyrometallurgical processes such as leaching, filtering, precipitating, roasting, sintering and smelting. As noted earlier, the analytical facilities and capabilities were enhanced to better deal with the complexity and number of samples. In effect, the laboratories attained a national reference character.

Non-ferrous ores and some of the precious metals by their complexity, mineral association and varying grades presented challenging problems in treatment.

H. Renaud and R. Bruce conducting gravity concentration test

Judging by the number of industry representatives making use of the facilities and assistance of the Mines Branch personnel as well as the number of visiting persons and groups from abroad, in some cases concerned with establishing similar facilities in their countries, it is fair to say that the pre-war reputation of the laboratories was fully maintained in the post-war period. The facilities had to deal with a wide weight-range of samples as large as several railway car lots at a time. The decade from the middle fifties to the middle sixties was probably one of the busiest periods for the laboratories of the Mineral Dressing and Process Metallurgy and later of the Mineral Processing Division.

The table shows the number and variety of investigations of base metal ores carried out at the Mines Branch for the years 1952, 1954, 1956 and 1958, and the total number of investigations that included iron, gold and other metals.

Base metal investigations by the Mines Branch - 1952-58

Year	Type of ore *	NWT	Prairies	Ont	Que	Maritimes	Total base metal	Total all types **
1952	Pb-Zn	6	-	-	4	-	10	
	Cu-Ni	-	-	4	2	-	6	40
							16	
1954	Cu-Pb-Zn	1	-	-	1	2	4	
	Pb-Zn	1	1	-	-	1	3	
	Cu-Ni	-	1	-	-	-	1	
	Au-Cu-Co	-	-	-	-	1	1	39
							9	
1956	Cu-Co	-	-	1	-	-	1	
	Co-Pb-Zn	-	-	-	-	3	3	
	Cu-Ni	-	-	4	3	-	7	
	Au-Ag-Pb-Zn	-	-	-	-	1	1	
	Ag-Pb-Zn	-	1	-	-	-	1	87
							13	
1958	Cu	2	-	2	2	-	6	
	Cu-Ni	-	-	2	-	-	2	
	Ni	-	1	3	1	-	5	
	Pb-Zn	-	-	2	-	-	2	
	Pb-Zn-Cu	-	-	-	-	1	1	
	Cu-Zn	-	-	1	1	-	2	
	Zn	-	-	1	-	-	1	
	Ag-Pb-Zn	1	-	-	-	-	1	79
							20	

* Co-Cobalt; Cu-Copper, Au-Gold; Pb-Lead; Ni-Nickel; Ag-Silver; Zn-Zinc

** Includes ferrous and other types

As seen from the above table, all four principal base metals were represented in the ores submitted by industry for testing, but low-grade nickel-copper ores demanded most of the attention of the Mines Branch. In the sixties the requirements from industry were approximately one third less, declining further in the seventies, thus progressively allowing the branch to plan its own research projects in lowering production costs, improving methods of recovery and spending more time on complex refractory ores.

Copper-nickel deposits in Manitoba came into prominence after the war. A leaching process for treating Lynn Lake ores proposed by Prof. Forward of the University of British Columbia was investigated with the assistance of the Mines Branch in a pilot plant operation during 1949-50. In 1957, a 100-ton sample of low grade copper-nickel ore from Manitoba was tested in the Mineral Dressing and Process Metallurgy Division. The mixed concentrates were roasted and smelted, producing a matte of 30% nickel and 20% copper. A particularly complex low-grade nickel-copper ore was also received from the Temagami District of northern Ontario. A sample of 54 tons was treated by flotation, which required considerable work because of the presence of talc. Eventually the talc was depressed and a good grade of nickel-copper concentrate was produced. An extensive smelting campaign was carried out on 250 tons of roasted nickel-copper concentrates, making 27 tons of nickel-copper matte to enable the company to design a smelter and a refinery in Quebec.

During the sixties the Non-Ferrous Metals Section of the Mineral Processing Division worked on zinc-lead-copper ores from Kidd Creek in Ontario and the Bathurst area in New Brunswick. In 1965, drill core samples of two main types of ore were first investigated from Kidd Creek followed by a 60-ton sample from surface trenching across a lead-silver-zinc zone. Because of the presence of covellite, a secondary cupric sulphide, some difficulty was experienced, but nonetheless a marketable 54% zinc concentrate with a recovery of 81% was obtained. The silver, closely associated with pyrite, was depressed with it in the tailing of the zinc flotation. The silver content in the pyrite amounted to 44%. Another sample weighing 43 tons from the main ore zone containing 19.3% zinc, 3.2% copper and 5.5 ounces of silver per ton was investigated. Due to an unfavourable zinc to copper ratio, the copper was floated and the zinc depressed. The copper concentrate assayed 27% copper with a recovery of 89% and contained the silver. The zinc concentrate assayed 55% with a recovery of 89.5%.

In 1965, work started on the complex copper-lead-zinc ore from the Bathurst area and continued for some four years. The main problem was that the mineral grains were extremely fine, all minus 325 mesh, and were disseminated in a matrix of pyrite; in effect the ore was composed of 95% sulphides. Eventually the problem was solved by a very fine primary grind to minus 400 mesh and extensive regrinding of intermediate (middling) concentrates. It was believed that the beneficial effect of regrinding was due to the conditioning effect on the sulphides rather than to a liberation of mineral in middling particles. This area of northeastern New Brunswick became an important production centre for base metals in the seventies and the Mines Branch continued to receive requests for treatment of various ores.

Another example of treatment of finely disseminated mineral particles was the successful flotation in 1967 of ore from Gaspé, Quebec containing the copper minerals of chalcopyrite and bornite, as well as gold and silver. However, the ore had to be ground to minus 325 mesh. A copper concentrate assaying 31.5% copper, 1.5 ounces gold and 6.2 ounces silver per ton was obtained with 93, 96 and 90% recoveries respectively. A grindability determination indicated that grinding costs should be normal because of the low "work" index of the ore.

The foregoing represents a very small number of the investigations carried out on base metals by the Mines Branch. Samples from a large proportion of post-war discoveries, some becoming present producers, were submitted at one time or another to the Mineral Dressing and Process Metallurgy Division and its successor for laboratory examination and often for pilot plant treatment to establish technically and economically viable flowsheets. The complexity of ores increased as may be noted from the examples quoted, indicating what may be expected in the future.

It may be of interest to make a comparison between the production peaks attained in World War II by the four principal base metals with those attained by 1970, together with the Canadian consumption of these metals in that year. The "plateaux" of production and international prices of these four metals at intervals of approximately a quarter century seem worthy of reflection.

Canadian base metal production, consumption - 1918, 1943, 1970

	Production		Domestic consumption
	Short tons	$ 000	Short tons
		Nickel	
Δ1918	46,259	37,003	
*1943	144,019	71,675	
1970	305,881	830,167	11,794 (all forms)
		Copper	
Δ1918	59,385	29,250	
*1940	327,797	65,773	
1970	672,717	779,242	237,838 (refined)
		Zinc	
Δ1918	17,542	2,862	
*1943	305,377	24,430	
1970	1,251,911	398,859	105,641 (refined)
		Lead	
Δ1918	25,699	4,754	
*1942	256,071	17,218	
1970	389,155	123,138	94,094 (primary & secondary)

Δ Peak year, 1st World War
* Peak year, 2nd World War

These four metals accounted for nearly 70% of the value of Canadian metallic mineral production in 1970. The small domestic consumption indicated the degree of reliance of this section of the mineral industry on export. Following the recession in the world economy from 1973, world trade in base metals started to falter and prices declined, particularly in the case of copper.

Other metallic ores which were investigated in the fifties at the request of provincial governments were: lithium, bismuth, aluminum, and tin.

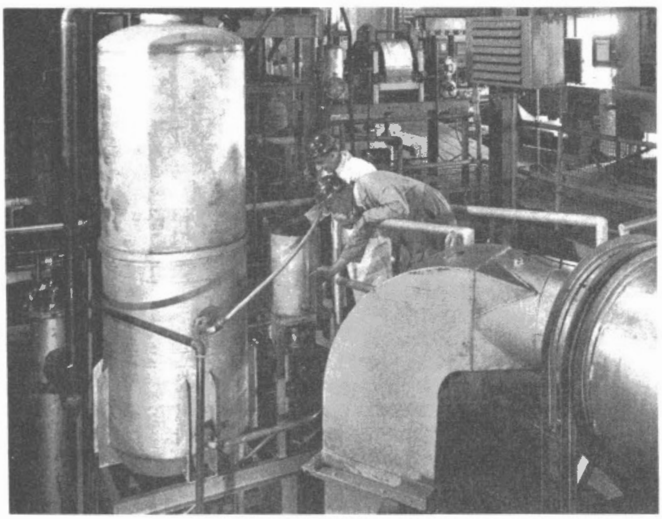
From 1948 to 1950 low-grade spodumene (lithium alumino-silicate) deposits in the Cat Lake District of Manitoba and from Amos, Quebec were investigated. Sink-float, flotation and decrepitation beneficiating methods were tried, followed by treatment with sulphuric acid to produce lithium sulphate which could then be reduced to metal. A recovery of 98% lithium was achieved. A report "Beneficiation of Canadian spodumene ore from Cat Lake, Manitoba" was prepared by H.L. Beer (Precambrian, pp 8-12,15, June 1951). In 1952, the purification of antimony by distillation and electrolytic methods was investigated and proved successful in combination in eliminating most of the impurities. In the same year a survey of all possible Canadian sources of germanium was carried out. Rapid spectrochemical work was developed to detect the small amounts present in mineral powders.

In 1953 the refining of bismuth metal was improved by a combination of distillation and chlorination procedures, resulting in increasing the purity of metal from 95 to 99.98%.

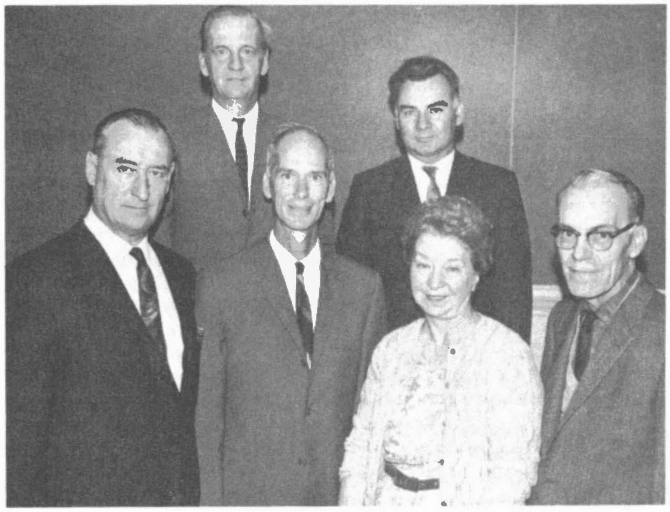
In 1958, fused alumina was produced by the continuous sintering of bauxite to provide a feed for electric furnace production of an abrasive.

To stimulate industrial activity in Nova Scotia and overcome Canada's dependence on the importation of bauxite, a second effort was made to extract aluminum from indigenous sources, in this case from Nova Scotia shales (Chapter 5). Bench-scale and pilot-plant experimentation was carried out. A process was evolved which was published in "Alum-amine process for the recovery of alumina from shale" by G. Thomas and T.R. Ingraham (MB RR 45, 1959).

A continuing objective has been to find sufficient tin to satisfy Canada's requirements which in the sixties amounted to about 4,000 tons per annum. There is a small combined production of tin amounting to about 350 tons per annum as a byproduct from treating multi-mineral ores at the Cominco operation at Kimberley and the Kidd Creek operation of Texasgulf. In 1962 the complex Mount Pleasant tin ore, which contains some eight elements - copper, lead, zinc, tungsten, molybdenum, bismuth, tin and fluorine - was first investigated at the Mines Branch. It was found that the sulphides were in an extremely fine state, and difficulty was experienced in obtaining marketable concentrates. The investigation was directed to recovering the tin oxide, cassiterite, and a concentrate recovering only 50 to 60% of tin was produced. About 10% of the tin was lost in the sulphides and the rest in slimes. The company could not find sufficient financing for this project which was deferred for some years. At this writing, investigation of this complex ore has been resumed by the Mineral Processing Division.



G. Sirianni and G. Viens working on aluminum-from-shale project, 1958



Mineral Processing Division. Recipients of 25-year service pins, back row - H.M. Woodroffe, P.R. Lachapelle; front row - H.S. Renaud, G.A. Brown, D. Gibson, H. Mercier

Physical Metallurgy

The non-ferrous metals field in physical metallurgy embraces the light alloys, principally aluminum and magnesium metal bases, and the heavy alloys, principally copper and zinc metal bases.

Aluminum and Magnesium

As mentioned in Chapter 5, during the early post-war period there was continued demand by the Department of National Defence and by the aircraft industry for light alloys that had favourable strength to weight ratios and good corrosion resistance. In this regard the demand was satisfied mainly by aluminum alloys often with magnesium additions, and to a smaller extent by magnesium alloys. Industry demand both in castings and wrought metal was also growing and there were many new applications. Exceptions were with equipment fabricated from aluminum alloyed with magnesium for underground coal mines and other hazardous sites where this was first tried and then withdrawn. This was due to ignition of fire-damp arising from an aluminum-magnesium alloy component being struck sharply by a steel article such as a pick causing a local "thermite" reaction.

Selecting 1970 as the year when the post-war period had attained the period of rapid growth, primary aluminum production in Canada from imported bauxite was 1,071,718 short tons, and consumption including secondary (reclaimed scrap) was 275,743 short tons of which approximately 33,000 were in castings and 233,000 in wrought products. On the other hand, the Canadian production of magnesium was 9,584 tons from domestic dolomite, and the 1969 consumption was 5,672 tons of which castings accounted for 798 tons, forgings 529 tons and aluminum alloys using magnesium, 3,710 tons.

Whereas aluminum alloys were produced by a few large companies of international status, magnesium alloys were not, hence a broader scope was available for experimentation with alloy formulation. From the mid-fifties to the mid-sixties, Meier, aided mainly by B. Lagowski (1956 -) and also by A. Couture (1951 -), carried out a long-term research project on various magnesium alloy formulations that included zinc, titanium, silver, zirconium and aluminum as additive elements. A series of eight reports described this work under the title "Properties of sand-cast magnesium alloys" (118). In addition a report: "Premium strength in sand-cast magnesium alloys" was published by B. Lagowski and J.W. Meier (MB RR 138, 1964).

Related to this research was the evaluation of properties as derived from both magnesium and aluminum test bars: "Effect of some test bar variables on the mechanical properties of aluminum alloys" by A. Couture and J.W. Meier (MB RR 102, 1962, issued 1964) and "Effect of test bar variables on the mechanical properties of magnesium casting alloys" by A. Couture and J.W. Meier (MB RR 151, 1965).

Magnesium alloy castings were studied for hot-tearing characteristics to which they were susceptible: "Hot tearing of magnesium casting alloys" by R.A. Dodd, W.A. Pollard and J.W. Meier (Trans Am Foundrymen's Soc, vol 65, pp 100-117, 1957).

Copper

Copper is the leading metal in the world in the heavy non-ferrous group, on the other hand, Canadian production of copper is half that of Canadian zinc production. In 1970 Canadian copper production was 673,747 short tons, about 10% of the world supply. Consumption of the refined metal was 237,838 short tons. About half of the consumption was related to electrical applications.

By 1970 there were in Canada 55 copper-producing mining companies, 11 promising exploration projects, 6 smelters and 2 refineries. About 472,000 tons were exported, of which about 60% was in refined form that included both semi- and finished products.

A major effort during the sixties was made in long-term projects to develop optimum properties of high strength casting aluminum-bronzes starting with the basic bronze containing 9% aluminum, 5% nickel, 4% iron and 1% manganese. Aluminum had a predominant effect on the mechanical properties and the other elements, particularly nickel, increased the yield strength. However, nickel caused loss of ductility under certain conditions. After considerable experimentation with wide compositional variation, it was deduced that these alloys showed their impact resistance (Charpy notched-bar test) to be temperature dependent and their impact properties to be influenced by cooling rate or section thickness.

With the aim of generally improving copper base castings and reducing scrap, hot-tearing and solidification characteristics were studied on a reference casting produced from 13 alloys including the high strength aluminum-nickel-bronze. This alloy and high strength yellow brasses had the best susceptibilities to hot-tearing with corresponding short freezing ranges: "Mode of solidification of copper base casting alloys" by J.O. Edwards and A. Couture and "Hot-tearing of copper base casting alloys" by A. Couture and J.O. Edwards (Trans Am Foundrymen's Soc; vol 74, pp 680-698 and pp 709-721, 1966). There is also a Mines Branch report on the second subject: "Hot-tearing of copper alloys" by the same authors (MB RR 164, 1965). A companion investigation was carried out on 10 copper base casting alloys which were vertically cast in 20 in. by 3 1/2-in. billets. The effect of thermal gradient, freezing range, mechanical properties and microstructure were studied: "Effect of thermal gradient and other factors on the properties of copper base casting alloys" by J.O. Edwards and A. Couture (Trans Am Foundrymen's Soc, vol 75, pp 383-393, 1967).

Zinc

Zinc quantitatively was the Canadian leading base metal by the end of the 1960's. From about 400,000 short tons in 1950, production rose nearly 3 1/2 times in ten years to about 1.4 million tons in 1970. This represented about 29% of the production of the non-Communist countries in the world. In 1970 there were 36 zinc-producing companies of which 19 were principal producers. In addition there were some 20 promising prospects. There were five metallurgical plants and one under construction (Ecstall) that included electrolytic plants at Trail and Valleyfield, and smelters and a roasting plant at Port Maitland, Quebec. In 1970 the quantity of zinc exported was 845,991 short tons in ores and concentrates and 351,454 tons in refined metal for a total of 1,197,445 tons. Domestic consumption of primary refined zinc was 105,712 tons which was 11% lower than the production in 1969 due to a 45% drop in die casting alloys. The principal uses in Canada were and still are in galvanizing, particularly the hot-dip process. Thus in 1970 primary refined zinc consumption in short tons was: galvanizing, hot-dip 52,468, electro 1,017, die cast alloys 17,469, copper alloys 12,038, other products, rolled, zinc oxide, etc., 22,459 for a total of 105,641 tons.

R & D work in the Mines Branch profited by the continuing industrial interest maintained through the Canadian Zinc R & D Committee formed in 1954 with Convey as chairman (Chapter 5) and representation from principal zinc producers such as Cominco and Hudson Bay and the users. A resident engineer was appointed and at times there were two such engineers whose salaries were paid by the committee. A forum on zinc was held at the Annual General Meeting of the Canadian Institute of Mining and Metallurgy in Toronto in 1955. As the result of this meeting the division prepared state-of-the-art reports related to the two research areas of galvanizing and alloys. In 1963 the scope of the committee was enlarged to include lead, and the name was changed to Canadian Zinc and Lead Research Committee. In 1973 the alloy project was discontinued and the name was changed again to Canadian Galvanizing Research Association.

Regarding alloys, a comprehensive project involving the addition of nickel, manganese, beryllium, titanium, zirconium, and lithium to zinc aluminum alloy (Zamak 3), with and without increased copper content, was carried out. None of these formulations had worthwhile effects on the properties of die cast test bars. Rolling trials also showed no promise and the alloy project was discontinued in 1958. Some R & D work on zinc aluminum alloys was carried out in the late sixties and early seventies with particular reference to the deleterious presence of lead.

On the other hand, the hot-dip galvanizing project which was started in 1957 is continuing at this time. Considerable improvements were achieved under the guidance of Meier until 1961 and thence of Edwards with Sebisty associated with this project for the whole period. Sebisty gained a considerable reputation in this area.

In the first phase of the project, a statistical investigation was made on the influence of aluminum as an addition and of lead as an impurity in iron saturated zinc baths on the structure and properties of coating steel sheets prepared under various conditions of bath temperature and immersion time. The most significant factors were shown to be the aluminum content of the bath and immersion time. A metallographic examination, reported separately, was made to evaluate the defects in the galvanizing process. Two papers were presented at the Fifth International Galvanizing Conference in Brussels in June 1958 which were also published as Mines Branch research reports: "Influence of aluminum, lead and iron on the structure and properties of galvanized coatings" by J.J. Sebisty and J.O. Edwards (MB RR 5, 1958) and "Study of surface carbides, differential steel attack and pore formation in the galvanizing process" by J.J. Sebisty (MB RR 6, 1958).

In the second phase of the project, individual and combined additions of tin, cadmium, antimony and copper with or without aluminum and lead additions were evaluated in two series of experiments. The combined series was reported in "Influence of combined additions of tin, cadmium, antimony and copper on the structure and properties of galvanized coatings" by J.J. Sebisty and R.H. Palmer of the Canadian Zinc and Lead Research Association (MB RR 86, 1961). This phase was extended to include a series of tests with elements not commonly used in galvanizing practice in aluminum-free and aluminum-containing baths, such as uranium, magnesium, nickel, vanadium, lithium, phosphorus, etc., producing quite variable results which were reported in a paper presented to the Seventh International Galvanizing Conference in Paris in June 1964 "Hot-dip galvanizing with less common bath additions" by J.J. Sebisty and R.H. Palmer (1964 - 1970) (MB RR 125, 1964).

In a third phase pursued simultaneously with the second, a study of the galvanizing behaviour of a variety of commercially-produced steel sheet materials was commenced in 1960. In this project both mild steel and low alloy steel sheets were used. In the case of the mild sheets the results indicated that the character of the coatings was influenced by the chemical composition and processing history. On the other hand, the galvanizing behaviour of low-alloy steel sheets was dependent only on chemical composition. Silicon had a predominant influence and caused extremely severe zinc attack. This research was reported in "Galvanizing behaviour of commercial steel sheet materials" by J.J. Sebisty and R.H. Palmer (MB RR 121, 1963).

A fourth phase of the galvanizing program, the behaviour of zinc coatings at elevated temperatures in the range of 200-400°C both by the hot-dip as well as by the electroplating processes was undertaken in 1961. Two grades of commercial galvanized strip were exposed at six temperatures in the range mentioned for periods of up to six months.

The electroplated zinc coatings failed by blistering at intermediate temperatures and the research in this direction was discontinued. The hot-dip material deterioration involved a variety of phenomena including surface oxidation, cracking deformation within the outer zinc layer, and localized alloying at the steel-zinc interface. Further experiments were made by "galvannealing" zinc coating which was completely converted to iron zinc alloys. Though some initial improvement was obtained, the coating eventually broke down in the same manner as did the normal galvanizing coating after prolonged heating. The study was extended to several grades of continuous-strip produced in different plants and it was established that the deterioration of materials was a function of the continuous-strip processing condition "Continuous-strip galvanized coatings at elevated temperatures" by J.J. Sebisty (Electrochemical Technology, vol 6, pp 330-336, Sept. - Oct. 1968; MB Reprint RS 76). The project was further extended to the study of the flaking mechanism in coatings on thick-wall galvanized products in another report by J.J. Sebisty and R.H. Palmer (MB RR 200, 1960).

By 1968 it was concluded that the extensive data obtained on the galvanizing process emphasized the need for a more fundamental study including that of the reaction kinetics of the iron zinc system. At this writing various aspects of the study are still in progress centred on the high-strength alloys and the galvanizing reactivity process of silicon alloys noted in the earlier work.

Related to the galvanizing program was a project undertaken in 1967 on galvanizing welded heavy section structural steels. Three grades of commercial structural steel in 3/4 in. and 1 1/2 in. section thicknesses were used to ascertain whether severe corrosion of the welded joints would take place as a result of embrittlement by hydrogen occluded in the galvanizing process. No evidence of cracking due to hydrogen was found after prolonged testing which was completed by 1970.

Lead

Lead is the third of the heavy base metals. The increase in domestic production of this metal from 256,071 short tons in 1942, the peak World War II year, to 389,185 in 1970 was approximately 50%, whereas production of both nickel and copper more than doubled and zinc production advanced about 4 1/2 times in the same period. Canada was third after the U.S.A. and Australia in the non-Communist world production of lead which amounted to 2.8 million tons in 1970.

The 1970 Canadian production of 389,185 short tons in all forms included 204,630 tons of refined metal. Exports amounted to 318,733 tons of which 152,821 was refined. Imports of metal and oxide totalled 4,459 tons.

A total of about 94,000 short tons of primary and secondary lead was consumed in 1970 in three principal categories - batteries, battery oxide and cable covering, 26,000 tons; chemicals, 22,000 tons; metallurgy (alloys and fabrications), 18,000 tons. Unclassified tonnage was 4,000. The quantity used in brass, bronze and copper alloys in general was only 318 tons and 1,475 tons was used in antimonial lead.

J.O. Edwards became head of the Non-Ferrous Section in 1960 and Meier transferred to the office of the chief of the division. Meier published a history and forecast on non-ferrous metal casting before he retired in 1970 after 29 years service in the Mines Branch (MB IC 239). Meier was a well qualified metallurgist in pre-war Poland, he was painstaking in his research in a broad field of non-ferrous metals. The director relied on him, as he did later on Edwards, for detailed advice on standards for metals. By 1965 in addition to Couture, Lagowski, Sebisty and Pollard, who joined Edwards and Meier in the early fifties, the following were added to the section: Dr. D.W.G. White (1957 -), Dr. R. Thomson (1964 -), R.H. Palmer (1964 - 1970), J.L. Dion (1964 -), Dr. A.F. Crawley (1965 -). At the time of writing Dr. L.V. Whiting (1970 -) replaced Palmer and Dr. G.E. Ruddle (1971 -) replaced White who was seconded to Dr. Harrison's office of Science and Technology at headquarters.

Other Byproduct Metals

Cobalt

It may be recalled that this metal received particular attention from Dr. Haanel in an effort to develop its use, by recovering it from the silver-cobalt ores of the Cobalt district of Ontario (Chapter 3).

At World War II end there was only a small production (Chapter 4) but by 1970, 51.4 million pounds of metal in all forms was produced. Canada was third after Zaire and Zambia, with about 90% being as a byproduct of nickel-copper and silver-cobalt ores. The production included concentrates shipped to overseas refineries. Several cobalt ores containing silver and copper were submitted by industry to the Mines Branch for treatment investigation. Cobalt was used in research both in the Extraction and Physical Metallurgy Divisions. In 1969 exports amounted to 1.2 million pounds of metal, mostly to the U.S.A. Consumption was approximately 394,000 pounds of metal, principally in electroplating and smaller amounts in chemicals. A monograph on cobalt was published in 1954: "Cobalt in Canada" by R.J. Jones (MB Rep 847, 1954).

Cadmium

Production of the metal as a byproduct of electrolytic zinc plants commenced in 1928 at about 1/2 million pounds per annum; it rose to one million pounds during the war but fell again to 500,000 - 800,000 pounds in the immediate post-war period. By 1970 the production attained 4.3 million pounds of contained metal in all forms that included 1.8 million pounds of refined metal. Canada was fourth in world production after U.S.A., Japan and U.S.S.R. The ores contained up to 0.07% cadmium and the concentrates 0.70%. No ores were received at the Mines Branch for treatment but research relating to cadmium was conducted in the Extraction and Physical Metallurgy Divisions. In 1970, 1 1/2 million pounds was exported principally to Britain and U.S.A. and 125,000 was consumed largely on electroplating with smaller quantities used in solders, pigments and chemical compounds.

Other byproduct metals

Aside from cobalt and chromium, several other byproduct metals (some previously mentioned) produced in Canada or which were important to Canada and with which one or more divisions of the Mines Branch dealt during the period under review were:

Antimony - byproduct of lead smelting - some imports required for Canadian needs
Bismuth - byproduct of certain lead-zinc, lead-zinc-copper, molybdenum and copper ores - export surplus
Indium - from zinc and lead residues - export surplus
Platinoids - from nickel-copper ores - export surplus, some imports and re-exports
Selenium and tellurium - byproduct from copper and nickel refineries - export surplus
Tin - byproduct of lead and zinc ores - small tonnage, large imports.

A proportion of Canadian gold and silver production is in reality a byproduct of base metal ores - gold to the extent of 20-25%; and silver nearly 90% - with the remainder coming from silver-cobalt and gold ores.

The production of these important metals demonstrate the degree of processing and the concomitant investment that was necessary to ensure the economical recovery of various metals from complex ores. The only disadvantage of the association of the "byproduct" metals was their dependence on the continuous production of the principal components of the sulphide ores.

Organization of Non-Ferrous Metals Section, Mineral Processing Division, 1965

When the Mineral Processing Division was formed from its predecessors, Mineral Dressing and Process Metallurgy and Industrial Minerals Divisions, R.W. Bruce was made head of the Non-Ferrous Metals Section assisted by G.O. Hayslip. Both had been in the Mines Branch since 1948. They were joined by G.I. Mathieu and R.P. Bailey, who started with the branch in 1960 and 1961 respectively. T.F. Berry transferred from the Extraction Metallurgy Division in 1962 and A. Stemerowicz joined the group in 1963.

R.W. Bruce

In 1965 the Non-Ferrous Metals Section was composed of the following professionals: head, R.W. Bruce (1948 -), T.F. Berry (1956 -), G.I. Mathieu (1960 -), R.P. Bailey (1961 - 1975) and A. Stemerowicz (1962 -).

In 1963 following Bill Hutchings' retirement and Pickett becoming head of the Metallic Minerals Subdivision, Hayslip was transferred to take charge of the Ferrous and Less Common Minerals Section. Bruce became head of the Metallic Minerals Subdivision in 1974 following Pickett's retirement.

Gord Hayslip - Mineral flotation being studied on a pilot-plant scale

Metal Corrosion

Corrosion research became an important activity in the Physical Metallurgy Laboratories of the Metallic Minerals Division during the war. Corrosion-resistant alloys of that period were limited compared with those developed in the post-war period and protective coatings were used on a large scale. Some examples from a long list of investigations carried out were:

- evaluation of corrosion resistance of selenium-coated steel strip (Investigation 1828)
- corrosion protection afforded to steel by a typical organic silicon oxide polymer (Investigation 1839)
- corrosive-resisting properties of a zinc coating on steel (Investigation 1846)
- nature of corrosion on under-surfaces of wings, fuselages and tail units of Lockheed 12A aircraft (Investigation 1867)
- preferred method of applying a corrosion-resistant coating to used magnesium parts (Investigation 1914).

In the development of the experimental atomic reactor at Chalk River, the National Research Council looked to Mines Branch for the physical metallurgy of structural metals as well as to the fuel rods. An important consideration was of course that any metals used in the reactor should be corrosion resistant. In this respect Lavigne, the head of the Mines Branch group at Chalk River, aided by Spence, was closely concerned with corrosion prevention. The Bureau of Mines was active in the NRC Associate Committee on Corrosion Research and Protection, the Corrosion Subcommittee of Atomic Energy Project, Royal Canadian Navy Committee on Corrosion and Fouling, and the Subcommittee for Fire Fighting Equipment of the Canadian Government Purchasing Standards which specified materials for such equipment.

In 1944 when R.R. Rogers, an experienced chemist, joined the Metallic Minerals Division as head of the Chemical Metallurgy Laboratory, part of the Physical Metallurgical Research Laboratories, he became the chemical expert on corrosion. After formation of the separate Physical Metallurgy Division in 1949, Rogers continued to work with the Physical Metallurgy Laboratories though he was transferred to the Mineral Dressing and Process Metallurgy Division where he continued as head of an enlarged Chemical Metallurgy Section. He was assisted by I.I. Tingley (1953 - 1964), who had joined the Physical Metallurgy Division, on two studies: "A literature study of corrosion resistance of wrought iron and open-hearth steel" (MB IC 111, 1958) and "A corrosion study in processing uranium ore" (MB RR 65, 1960).

The Mineral Dressing and Process Metallurgy Division and its successor, Extraction Metallurgy Division, became responsible for the chemistry of corrosion.

The specialization of this group was a long-term study directed to improving zinc, cadmium, chromium and silver electroplating processes, particularly in the context of the problem of embrittlement of high-strength steels by hydrogen produced during electroplating. The first two published studies dealt with zinc and cadmium plating, "Control of zinc electrodeposition to decrease hydrogen embrittlement in steel" by W. Dingley (1945 - 1975) and J. Bednar (1960 -) (50th Annual Technical Proceedings, American Electroplating Society, June 1963), and "Prevention of significant embrittlement in certain types of high-strength steels, prior to and during cadmium electroplating" by J. Bednar, W. Dingley and R.R. Rogers (Electrochemical Technology, pp 497-501, Sept. - Oct. 1966).

Improved chromium plating on high-strength steels was achieved by preplating the steel with copper as reported in "Preplating high-strength steels with copper to prevent embrittlement during chromium plating" by C. Freeman, W. Dingley and R.R. Rogers (Electrochemical Technology, vol 6, pp 64-66, 1968). Later an improved electroplating process was evolved by devising a low-ratio sulphate bath that lowered hydrogen release and reduced the tendency to hydrogen embrittlement documented in the report "Chromium plating from a low-ratio sulfate bath: improvement by addition of sodium hydroxide" by J.C. Saiddington and G.R. Hoey (Plating, vol 57, pp 1112-1116, Nov. 1970). The authors of this invention were given the American Electroplating Society Award. A report of a companion study was also published in "Microscopic study of the formation of cathodic films on iron during electrolysis of chromium plating solutions at various CrO_3:SO_4 ratios" by J.C. Saiddington and G.R. Hoey (Journal Electrochem Soc, vol 117, No 8, pp 1011-1020, 1970).

An improved method of electroplating silver on steel was developed by increasing the sodium hydroxide

W. Dingley inspects samples in earlier accelerated marine corrosion test (Photo - NFB)

to sodium cyanide ratios to levels higher than those used in conventional cyanide plating baths with optimum compositions being determined by statistical analysis of extensive test data: "Improved silver cyanide plating baths: laboratory development" by W. Dingley, J. Bednar and R.R. Rogers (Plating, vol 56, pp 1129-1134, Oct. 1969; MB RS 87, 1969).

A long-term research project was started in 1964 on the atmospheric corrosion of steel as well as galvanized surfaces by the effect of combustion of sulphur dioxide in a humid atmosphere producing sulphurous acid or, as it is popularly known, acid rain. The phenomenon and the prevention of corrosion by sulphurous acid of mild steel and zinc were studied. Ammonium oxalate and "hexamine" as a combination were found to act as inhibiting agents: "Additives prevent low carbon steel corrosion in sulfurous acid" by W. McLeod (1960 - 1974) and R.R. Rogers (Material Protection, vol 5, pp 28-29, Dec 1966, Reprint MB RS 30); also "Additives prevent corrosion of zinc in sulfurous acid" by the same authors (Material Protection, vol 8, pp 25-27, Apr. 1969).

It was estimated by the Extraction Metallurgy Division that the direct cost of corrosion in the Canadian mining and metallurgical industry might amount to $60 million annually. This was the reason for a long-term R & D project started in 1970 on the identification of corrosion problems and preventive measures: "Corrosion control in Canadian sulphide ore mines and mills" by G.R. Hoey and W. Dingley (CIM Bull vol 64, No 709, pp 62-69, May 1971).

As of this writing, R & D in corrosion continues in electroplating, particularly in relation to chromium and in the problems of corrosion in the mining industry.

In 1965, corrosion research was part of the Pyrometallurgy and Corrosion Section composed of the following professional staff:

Head, Dr. R.R. Rogers, (1944 - 1969)
G.E. Viens (1945 -)
W. Dingley (1945 -)
G.V. Sirianni (1949 -)
R.A. Campbell (1950 -)
G.N. Banks (1953 -)
W.A. McLeod (1960 - 1974)
J.C. Saiddington (1961 -)
R.L. Sachdeva (1962 - 1967)
Dr. A.W. Lui (1964 -)

In 1967, Corrosion became a separate section with R.R. Rogers, head, W. Dingley, W.A. McLeod, J.C. Saiddington, A.W. Lui and Dr. G.R. Hoey, who joined the Mines Branch in September 1967. Rogers retired in 1968 and was succeeded by Hoey as section head.

The Physical Metallurgy Division in the post-war period had major interests related to the subject of corrosion and its prevention identified by three areas:

- the development and use of corrosion-resistant alloys (in the fifties particularly in regard to titanium and zirconium)
- galvanizing
- corrosion phenomena associated with the use of metals such as stress and fretting corrosion from vibration of machine components.

In 1958, S.L. Gertsman, chief of the division, named the activity surface treatment and corrosion. In 1960, Dr. G.J. Biefer joined the division and was placed in charge of the corrosion section. He was assisted by H.M. Weld (1948 -) and B. Olivier (1945 - 1971). Weld had developed an improved plating technique as part of an atomic fuel sheath bonding process. Weld's methods were adopted by U.S.A. and Canadian contractors after they had spent considerable effort on their own methods.

Most of the activity of the section was related to testing various ferrous and non-ferrous alloy formulations. However, attention was also paid to corrosion phenomena in the mining industry resulting in the report "Corrosion fatigue of structural metals in mine shaft waters" by G.J. Biefer (MB RR 167, 1965) and a companion study by the same author: "Polarization measurements on ASTM-type 6061-T6 aluminum alloy in three Ontario mine shaft waters" (MB TB 73, 1965).

Only a few examples of the corrosion-resistant alloys can be given because of space limitations. A comparison of field and laboratory corrosion tests of AISI type-430 stainless steels was conducted by J.G. Garrison and G.J. Biefer (MB TB 91, 1967). Sea water crevice corrosion tests with the same steel and additions of uranium were made by these two authors (MB TB 98, 1968). The effects of various alloying elements on the corrosion of this steel were studied by G.J. Biefer (MB TB 87, 1967) as well as the related polarization behaviour (MB TB 90, 1967). Exploratory stress-corrosion cracking tests were carried out on some low-alloy, high-strength steels by G.J. Biefer (MB TB 111, 1968). J.G. Garrison, who joined the Mines Branch in 1958 and left in 1974, was a senior technician in the Ferrous Metals Section. Dr. B.C. Styrett joined the Corrosion Section in 1967 and stayed three years. In 1971, Dr. J.B. Gilmour came and at this writing is with Dr. Biefer who remains head of the Corrosion Section. Weld transferred in 1968 to the office of the chief of division - on special projects.

A long-term study of corrosion was undertaken in the Industrial Minerals Division in the fifties, continuing in the Mineral Processing Division after 1959.

This was part of the long established industrial waters program, on water supplied to army camps and used for industrial and domestic applications. This project that started in 1956 was carried on partly in cooperation with the National Association of Corrosion Engineers. In one phase of the study, 2-ft lengths of aluminum, copper, galvanized iron and black iron were placed in water lines at seven Canadian locations. Samples of water flowing through the lines and other pertinent data were collected quarterly until the specimens were removed for evaluation. A laboratory study was undertaken on the effect of water quality on the corrosion of galvanized iron tanks by hot water at both atmospheric pressure as well as at 30 pounds per square inch. A review was made of the use of copper in domestic water systems by J. Ungar (1958 - 1961) (MB IC 107, 1959).

Two further research studies were made by Ungar related to colour contamination of natural waters: "Further studies on the measurement of organic (colouring) matter in natural waters" by J. Ungar and J.F.J. Thomas (MB TB 39, 1962) and "Infrared absorption by colouring matter in natural waters" by J. Ungar (MB RR 106, 1963). These reports were published after Ungar left in 1961.

Consideration was given to organizing a three-division program on corrosion into a coordinated branch program, but the diversity of approach and viewpoint made this impossible, though for about four years an interdivisional committee on corrosion did function, composed of representatives from Physical Metallurgy, Mineral Processing, and Extraction Metallurgy Divisions.

Physical Metallurgy Division

Like Mineral Sciences, this division does not lend itself purely to a commodity approach hence this part of the narrative deals with the division's activities that were not earlier described under specific metals. The story of the transition of physical metallurgy R & D from modest beginnings in Dr. Haanel's days to the largest activity of the Mines Branch during World War II and thereafter will be recalled from previous chapters.

Dr. Convey was selected in 1948 by Timm and Parsons as the chief of the division because of his fundamental expertise in atomic and metal physics to lead the branch into the "nuclear age" so to speak, which embraced not only the emergence of atomic energy in a non-destructive role but also the shift to a new plateau of expectation and demand of performance from metals brought about by the war.

The transition from the war period virtually started in 1945 but the demands on the division in fact increased because, in addition to government requirements in the two areas mentioned, there was a growing demand from an expanding industry, particularly from the Canadian foundries. As Parsons in his annual report for 1946-7 said, "Few of the approximately thousand plants in Canada are large enough to employ skilled metallurgists". As mentioned in Chapter 5, the Steel Castings Institute of Canada sought close rapport with the branch. A resident engineer was appointed by the Institute to participate in the research, and the practice is in effect at this writing. The industrial Advisory Committee on Magnesium Research formed in 1945 with membership from industry, National Defence and the Bureau of Mines was requested by National Defence to undertake a broad research program on problems with fabrication of magnesium alloys to enable conversion of defence equipment for airborne operations and service at low temperatures. Similarly, both the atomic energy project, the aircraft industry and National Defence were looking for corrosion and temperature resistant alloys with favourable strength to weight ratios, thus titanium and zirconium played an important role in the physical metallurgy research during the fifties.

The scientific group of Metal Physics with Cunningham as head was strengthened by Convey by bringing in a number of scientists, some of whom he had trained at the University of Toronto. Spectroscopy was playing an increasing part in the growing development of steel alloys and identification of impurities; Convey co-authored with Dr. J.K. Hurwitz (1948 - 1957), one of his former pupils, a Mines Branch report to assist in the rapid and accurate quantitative analysis of a wide variety of alloy steels - "The spectrum of steel - a table for the selection of homologous spectral lines" by John Convey and J.K. Hurwitz (MB Rep 838, 1954).

Organization of Physical Metallurgy Division, 1957

The appointment of Dr. Convey as director was logical first in the light of his research background, and second because of prevailing opportunities for developing, with the aid of R & D, a stronger secondary metal industry on the basis of skills and resources acquired during the war.

In Chapter 5 the organization and list of the senior staff was given as at February 1951 when Dr. Convey was chief of the young division formed in 1949. The following is the organization and list of senior staff as of April 1957:

Assistant chief - S.L. Gertsman (1946 -)
Note: MacPhee replaced Convey and served as chief until his death in 1957.

Administrative officer - M.J.B. Bradley (1949 -)

Metal Physics:
- Head - Dr. R.L. Cunningham (1942 -)
- Dr. J.K. Hurwitz (1948 - 1957)
- Dr. C.M. Mitchell (1948 -)
- H.M. Weld (1948 -)
- Dr. Y.L. Yao (1950 -)
- K.S. Milliken (1950 -)
- Dr. W.J. Wrazej (1951 - 1964)
- Dr. J.A. Bland (1957 - 1959)

Ferrous Metals:
- S.L. Gertsman
- Dr. W.A. Morgan (1954 - 1962)
- D.E. Parsons (1950 -)
- R.D. McDonald (1955 -)
- D.R. Bell (1956 -)
- D.K. Faurschou (1951 -)
- R.K. Buhr (Foundry)(1953 -)

Non-Ferrous Metals:
- Head - J.W. Meier (1941 - 1970)
- J.O. Edwards (1948 -)
- A. Couture (1951 -)
- B. Lagowski (1951 -)
- J.J. Sebisty (1951 -)
- W.A. Pollard (1952 -)

Refractory Metals:
Head - H.V. Kinsey (1942 -)
Dr. A.J. Williams (1954 -)
Dr. J.W. Suiter (1957 - 1958)

Nuclear Metallurgy:
Head - N.S. Spence (1953 - 1975)
C.F. Dixon (1954 -)

Metal Fatigue:
Dr. T.W. Wlodek (1942 - 1970)
W.H. Bott (1947 -)
J. Harbec (1956 -)

Rheology and Fracture:
H.H. Bleakney (1930 - 1935 and 1952 - 1963)
Dr. F. Weinberg (1951 - 1967)

Engineering Physics:
Head - R.C.A. Thurston (1946 - 1975)
F.W. Marsh (1950 -)
J.G. Buchanan (1950 - 1957)

Mechanical Metallurgy:
Head - N.B. Brown (1938 - 1960)
P.J. Todkill (1949 -)

Radiography:
W.E. Havercroft (1947 - 1975)

Foundry:
M. Feltrin (1929 - 1965)

Foundry Sand Laboratory:
A.E. Murton (1944 -)

Metal Forming:
Head - J.A. Perry (1945 - 1974)
H.R. Huffman (1948 - 1960)

Welding:
H.J. Nichols (1943 - 1958)
W.P. Campbell (1947 -)
V.L. Caron (1948 -)
S.A. Agnew (1950 - 1957)

The designations used in the foregoing organization reflected the particular emphasis of the subject area or specialization of the individual, for instance, Rheology and Fracture and Fatigue of Metals could have been grouped with Metal Physics or Engineering Physics.

Disciplines - Metal Physics, Processing and Application

In essence, the program of the Physical Metallurgy Division was comprehensive in its orientation from melting the "base" metal with additions of alloying elements to the utilization of vendible metallic products, the essential coverage of the applied science of physical metallurgy. The program divided itself into three principal discipline areas: metal physics, metal processing and metal applications.

Metal physics was concerned with the fundamental properties and structure of metals. Research projects were mostly carried out by graduate scientists who, being aware of the gaps in knowledge, undertook projects on their own initiative under general direction in the two areas, physics of melting and solidification, and in solid state physics (designated by Gertsman as structures and transformations). This meant that in the first area, projects on the liquid properties of metals, segregation and diffusion on cooling were studied. Projects in the second area included structure and imperfections of crystal lattice (dislocations and vacancies), preparation and study of single crystals of metals or minerals, and phenomena such as forces holding together atoms of metals and alloys, plastic deformation, fatigue, etc.

It will be seen from the foregoing that the scientist was in reality involved across the whole range of activities of the division from the study of the substance of metal through its various manipulations to its behaviour in application.

Metal processing. The main processes that test applicability for a particular formulation of a metal, more usually an alloy consisting of a "base" metal with one or more additives, are represented by the technologies of melting, casting, and solidification and by the less practised technology of powder metallurgy, followed by metal forming, fabrication, and welding.

Metal application. A group of activities that were initially grouped under mechanical metallurgy that included the evaluation and sometimes the design of a modification of metal fabrication, testing of metal strength and other properties at the start or during processing, quality control of cast and welded parts and, above all, study of the behaviour of metal products in different environments.

In addition to the disciplinary organization of the division there was the important group of metallurgists, most of them with engineering degrees, that represented the metal commodities. The two largest groups were the ferrous and non-ferrous metals followed by the refractory metals and nuclear and powder metallurgy.

All these groups were essentially responsible for R & D on alloys and many were identified as specialists of certain metals, for example Gertsman on cast steel, Meier on light metals, Edwards on heavy non-ferrous metals, Kinsey on refractory metals, Spence on metals in nuclear engineering and later, on metal powders. The metallurgists of these groups piloted their projects through process laboratories (foundry, metal forming, welding etc.) as well as the testing laboratories. They also dealt with external inquiries that included metal failures on which diagnostic work was done, such as metallography, X-ray examination, etc., and they prepared the reports.

The ferrous R & D work accounted for about two thirds of the volume of the total work of the division; most of the refractory metals were used in steel formulations.

Ferrous alloy specifications on this continent are now formulated by the American Iron and Steel Institute but were formerly formulated by the Society of Automotive Engineers. As a result there was limited scope for the commercial introduction of ferrous alloys by Mines Branch engineers and scientists. On the other hand, non-ferrous metals are quite different as the number, particularly of different metals, is large. A number of standardization organizations had their own committees on specific metals or group of metals, such as Canadian Standards Association (CSA) which was linked through advisory committees with the International Organization for Standardization (ISO), and with the American Society for Testing and Materials (ASTM) with strong representation from Canada. There were also metallurgically oriented committees in the Canadian Government Specifications Board and in the Organization for Economic Cooperation and Development. As the result of this different approach on standardization specifications of non-ferrous metals, there was more scope to develop new alloys and have them accepted by one or the other of the organizations. Meier was the principal officer involved in standardization but many of the non-ferrous group were concerned with this activity.

Both ferrous and non-ferrous groups were active in the American Foundrymen's Society which sponsored many research projects in which the branch participated. No comparable organization existed in Canada with the exception of the Steel Castings Institute of Canada. The metallurgists were also brought together in the largest metallurgists' organization of the world - the American Society for Metals (ASM), with chapters in various parts of Canada. Welding was well represented in Canada by the Canadian Welding Bureau and the Canadian Welding Society.

Through the decades of the fifties and sixties, activities of the division were more influenced than those of the other divisions by the requirements of the Departments of National Defence and Transport, particularly the former which funded many of its projects. The division was then regarded by DND as their principal metallurgical adviser as it had been in wartime.

In addition there were substantial demands from industry as the division offered broad and detailed knowledge on metals. In a sense the division was a self-contained community with the exception of chemical analysis and sharing of workshop facilities, and could have functioned as an institute on its own.

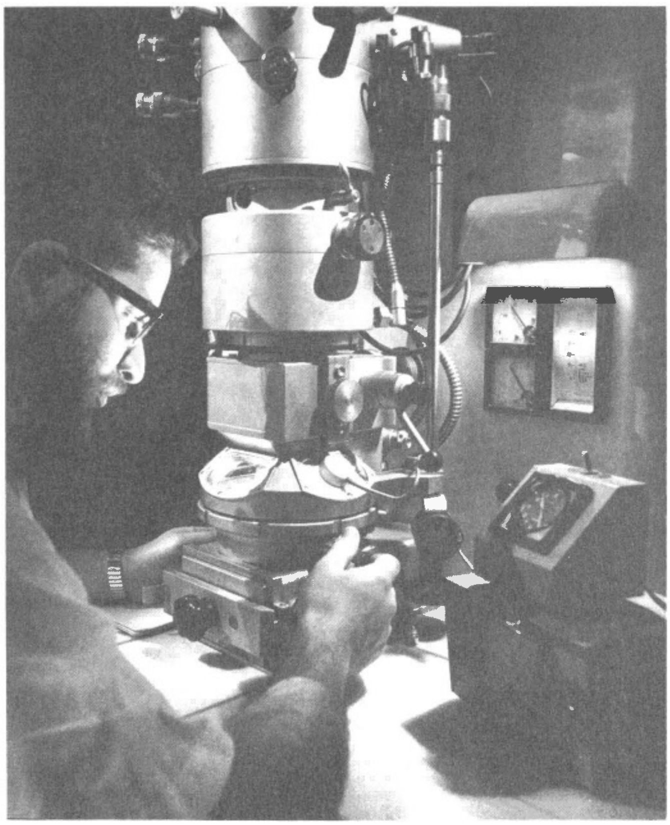
Because of the available facilities and skills, the staff as a whole was involved with problems brought to them from external sources, with perhaps the exception of a few sheltered scientists in the Metal Physics group. Even they were apt to participate in solving some of the problems on account of their expertise and their own interest to profit from examination of a failure or an abnormality in metals.

Space permits of only a few examples of R & D in the groups enumerated above.

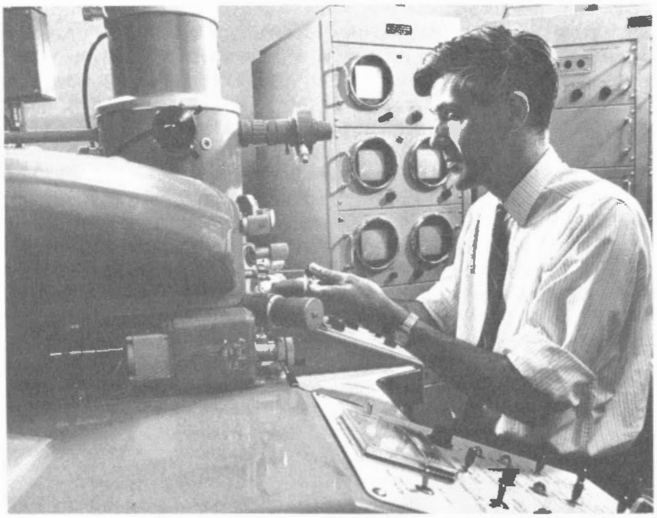
Metal Physics

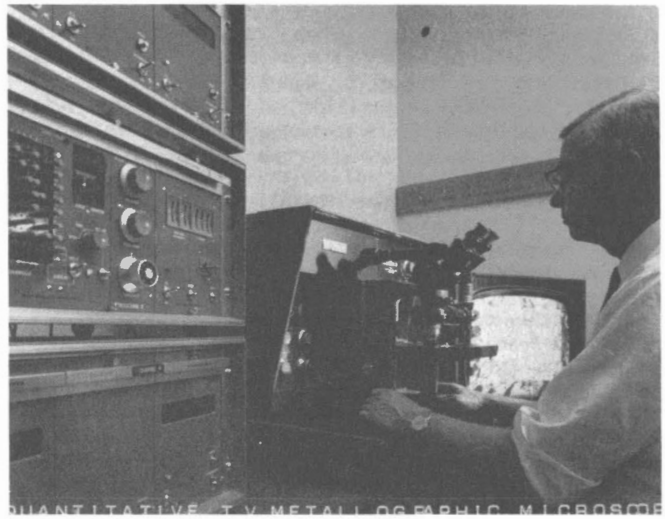
In measuring interatomic spacing in crystals, a computer program was developed for analyzing X-ray diffraction data; the program was designed to process data from both the diffractometer and the camera and applied to structures of any symmetry.

An interesting technique was studied for determining the orientation of single crystals of metals or minerals by ion bombardment that ejected atoms in crystallographic directions. This research continued with



Left - C.M. Mitchell uses an X-ray diffraction unit acquired in the early 1950's (Photo - NFB); Right - E.E. Laufer with first transmission electron microscope installed in PMRL in 1959, reported to be the first in Canada (Photo - George Hunter)





Left - H. Thresh uses the electron probe microanalyzer installed in PMRL in 1964. This instrument makes possible identification of final dispersed compounds in an alloy (Photo - George Hunter); Right - D.R. Bell uses quantitative TV metallographic microscope (Photo - George Hunter)

an investigation of surface atom arrangements in metal crystals.

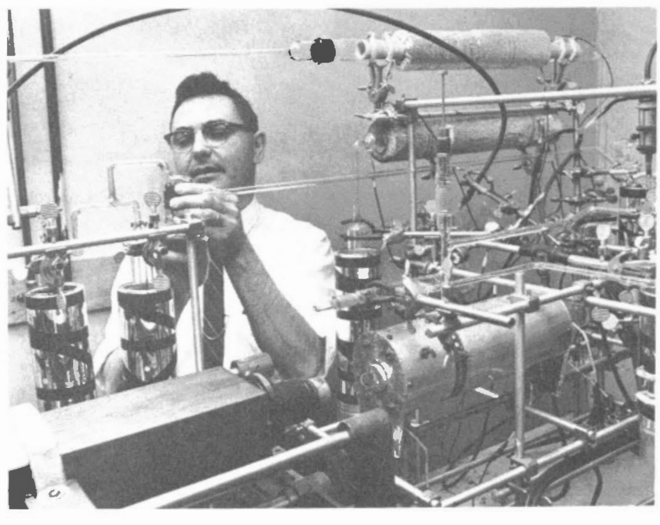
Another study during the early fifties was grain boundaries in metals to obtain a better understanding of segregation of impurities, diffusion, dislocation and lattice vacancies, in other words micro or submicro structure. Transmission electron microscopy and later scanning electron microscopy was used. Towards the end of the period an electron probe micro analyzer was introduced. Magnification by as much as 30,000 diameters was made practicable. Photographic images could then be magnified by ordinary optical means with an overall magnification of 100,000 or more.

Selected references are: "Ejection of atoms from metallic single crystals" by R.L. Cunningham and J. Ng-Yelim (RS 10, 1966, reprinted from the American Journal of Physics, vol 33, No. 12, 1064-1069, 1965); "Simplified apparatus and technique for the determination of crystal orientation by ion bombardment" by R.L. Cunningham and J. Ng-Yelim (MB RR 146, 1965). "Grain boundaries in metals" by F. Weinberg (MB RR 44, 1959). "The role of lattice defects in the precipitation of carbon in alpha iron - direct observations of imperfections in crystals" by E. Smith (Interscience Publication, New York, 1962). "Tools and techniques in physical metallurgy" published by Marcel Dekker, 2 volumes, New York, 1970. Editor: Dr. F. Weinberg; Chap 2 "X-ray diffraction" by C.M. Mitchell; Chap 3 "Crystal growth and alloy preparation" by F. Weinberg and J.T. Jubb; Chap 6 "Electron microscopy" by E. Smith.

In the physics of melting and solidification there were two principal projects: properties of metal liquids and the progressive solidification of the melts. The first program was carried out in cooperation with the Canadian Zinc and Lead Research and Development Committee and was concerned with the properties of liquid metals, mainly zinc and lead-based alloys, though later steel was investigated. The effects of temperature and composition on viscosity, density and surface tension were studied.

The second project was involved in studies of solute segregation, particularly related to dilute binary alloys and later extended to ternary alloys. Tracer elements were used. Solute distributions obtained during the progressive solidification were analyzed by computer. It was possible to describe the solute distribution curves using two physical parameters: effect of the coefficient of segregation, and diffusion.

Selected references are: "Viscosity of pure liquid zinc, determined by oscillating a cylindrical vessel" by H.R. Thresh (1960 - 1967) (MB RR 133, 1964); "Theory and experiment in methods for the precision measurement of surface tension" (MB RR 157, 1965) and "Surface tension of molten zinc and some zinc alloys" (MB RR 160, 1965), both by D.W.G. White (1957 -).



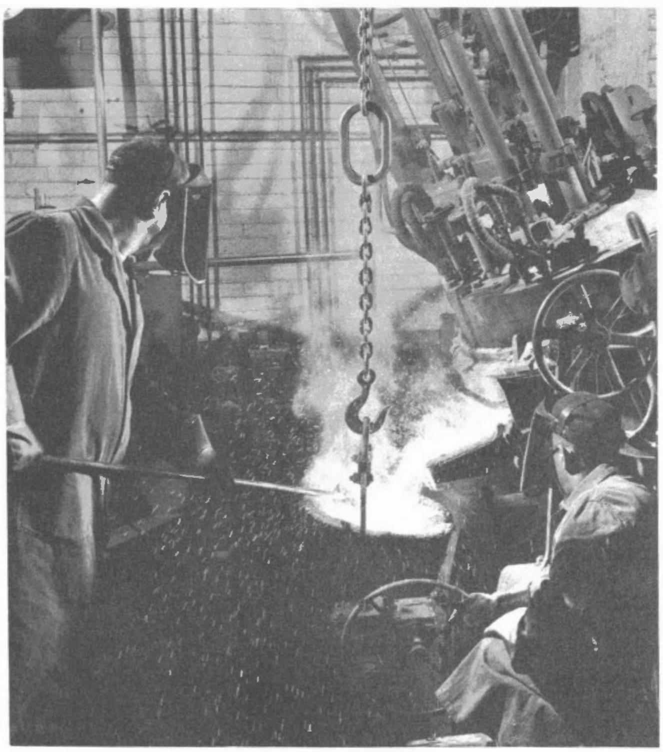
D.W.G. White measures the surface tension of liquid metal (Photo - George Hunter)

Metal Processing - Foundry

The melting to solidification sequence on a pilot-plant scale was carried out in the experimental foundry of the branch where melts up to 500 pounds in an electric arc furnace were produced. For light metals like aluminum and magnesium, a separate facility was provided.

An important project on nodular iron in the immediate post-war period was concerned with an addition of magnesium to pig iron yielding a much less brittle and higher strength product compared with standard cast iron. It did not receive wide acceptance due to the hazards associated with an introduction of a low boiling point metal into molten iron. "Nodules and nucleii in nodular iron" by J.E. Rehder (American Foundryman, vol 21, No. 2, pp 44-48, 1952) and "Nodular iron hot-forged and rolled experimentally" by J.A. Perry and J.E. Rehder (Iron Age, vol 168, No. 14, pp 229-233, 1951). However, interest in the past few years in this alloy has been revived.

As mentioned briefly in Chapter 5, the steel castings industry presented the Bureau of Mines through the Steel Castings Institute of Canada with problems on melting, gating, risering, and heat treatment of carbon and alloy steels. Furthermore, the serious problem of metal penetration of core sands was studied together with improved methods of sand conditioning. The aim of this early practical program was to improve the product and to reduce scrap and the costly cleaning phase of the foundry process. The program was carried out in cooperation with the American Foundrymen's Association (Committee on Physical Properties of Iron Foundry Moulding Materials at Elevated Temperatures). A casting developed by the division was adopted by the association as standard for determining quality of sand to resist metal penetration: "Metal penetration" by S.L. Gertsman and A.E. Murton (American Foundrymen's Society Report S1-16, 1951).



E. Cere and A. Levesque pour molten steel from 500-lb arc melting furnace (Photo - George Hunter)

There was comparable activity on the non-ferrous or light metal side by Meier and Rylski. A research project was undertaken in 1947 sponsored by the American Foundrymen's Society on centrifugal casting of alloys. Three reports were published on special foundry equipments, various sand mixtures and a preliminary investigation of metal flow as affected by pouring method and design of mould cavity (Trans Am Foundrymen's Soc, vol 57, pp 602-631, 1949). The fourth report on gating was published in 1953 (Trans Am Foundrymen's Soc, vol 61, pp 744-762). All these reports were by J.W. Meier and O.Z. Rylski. Vacuum melting furnaces were used for melting and alloying metals, particularly the reactive type.

The study of vacuum degassing and casting commenced in the late fifties. The process was aimed at removing hydrogen and other gases that caused embrittlement of the steel which is particularly harmful in higher strength steels. Comparative studies of ordinary and degasified casts were pursued during the next decade: "Vacuum degassing of steel, Part I : literature survey and preliminary work" by D.E. Parsons and W.A. Morgan (MB RR 47, 1959).

A probe for the direct determination of oxygen content in a steel melt was invented and after further development was marketed by a company: "Oxygen probes in steel foundries" by S.L. Gertsman, D.K. Faurschou and J.C. Pope (Foundry, vol 98, pp 78-82, Sept. 1970).

The unique facilities of the foundry and the skills of its personnel were used quite intensively by Canadian industry for a number of purposes in the fifties and sixties. There was a continuing demand for the production of special alloys for industry's own research projects as there were no comparable facilities available elsewhere in Canada. Furthermore, ideas related to novel processes that could enlarge metal markets were tried out in these facilities, for example the first trials on the bottom blown oxygen injection to produce steel were done in the mid-sixties in the foundry; this led to the commercial steelmaking process known in North America as Q-BOP. One company had an idea for a new method for continuous casting of steel horizontally using molten salt for the heat transfer medium as well as for the support of the metal bar being produced; although the process proved unsuccessful no other facility could be found in which to perform the experiments. At another time a special cast shape of high-purity iron was required by the Geological Survey as a part for a magnet in a piece of sophisticated equipment and this was also made in the foundry as no other source could be located.

Visitors to the laboratories may have noticed commemorative plaques in various locations of the department. Plaques were produced commemorating the Olympics as well as the circumnavigation of the Americas by the C.G.S. Hudson. Dr. Convey initiated the idea of a special retiring gift for employees with 25 years or more service in the shape of a beaver on a suitably engraved cast base. The beaver is produced by the "lost wax" process referred to in Chapter 4. A recent plaque was produced by the new vacuum moulding

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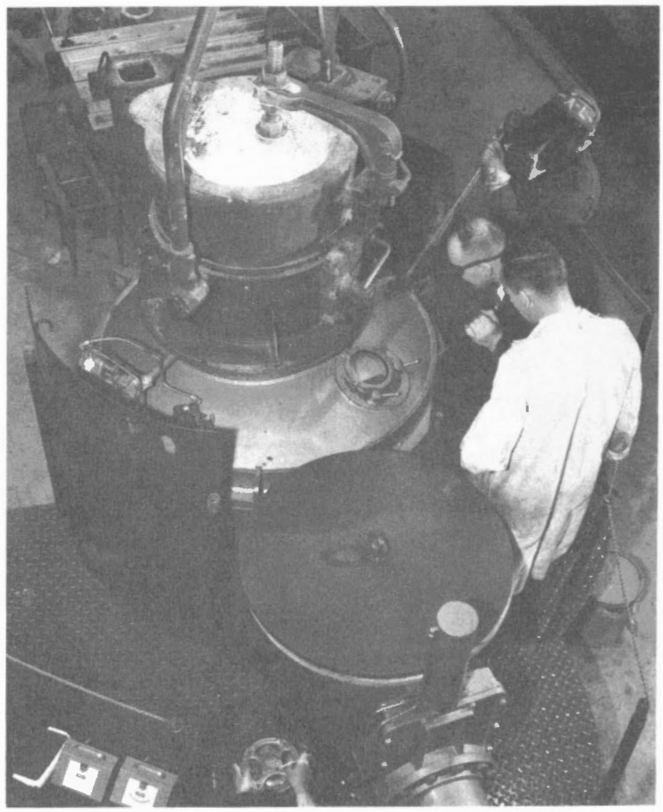

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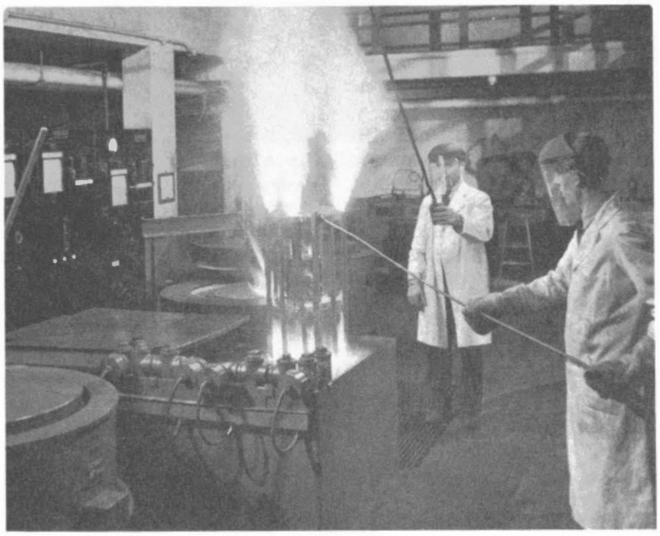
1 - J. Shields starts furnace to melt aluminum alloy while J. Buck makes additional magnesium alloy melt; 2 - R.H. Landry loads consumable electrode into vacuum-arc melting furnace (Photo - George Hunter); 3 - H.P. Guindon cleans Balzer vacuum induction melting furnace (Photo - George Hunter); 4 - A. Levesque (mask), M. Feltrin (goggles) and D.E. Parsons study vacuum stream degassing of a steel melt in PMRL experimental foundry

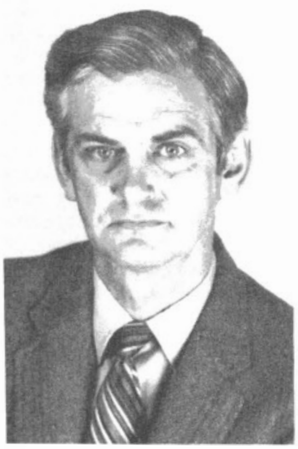
process for the entrance to the Sir William Logan Building at 580 Booth Street.

The foundry facilities were heavily taxed for the two decades into the seventies, not unlike the mineral processing side, in keeping with the expansion of the minerals and metals industries. In the seventies the position started to ease and more time could be spent on R & D related to foundry practice: "New tool to improve gating design" by S.L. Gertsman, M.C. Ashton and R.K. Buhr (Foundry, vol 99, pp 54-56, Jan. 1971), and "Evaluation of tests for control of foundry-sand systems" by A.E. Murton (Trans Am Foundrymen's Soc, vol 77, 1969).

Though space does not permit giving details, heat treatment was the responsibility of the foundry. Mike Feltrin, the foundry foreman, retired in 1965 after 36 years of service as the chief melter of the branch. For his contribution to the World War II effort he was



H. Fairfield and J. Kosowan quench drill steel rods at 1550°F in oil bath (Photo - NFB)



R. Buhr

Foundry group, 1966: front row, l-r: E. Brackenbury, A. Hébert, M. Feltrin, J. Brick, N. Devine, E. Constantineau; back row, l-r: A. Bélanger, L. Clement, A. Levesque, J. Ward, G. Swain, J. Kosowan, J. Shields, W. Cere, M. Cunningham, E. Regimbald

awarded the Order of M.B.E. by the King. He was succeeded by W.H. Cere who retired in 1971, followed by R. Lacroix. Bob Buhr operated the foundry with the technical staff and professional assistance from the ferrous and non-ferrous groups for running the melts. In 1967 Dr. M.C. Ashton (1967 - 1973) was assigned to the foundry. At this writing the professional staff of the foundry section are as follows: R.K. Buhr, who is both an army and R.C.A.F. veteran, head; C.J. Adams, Dr. K.G. Davis, A.E. Murton, Dr. E.I. Szabo.

Metal Processing - Powder Metallurgy

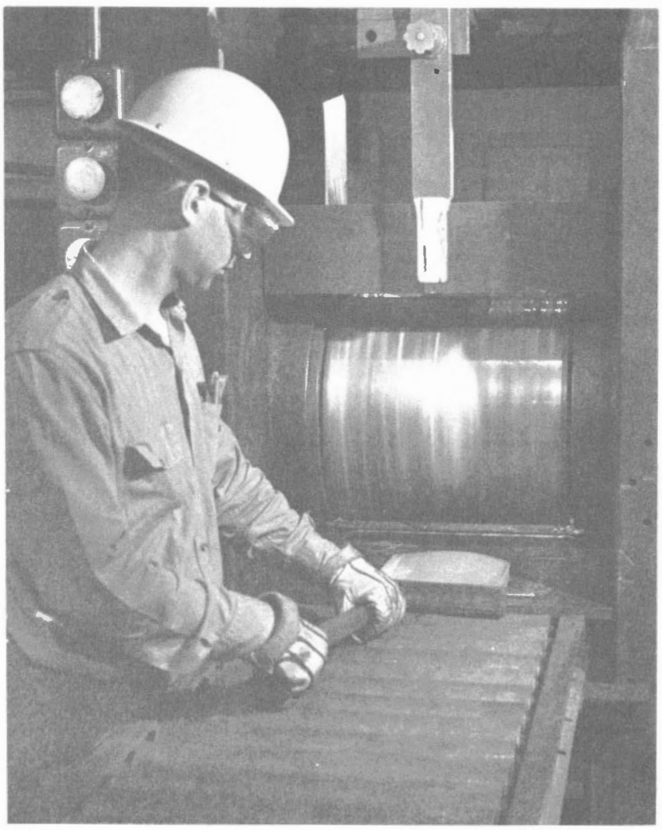
Powder metallurgy as a metal production process dates from the use of cemented carbides, mostly in the tungsten carbide cutting tools that made their appearance between the two world wars. However, towards the end of the last war powder metallurgy was regarded as an economical process to produce small components without machining. Several investigations in 1946 were carried out in the Bureau of Mines on sintering and compacting of metal powders but the start on a continuous basis was first made in the fifties at the request of Atomic Energy of Canada Limited on sintered aluminum powder. Eventually a 3.5% zirconium aluminum powder was produced. In addition, the fields of dispersion-hardened alloys and slip casting employing nickel powder were investigated. In 1962 a study was commenced on hypereutectic aluminum-silicon alloys containing 25, 35 and 45% silicon. These alloys were fabricated by hot pressing and extrusion with densities from 97 to 100%. They possessed high strength to weight ratios, low thermal expansion and good wear resistance. Their tensile strengths were 33,000, 32,000 and 40,000 psi: "Hypereutectic aluminum-silicon alloys produced by hot compaction of atomized powder" by H.M. Skelly and C.F. Dixon (MB RR 184, 1966).

In 1967 a project was started on the evaluation of nickel powders produced by the Sherritt Gordon Company for nickel coinage. This process was compared with hot and cold rolling of nickel strip which was eventually adopted for coinage use. An extensive program on iron powders was undertaken with the aim (a) to characterize Canadian-produced metal powder in a scientifically less ambiguous way, and (b) to study the factors involved in processing these powders into strong finished shapes. This project was not completed when the section was dissolved in 1974.

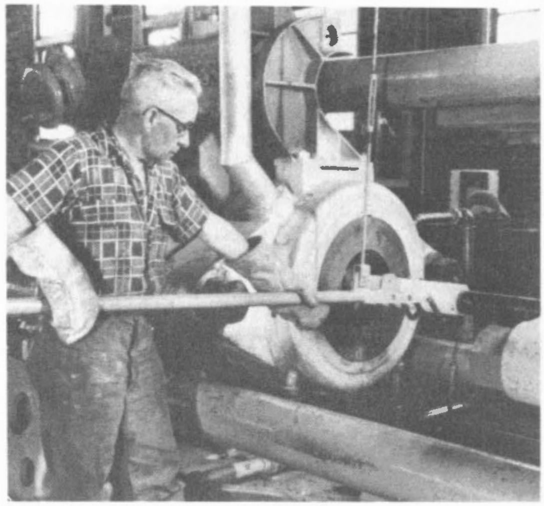
The group was led by N.S. Spence, an R.C.A.F. veteran, (1953 - 1975) who had two professionals as assistants: C.F. Dixon (1954 -) and H.M. Skelly (1961 -). Nev Spence was stationed at Chalk River from 1953 when he joined the Mines Branch and assisted Dr. Lavigne in the atomic energy project on matters pertaining to the structural metals in the experimental reactor. When he came back to Ottawa in 1956, Dr. Convey continued to consult him on the nuclear metallurgy and later on matters related to the Mint. The powder metallurgy program of which he was placed in charge was inaugurated in 1958. Nev retired in 1975 having earned the reputation of being a knowledgeable and reliable colleague.

Metal Processing - Forming

This section handled all metal semi-finished fabrication other than mould and die castings. On joining the Bureau of Mines in 1945, Perry was given the task of equipping the Metals Forming Laboratory as noted in Chapter 5. Somewhat less than three-quarters of a million dollars was expended on the equipment that included forging, rolling, extrusion and wire drawing machines. The laboratory was commissioned in 1947 and



J. Vallières hot-rolling nickel slab in 18-inch rolling mill (Photo - George Hunter)



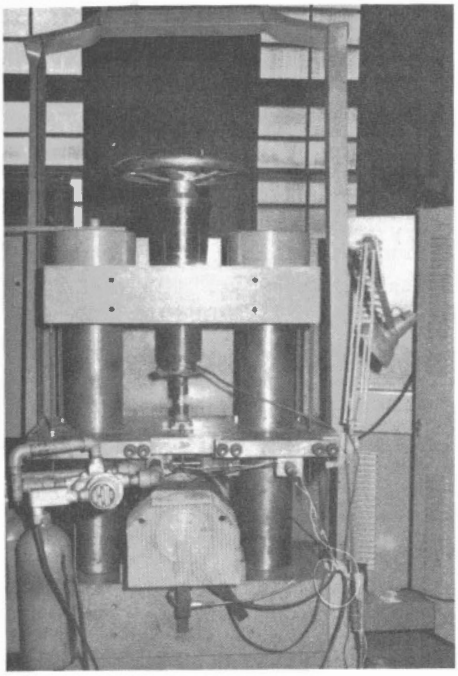
A. Baker charges aluminum billet into extrusion press to form a sheath tube for prototype uranium fuel element

for the next five years it was almost exclusively dedicated to classified work. Perry worked on the production techniques for uranium rods, protective sheathing and rod assembly using rolling, hot and cold extrusion, simultaneous extrusion and extrusion cladding. Typical of his best work was cold zinc cladding, extra thin wall extrusion of high-purity aluminum and the rolling of uranium in thin sections with special crystallographic textures for tests of dimensional stability under irradiation. This last was of pressing interest to reactor safety at the time and received international attention.

A very large proportion of ferrous and non-ferrous alloys after casting in the foundry was transferred to the Metal Forming Laboratory for one or more of the metal "deformation" processes. One of these was reported in the literature before the rush of work precluded Perry, as it did Buhr, from publishing until the rush was over in the seventies: "An ABC of cold extrusion of steel" by John Perry (Trans CIM, vol 57, pp 64-67, 1954).

A research assistant, Dr. E.W. Winkler, was appointed in 1964 to assist in the R & D work and he left in 1969 to be replaced by Dr. M.J. Stewart in 1971. A cam plastometer was designed and constructed in 1972 by the Technical Services Division from ideas given by Perry which provided means of studying the amount of force at known and constant strain rates required for various hot working operations on metals and alloys. The effects of preferred orientation on the plasticity at high strain rate of aluminum-copper alloys and Type 304 stainless steels were studied. A technique was developed whereby aluminum-copper castings, 4 in. in diameter by 10 in. long were directionally cast to give a uniform axial orientation. The feasibility of using the super-plastic phenomenon to produce zinc-aluminum-copper alloy forgings at very low forging loads was investigated (M.J. Stewart, Can Metall Quarterly, vol 12, No. 2, pp 159-169, 1973).

Perry retired in 1974 after nearly 30 years service in the Mines Branch having demonstrated his abili-



Cam plastometer in Metal Forming Laboratory

ties in the best tradition of intuitiveness possessed by good engineers.

Metal Processing - Welding

Welding is the important metal joining process. The systematic treatment of this subject in the Bureau of Mines started during World War II and was related mainly to military hardware. The scope included both experimental welding and diagnosis of failed fabrications. After the war, R & D activities were concerned with weldability of the large number of new alloys in various environments that particularly included the extreme climatic conditions in Canada and with the improvement of the welding process. In 1948, a study was made for the Department of National Defence on the substitution of rivetting by welding of structural steel work at Churchill, Manitoba. R & D continued on various aspects of this area for many years "Welding in cold climates - theory and practice" by K. Winterton (Monograph on corrosion performance in cold climates, National Association of Corrosion Engineers, Apr. 1971). Welding was associated with the atomic energy project and the titanium project, the latter was reported on by K. Winterton (MB TB 71, 1965).

Projects on ship steels, pipeline steels (in 1962), uranium carbon steels, chrome-molybdenum-vanadium heat resisting steels, maraging steels, (high-nickel martensitic steel toughened by controlled cooling and ageing), and even ultra high-strength nickel steels (Inconel) were all studied for their welding properties: "Some problems in welding Inconel 718" by J. Gordine (1967 -) (Weld Journal, vol 50, pp 4805-4845, Nov. 1971). Recently, considerable attention has been given to plant and field welding of pipelines and at this writing is one of the important projects of the branch.

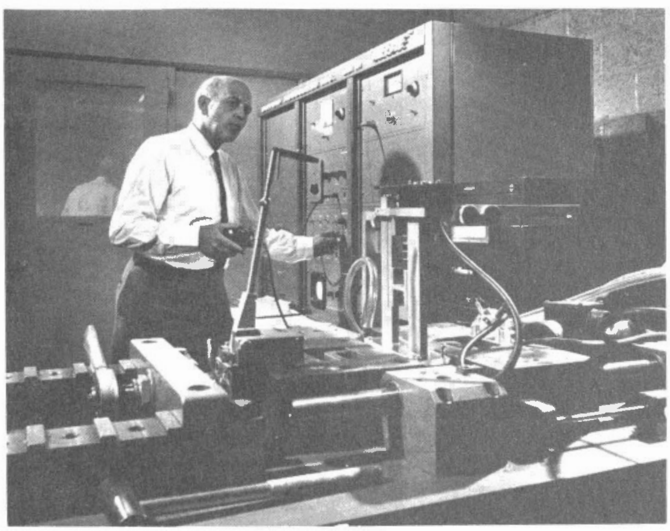
No extensive welding R & D was done on non-ferrous metals, although in 1961 leaded bronze castings were repaired by welding using a filler wire composition of 92% copper and 8% tin. An ultimate tensile strength of 40,000 psi and an elongation of 29% on a 2-in. gauge length were obtained: "Metal inert-gas welding of tin bronze castings" by M.J. Nolan (1948 - 1974) and K. Winterton (MB RR 92, 1962). Some further research was done in 1965 with a phosphor bronze (0.2% phosphorus) filler wire that indicated certain welding advantages particularly with the addition of silicon.

It should be noted that most of the welding was done by the inert-gas metal arc process. Considerable study was done on the factors influencing heat-affected zone cracking which is one of the difficulties of the welding process: "Weldability prediction from steel composition to avoid heat-affected zone cracking" by K. Winterton (Weld Journal, vol 40, Welding Research Supplement, pp 2535-2585, June 1961).

In 1964 a new gas-shielded vertical welding machine was installed in the laboratory, providing means of welding plates 3/8 in. to 1 1/2 in. thick in a single pass. These welds were tested by the explosive bulge test with the assistance of the Explosive Laboratory of the branch.

Two useful reviews were prepared by K. Winterton: "Selection of steels for the avoidance of brittle fracture" (MB IC 120, 1960); and "Brief history of welding technology" (MB IC 124, 1961).

Earlier the welding section was headed up by H.J. Nichols (1943 - 1958) who resigned in 1958 and was replaced by Dr. K. Winterton. W.P. Campbell and V.L. Caron had joined in 1947 and 1948 respectively. In 1965 the principal staff was: Head - Dr. K. Winterton (1958 -), W.P. Campbell (1947 -), L.G. Girard (1961 - 1966), M.J. Nolan (1948 - 1974) At this writing the welding section is composed of: Head - Dr. K. Winterton, W.P. Campbell, Dr. Z. Paley (1966 -), and Dr. J. Gordine (1967 -).



K. Winterton operates "Gleeble" apparatus to imitate controlled thermal cycle in a welding joint (Photo - George Hunter)

Metal Application - Service Evaluation

A set of activities that initially were grouped under Mechanical Metallurgy represented essentially R & D on the behaviour of metal products in service.

A large proportion of the work under this heading was concerned with problems encountered by users of metal fabrications as mentioned early in this chapter. These investigations would embrace the questions of design and suitability of materials. Fabrications investigated included: circular blade saws, plowshares, snowplows, fourdrinier wire screens used in the manufacture of paper and ultra high strength steels for hydrofoil fins, etc.

There was also development of new applications, as for example in 1955 the design and production of an 81-mm mortar base plate was completed for the Department of National Defence. Two types of base plate were produced, one of hammer forged aluminum alloy and the other of cast magnesium alloy. The aluminum alloy plate was about 50% lighter in weight than a standard steel plate and about half as expensive to produce; the magnesium plate was also successful and it was about 60% lighter than the steel plate. This work was done by Wlodek and his associates in the then Mechanical Metallurgy Section.

Two development projects are worthy of note because of the time spent on them. The first was directed to the improvement of mining drills. In 1947, shot peening, a method of increasing fatigue strength of metal components, was tried on drill rods with good effect. Four different laboratory drilling machines and testing methods were developed for use under simulated service conditions. The method of cold working critical areas of mining drill rods by spiral rolling suggested by Wlodek and later patented gave promising laboratory and field tests: "Mechanical-metallurgical improvements in drill steel" by T.W. Wlodek (Trans CIM, vol 58, pp 52-58, 1955). Push-on drill bits of improved fatigue resistance were designed and tested experimentally and the project ended in 1963.

The Department of Transport had used mild steel buoy chains. These were replaced on the recommendation of the Alloy Steel Chain Cable Advisory Committee in 1963 with a low-alloy chain permitting a reduction of link size from 1 1/4 in. to 1 1/2 in. diameter to 1 in. diameter. The division suggested a copper-nickel-steel from which a 5/8 in. diameter chain was made. In tensile tests the high-strength steel chain yielded at 70,000 psi whereas the low-alloy chain yielded at 50,000 psi. A 10-ton heat of this steel was prepared in the foundry and was evaluated with particular reference to weldability of the steel. A chain 270 ft long was produced for tests in the Bay of Fundy; however, a hand-welded link failed and the chain was lost. A second chain was fabricated and placed in two locations in Nova Scotia in shorter lengths. No results were reported as presumably they were superseded by the results of a comparative test at the Inco laboratory in North Carolina between chains made from Stelcoloy "G" and the copper-nickel-steel made in the Mines Branch. The tests lasted for over two years in three marine locations: quiet water, splash water locations, and buried in mud. Corrosion of both alloys was noted but not that of the weld in continuous quiet water. In splash water conditions and mud there was no corrosion. As the copper-nickel-steel was not commercially available and the results were so close, no further action was taken and the project was discontinued in 1968.

Metal Application - Engineering Physics

This activity was originally the Mechanical Testing Section and was formed as a separate group in 1953. Thurston became head and was joined by J.G. Buchanan (1950 - 1957) and F.W. Marsh (1950 -). In broad terms, Engineering Physics represented the applied side of metal physics and there was some overlap between the two groups. The aim of Thurston's group was the study of the behaviour of metal components and assemblies under stress environment encountered in service. Subjects related to engineering physics were: metal fatigue, which at that time was the responsibility of T.W. Wlodek with W.H. Bott and J. Harbec as his associates, and rheology and fracture which was also a separate sub-section under H.H. Bleakney with his associate F. Weinberg.

Experimental stress analysis was considerably advanced during the war by the strain gauge techniques used particularly in aircraft technology. There was a joint program between the Mines Branch and the NRC Structures Laboratory in this area. Thurston's group was very helpful in developing strain gauge and other measuring methods in detecting stress changes in rock environments during the early research studies of the mining group in the Fuels Division to be described later.

Though several methods were available for measuring depths of cracks in metallic components, they all had drawbacks. A direct current four-electrode conduction method was developed in 1955: "The measurement of crack depths by direct-current conduction method" by J.G. Buchanan and R.C.A. Thurston (Non-destructive Testing, vol 19, pp 36-39,43,44, Sept. - Oct. 1956). An improved crack depth instrument was designed in the sixties. A companion study resulted in the development of an instrument for measurement for both crack depth and wall thickness: "The measurement of wall thickness of metal from one side only, by the direct current method" by J.G. Buchanan, F.W. Marsh and R.C.A. Thurston (Non-destructive Testing, vol 16, pp 31-35, Jan. - Feb. 1958).

Thurston reviewed the mechanism of metal fatigue at the 1957 CIM annual conference (Trans CIM, vol 60, 1957) and fatigue cracks and their effect on reduced static strength of metal in a Mines Branch publication: "Propagating and non-propagating fatigue cracks in metals" by R.C.A. Thurston (MB IC 115, 1960).

Wlodek, too, discussed metal fatigue, in this case related to mine drills. Thus he reviewed in 1958 the relative merits of shot peening, induction surface hardening, spiral rolling and the combination of these methods as a means of increasing the fatigue life of mine drills in the report "The effect of different surface treatments on the fatigue strength of drill steel" by T.W. Wlodek, (CIM Bull, pp 89-101, Feb. 1958, reprinted MB RR 37, 1958).

Bleakney proposed on the basis of experiments with low-carbon and alloy steels to redefine the criteria of deformation of metals prior to failure. He accepted "reduction in area" but questioned "elongation". The results of his research was the development of a device in which an electric current was broken when a particular value of strain was reached, indicating the point of separation between general and localized deformation: "Criteria of ductility in uniaxial tension" by H.H. Bleakney (Trans CIM, vol 65, pp 73-79, 1962, also MB RR 75, 1961).

While working with Bleakney, Weinberg studied grain boundary phenomena during shear, melting and creep. Tricrystals of aluminum subjected to a dead load equivalent of 350 to 500 grams per square centimetre shear stress were observed for grain boundary deformation and creep. Furthermore, boundary shear occurred together with grain boundary migration: "Grain boundary shear in aluminum" by F. Weinberg (Acta Metall, vol 6, Nov. 1954).

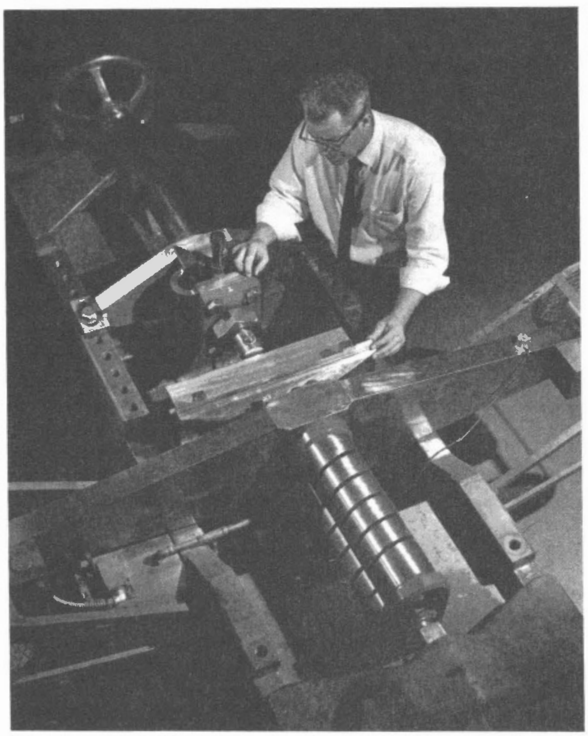
Bicrystals of aluminum and tin were examined for melting characteristics of grain boundaries. Large angle grain boundaries melted prior to or at the melting of the whole specimen depending on the applied stress. Specimens containing small-angle grain boundaries behaved as single crystals: "Grain boundary melting" by F. Weinberg and E. Teghtsoonian (Research in Progress Section of the AIME, New York, Feb. 1956).

Experiments to determine fracture characteristics of bi- or tricrystals of superpure aluminum with various configurations of controlled boundary resulting in different stress distributions were carried out. The fractures did not accord with expectations of opinion expressed in the literature. "Behaviour of grain boundaries during creep" by F. Weinberg (Research in Progress Section of the AIME New York, Feb. 1956).

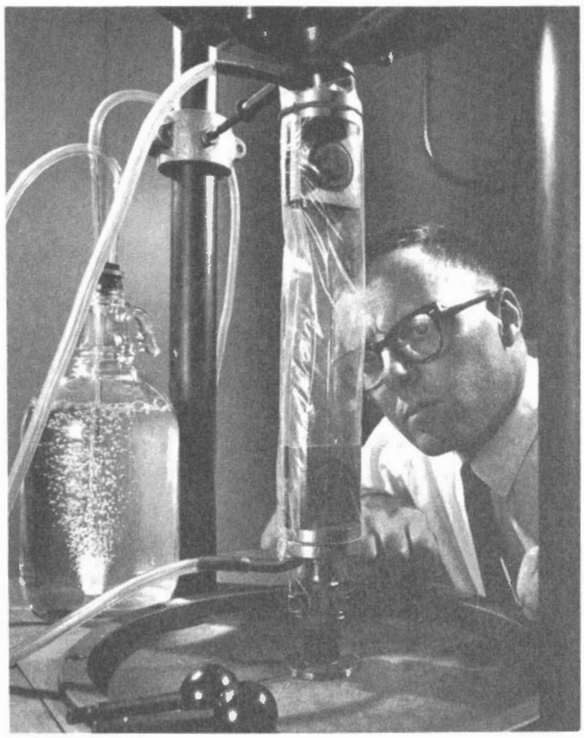
Weinberg became head of the Metal Physics Section in 1961. In the same year, Wlodek was transferred to the director's office on special projects and Bleakney resigned in 1965. Thurston continued as head of Engineering Physics until 1971, when he assumed the position of research coordinator in the office of the chief of the division.

The Engineering Physics Section continued into the seventies to devote considerable effort to metal fatigue and failure phenomena and the solution of problems in this area. The general subject of fatigue properties was reviewed in "Fatigue properties of materials" by E.G. Eeles (1957 - 1970) and R.C.A. Thurston (MB TB 97, 1968). Fatigue cracking was a related subject of study in "Fatigue crack propagating rate in metals" by S. Nunomura and R.C.A. Thurston (Proc Internat Conf on the Strength of Metals and Alloys, pp 1015-1020, Tokyo 1967, pub 1968). Research was undertaken on the environmental influences relating to fatigue properties of light metals: "Atmospheric and surface effects in the fatigue of aluminum alloys" by E.G. Eeles and R.C.A. Thurston (Journal Am Inst Aeronautics and Astronautics, vol 8, 1970).

A major program under the auspices of the Organization for European and Economic Cooperation described as "stress testing and spectrum loading" was started in 1958 and continued to 1970 with participation of twelve countries including Canada. The program involved the pre-stressing of specimens in direct stress or rotating bending machines at three stress levels for various cycle ratios. Selected metals were chromium-molybdenum steels and an aluminum alloy. The steel program was completed in 1965. It was concluded



J.A. Ellis carries out fatigue tests on metal specimen (Photo - George Hunter)



E.G. Eeles measures the effect of humidity on fatigue of an aluminum alloy (Photo - George Hunter) with some reservations that double damage treatments at low stresses just above fatigue limits and intermediate stresses tended to increase the residual life at higher stresses provided that the number of cycles at intermediate stresses were small. The aluminum program was changed from the original and some countries dropped out of the program which was discontinued in 1970 as far as the Physical Metallurgy Division was concerned. An OECD report was published on the steel program.

At this writing, Engineering Physics has been combined with Refractory Metals and the staff is composed of: head, Dr. A.J. Williams, D.C. Briggs (1958 -), Dr. D.M. Fegredo (1962 -), Dr. M.J. Godden (1968 -), Dr. F.S. Jeglic (1972 -), F.W. Marsh (1950 -), L.P. Trudeau (1966 -), and Dr. O. Vosikovsky (1971 -).

Metal Application - Testing Laboratories

The Strength of Materials Laboratory known as the Mechanical Testing Laboratory, considerably enlarged from the early days of Dr. Haanel, was equipped to carry out comprehensive tests of physical properties such as tensile, compressive and shear strength, impact strength, hardness, etc. on test pieces prepared by the Technical Services Division. For example, in 1961, 18,500 specimens from 100 different varieties of metals were prepared. Norman Brown retired in 1960 and P.J. Todkill became head. J. Harbec joined the laboratory in 1956 and these two officers are still in charge.

The Non-destructive Testing Laboratory came into existence in 1950 when an industrial X-ray laboratory was formed particularly to examine castings and welds. W.E. Havercroft was transferred from the Radioactivity Division to head up the Non-destructive Testing Laboratory which included not only X-ray but facilities for ultrasonics. At the request of the Department of National Defence the training was undertaken of RCAF personnel in radiography as applied to the inspection of aircraft components, particularly castings. In 1960, the Canadian Government Specifications Board Committee on Industrial Radiography requested the Mines Branch to undertake and supervise the examination and certification of industrial radiographers. The laboratory received international recognition and participated in continuous exchange with laboratories in other parts of the world.

G. Smelsky

As gases have a deleterious effect on properties of metals, analytical facilities for determining oxygen, nitrogen and hydrogen were developed in the early fifties in Dr. Cunningham's Metal Physics group. Dr. Yao was involved in the early work and was succeeded by G. Smelsky (1952 -) in the middle fifties. The laboratory was administered from the sixties by N.S. Spence.

The foregoing narrative has attempted to deal in a summary manner with the major research program areas of the Mines Branch using an organizational sequence that embraces R & D of the metal substance through pilot plant metallurgical processes to behaviour in the utilization of metal products. Projects have been selected as illustrative of the scope of the R & D work. Space does not allow of further description, particularly of the sophisticated laboratory instruments and plant equipment that have been developed over the years. A two-day seminar on research-in-progress was held on June 12-13, 1967 in honour of the Canadian Centennial.

Before closing this section, a tribute is paid to Sol Gertsman for the courage he demonstrated in facing failing health in the latter part of this narrative.

Physical Metallurgy Division. Recipients of 25-year service pins

l - r: S.L. Gertsman, R.V. Narroway, D.F. Dowling, W.H. Bott, W.E. Havercroft

INDUSTRIAL MINERALS

To avoid confusion related to organizational changes during the 1946 to 1950 period it may be useful to return to the dissolution of the former Industrial Minerals Division in 1946. In 1945, Fréchette, its chief, retired and Parsons was requested by Timm to take over the responsibility for beneficiation of industrial minerals.

However, in 1946 Parsons became chief of the Bureau of Mines and Monture became chief of the Mineral Resources Division, restored to its former appellation from the Economics Division with enlarged responsibilities for evaluation and beneficiation of industrial minerals as well as for the evaluation of industrial waters and road materials. Ceramics was transferred to the Mineral Dressing and Metallurgy Division (renamed in 1949 Mineral Dressing and Process Metallurgy when the Physical Metallurgy Division was formed in 1949), successor to the Metallic Minerals Division, with Traill appointed as chief and remaining in this division until 1950.

During this five-year interregnum, despite the priority given to uranium, considerable contributions were made in the evaluation of industrial minerals and waters and in the beneficiation of minerals used in construction materials and of ceramics. Technical assistance to producers of the various non-metallic minerals, as in the past, was continued.

Reconstitution of the Industrial Minerals Division following formation of the Department of Mines and Technical Surveys was probably decided by two factors - rapid increases in demand and imports of industrial minerals (imports then exceeded domestic production) - both as a group and individually. Much of the industry was in the hands of small Canadian entrepreneurs who looked for technical assistance from their government R & D institutions. The departmental statement for fiscal year 1950-51 read in part "...and the need for more extensive research, particularly the utilization of these minerals..." emphasizing the application role practised by the Mines Branch from the start of its existence.

The division was reformed in June 1950 with M.F. Goudge as chief. Its objectives were the same as before with greater emphasis on the need to improve the purity for performance quality of various minerals used in chemical and other manufacturing industries as well as for construction purposes. Furthermore, despite almost continuous growth in demand for most commodities, it was recognized that industrial minerals in Canada must compete with those from the United States and from even further afield. In many instances that aim was attained in large measure. The value of production of industrial minerals increased somewhat faster in relative terms than metallics. Using the datum of 1950, the value of industrial mineral production was $227 million and that of metallics $617 million. By 1965, before the advent of accelerated inflation, the values of their respective outputs were $761 million and $1,908 million respectively. Generally speaking, a large proportion of Canadian industrial minerals had to face keener price competition than metallics and mostly from the U.S.A.

M.F. Goudge (Photo - NFB)

In 1950 the division was organized into four groups: Non-Metallic Minerals, Ceramics, Industrial Waters and Construction Materials (Chapter 5). Later a Milling Section was designated (119).

In addition to non-metallic minerals, resource potential surveys were made of the minerals of alloying metals like manganese and chromium, light metals like magnesium and lithium, and less common metals such as niobium, tantalum and beryllium. A special industrial minerals survey was undertaken in Newfoundland by the branch commencing in the early period before the division was formed. However, completion of the survey and publication of the report were in the new period (120).

Industrial Minerals organizationally lasted as a separate division from 1950 to 1959, almost the same length of time as the first division from 1936 to 1946. In 1959 it became part of the new Mineral Processing Division. It is significant that the professional recognition of the technical and market differences between metallics and non-metallics by the CIM and the AIME in the 1930's (Chapter 4) justified the separate existence of Industrial Minerals as an integral section in both institutes to this day.

Resource Evaluation

The resource specialists were assigned or elected to join either the Mineral Resources Division or the Mineral Dressing and Metallurgy Division in 1946 when the old Industrial Minerals Division was dissolved, and again when the Industrial Minerals Division was reconstituted in 1950. The inclination of the officer concerned towards participation in laboratory activity as distinct from field work and office activity was probably the principal factor that decided his assignment.

In industrial minerals the integrated approach of acquiring an intimate knowledge of the resource from

Industrial Minerals Division staff, 1951:

Front row, left to right: Vera Becker, Phyllis Nield, Lucy Mangione, (Mrs. Norm Champ), Teresa Bélanger, Eileen James (Prudham), Madeleine Kane, Cecile Mulligan (née Leclair), Betty Townsend (née Moffett), Rena Mills, Kay Fraser, Marjorie Rice, Ghislaine Lecours;

Second row: Vic Haw, Graham Brown, Monty Goudge, V.L. Eardley-Wilmot, Jim Nevin, Art MacPherson, Madeleine Saulter, Geoff Bruce, visitor, Leo Vallée, Jim Thomas, Joe Bond, Lou Beer, J.G. Phillips;

Third row: George F. Carr, Bob Simpson, Harry Lauder, Norm Champ, Steve Romanchuk;

Back row: Gordon Matthews, Darcy Charette, Ian Wright, Ralph Shonk, Gerry Miller, Hector Mercier

its occurrence through to product utilization was more vital than in the case of standard metals, as markets and narrow profit margins made them very sensitive to price fluctuations and to differences in purity, dictating whether they could be worked economically.

During the interregnum from 1946 to 1950, several new staff members were recruited for industrial minerals, and these were assigned to the Mineral Resources Division: H.M. Woodrooffe (1946 - 1974), A.R. MacPherson (1946 - 1951) both with army war service, C.G. Bruce (1948 - 1955), G.F. Carr (1948 - 1956), T.H. Janes (1948 - 1957) and V.A. Haw (1950 -), the latter with aircrew war service.

In the new Industrial Minerals Division, V.L. Eardley-Wilmot was appointed senior engineer of the Non-Metallic Minerals Section, having transferred from the Mineral Resources Division. He retired in 1951 after 30 years of service in the Mines Branch, and he was succeeded by Woodrooffe, who in 1959 became head of the Industrial Minerals Group in the Mineral Processing Division, becoming chief of that division in 1965.

The Non-Metallic Minerals Section was divided into two sub-sections: the first retaining its original designation and the second named Industrial Minerals Milling when R.A. Wyman joined the branch in 1954. He became section head, a position he holds at this writing.

Non-Metallic Minerals Section

The advantage of such a group closely allied to the processing group was obvious, and in fact some of the members participated in the work of the Milling Section or undertook their own laboratory investigations in addition to their field work. In 1957 the composition of this group was: H.M. Woodrooffe, head; R.K. Collings (1952 -), J.E. Reeves (1956 - 1969), E.G. DeWolf (1956 - 1957), C.M. Bartley (1957 - 1974) and J.S. Ross (1957 - 1965).

One of the principal responsibilities of this section was the preparation of reviews relating to industrial minerals for the departmental publication, "Canadian Mineral Industry" (Canadian Mineral Yearbook from 1962). Ceramics and most of the construction materials were reported on by officers of those sections. The following list identifies the commodities and specialists concerned for the year 1964:

H.M. Woodrooffe	- Asbestos
R.K. Collings	- Silica, salt, gypsum and anhydrite
J.E. Reeves	- Graphite, lithium minerals, mica, nepheline syenite, phosphate, talc and soapstone, pyrophyllite
C.M. Bartley	- Potash, sodium sulphate, sulphur and fluorspar
J.S. Ross	- Arsenic trioxide, barite, bentonite, cement, diatomite, lime, limestone, magnesite and brucite, mineral pigments and fillers
J.G. Brady	- Clay and clay products
F.E. Hanes	- Sand, gravel and crushed stone, roofing granules, building and ornamental stone
H.S. Wilson	- Lightweight aggregates

The Mineral Resources Division, after 1950, retained responsibility for reporting on metal commodities and hydrocarbons except that coal was the Fuels Division's responsibility. Until separation of the Mineral Resources Division from the Mines Branch in 1957 the Industrial Minerals Division had the responsibility of reporting on light and less common metal ores.

There was no change in policy on the division of responsibilities until the formation of the Department of Energy, Mines and Resources in 1966. Mineral Resources became a branch, and the reviews were gradually taken over by it. In 1970, only two reviews - clays and lighweight aggregates - by Brady and Wilson respectively, were prepared in the Mines Branch for the last time. This change was regrettable as it is undeniable that considerable knowledge of and expertise in a commodity are acquired by working intimately on and solving technical problems of that particular resource.

Silica

In the period from 1946 to 1950, one of the preoccupations with industrial minerals was the large importation of high-quality silica containing less than 0.3% of ferric oxide for the manufacture of glass, sodium silicate, and silicon carbide, and even for use in the foundry industry; this led in 1947 to the re-examination of deposits and beneficiation studies. A review of the position of silica in Canada was published: "Silica in Canada" by A.R. MacPherson (Memorandum Series 104, 1949).

Silica in Canada was and still is obtained mostly from sandstones and quartzites. Two processes were developed during 1950 and 1951, the first consisted of grinding and roasting followed by acid leaching and washing, 20 tons from Gananoque, Ontario being thus treated. The second process was a dry method which entailed grinding, air classification and elimination of iron minerals by magnetic separation. Some 100 tons of Nepean sandstone near Bells Corners, Ontario was thus treated, and it was said at the time that the product could meet industry specifications.

When Collings joined the Mines Branch in 1952, high-quality silica was one of his main projects. He published a revised version of MacPherson's report (Memorandum Series 134, 1956). Research on high-quality silica production was continued for several years, finally demonstrating that attrition scrubbing at high pulp densities and pyrite removal by flotation gave good results, and this method was adopted by operating plants. The deposits that yielded glass-quality sand were derived from the Potsdam sandstone of western Quebec and eastern Ontario and particularly those of St. Canut and St. Donat, Quebec: "Silica sand - Canadian sources of interest to the domestic glass industry" by R.K. Collings (Journal of the Can Ceram Soc, vol 32, pp 39-45, 1963, reprinted as MB TB 69, 1965).

Space does not permit of detailed descriptions of the variety of industrial minerals dealt with by this section as well as by the Industrial Minerals Milling Section. From 1952 to 1959, samples received and tested by the Industrial Minerals Division as well as by the Mineral Dressing and Process Metallurgy Division for metallic ores were tabulated and included in the annual reports of the department. The peak year in the 1950-59 period was 1958, when 684 samples were received or collected. Of these, 393 were related to construction materials and ceramics, the remainder represented 27 varieties of industrial minerals from all provinces except P.E.I. and the Yukon. They were studied in varying degrees of detail:

andalusite	- Nova Scotia 3
apatite	- Ontario 2, Quebec 4
asbestos	- Yukon 1, British Columbia 1, Ontario 3, Quebec 12
barite	- British Columbia 1, Quebec 1, New Brunswick 2
bentonite	- British Columbia 17
beryl	- Manitoba 4, Quebec 2
diatomite	- British Columbia 3, Ontario 1, Quebec 1
dolomite	- Ontario 1, Quebec 2
feldspar	- Ontario 5, Quebec 1
fluorspar	- British Columbia 1
garnet	- British Columbia 1, Ontario 13
graphite	- Ontario 6, Quebec 5
gypsum	- Ontario 1, Nova Scotia 1
kyanite	- Ontario 1
limestone	- Ontario 5, Quebec 1
magnesia	- Quebec 3
magnesite	- British Columbia 5, Quebec 4
marl	- Ontario 5
mica	- British Columbia 1, Ontario 3, Quebec 2
nepheline syenite	- Ontario 11
phosphate	- Quebec 11
potash	- Saskatchewan 1
pyrophyllite	- British Columbia 3, Newfoundland 20
quartz crystals	- Quebec 5
silica	- British Columbia 5, Manitoba 2, Ontario 64, Quebec 12, Nova Scotia 5
talc	- British Columbia 7, Ontario 16, Quebec 13
zeolites	- Nova Scotia 1

Complete milling tests were conducted on feldspar, quartz, graphite, apatite and marl, and in each case a concentrating method was developed by the Milling Section. In addition, flotation studies were continued on beryl and zeolites.

In 1958 the total inquiries, accompanied in some cases by samples additional to the above, numbered some

1750, a large proportion of which were answered by the section.

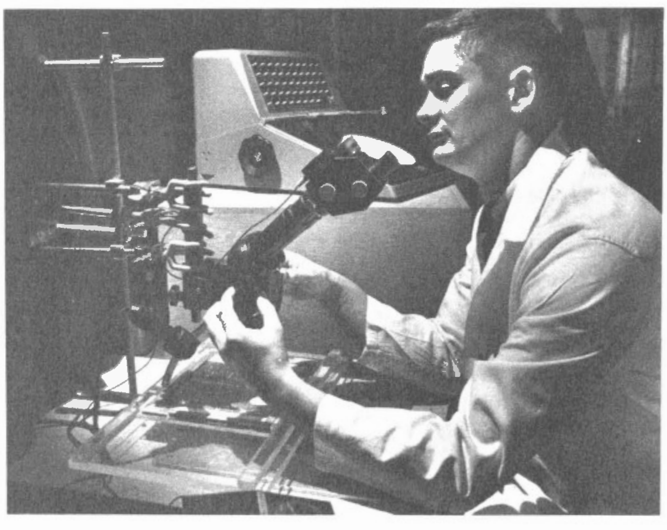
In the sixties, following the peak of the fifties, the average number of industrial mineral samples received that required treatment, tests, or investigations of some kind levelled off at 150-200 per annum, thus providing greater opportunity for more in-house research.

The three leading minerals of international significance that at this writing and for nearly the whole of the prior decade accounted for over three quarters of the value of all industrial minerals produced, excepting structural minerals, are: asbestos, potash and sulphur.

Asbestos

It will be recalled that the Mines Branch was associated with the development of the asbestos industry from Dr. Haanel's time. In the post-World War II period there was a spurt of prospecting for the mineral, resulting in a number of new deposits being discovered. Samples numbering from a few up to 26 were sent to the Mines Branch for evaluation in 1956-57. The largest numbers were usually from Quebec, but some of the new finds were in the Yukon, British Columbia, Ontario and Newfoundland, resulting in new mines and extensions in the sixties and adding to Canadian production.

A comprehensive study was undertaken in 1957 to correlate the physical and chemical properties of asbestos fibres with its performance in industry, and this research was carried on to 1969. A.A. Winer joined the group in 1962 and devoted considerable time to this problem which was related to the orientation and dispersion of asbestos fibre, alignment of fibres, as well as to the length, diameter and surface area of the fibres. Optical examination at a magnification of up to 170,000 and high-speed photography were used to photograph dispersed fibre. Eventually a method for determining the length to diameter relationship of fibre was developed, consisting of photographing a fibre in liquid suspension, the length being obtained by a semi automatic sizer and the diameter by an image-splitting device. The surface area determination was achieved by gas adsorption using a low-cost chromatograph: "Investigation of the surface of chrysotile asbestos fibre" by A.A. Winer and L.L. Sirois (Conference of Metallurgists, Queen's University, 1967, MB Reprint RS 49, 1967).



F. Barton measures length distribution of asbestos fibre (Photo - George Hunter)

Impurities associated with asbestos fibre and with the host rock, particularly of magnetite were studied; field instruments were developed at the Mines Branch and the Geological Survey for measuring lowfield and saturated magnetic susceptibility: "Lowfield magnetic susceptibility of asbestos" by A.A. Winer, D. Karpoff (1966 - 1970) and D.T.A. Simonds (MB RR 232, 1970) and "Magnetic properties of asbestos, with special reference to the determination of absolute magnetite contents" by E.J. Schwartz and A.A. Winer (CIM Bull, pp 55-59, Dec. 1971).

A more rapid method for measuring moisture in asbestos fibre was devised which has since been used by producers in Canada and abroad: "Azeotropic distillation for the measurement of free water in chrysotile asbestos" by A.A. Winer and P. Prud'homme (Investigation Report 71-4, Mineral Processing Division, 1972). The term azeotropic refers to a mixture having a constant boiling point.

Research on the orientation of fibres gave rise to the practical discovery that by using an electrical field, asbestos fibres could be oriented in liquids and plastics. This property has been used to strengthen plastics. Canadian, British and U.S.A. patents were obtained.

In dealing with this difficult particulate field Winer applied his experience to the broader field of particles: "Practical problems in particle size and surface area measurements" by A.A. Winer and I.F. Wright (Journal of Can Ceram Soc, vol 35, 1966, Reprint MB RS 39, 1967). Winer also worked with the metallic minerals research group in relation to surface electrical phenomena (CIM Bull, pp 410-414, Apr. 1969).

Chrysotile asbestos has been the principal industrial mineral export of Canada from the start of its production some 100 years ago. In 1949 the production was nearly 575,000 short tons valued at nearly $40 million. This was lower than the normal productive capacity of about 700,000 short tons due to a prolonged strike. Exports in 1949 amounted to 534,000 short tons of milled, crude and waste products together with manufactured goods, the latter valued at $365,000; imports of manufactures were valued at $2.6 million. In that year Canada accounted for about 70% of the world's production of asbestos.

In 1969 the Canadian production amounted to 1.6 million tons valued at $195 million whereas exports were 1.56 million tons valued at about $216 million. Exports of manufactured products were valued at $4 million and imports were $13 million including unmanufactured asbestos at $1.4 million.

Owing to increased world production, particularly in the U.S.S.R. and South Africa, Canada's share of the world's output had slipped to about 30%, although accounting for about 70% of the world's exports of fibre. In 1974, asbestos production had increased to 1.8 million short tons valued at $302 million.

Potash

The first commercial production of potash in Canada was started in 1962 by International Minerals and Chemical Corporation (Canada) Limited (IMC) at Esterhazy, Saskatchewan, with an annual production capacity of 2,100,000 short tons of potassium chloride or 1,280,000 tons K_2O equivalent. By 1969, seven other companies had all commenced new mines. These with IMC's second unit developed a total annual capacity of 12,480,000 short tons. This was a remarkable achievement, reminiscent of the uranium mining success story of the fifties, bearing in mind these were underground mines with shafts down to 3500 feet in depth that required ground freezing and steel ring lining or tubbing when traversing the Blairmore formation - techniques used in many of the deep coal mine shafts in Europe. Late in 1970 another underground producer, Hudson Bay Mining and Smelting Company Limited, located in the Regina district, went on stream.

One of the mines, Kalium Chemicals Ltd., in the Regina district was a solution mine and it should perhaps be noted that some research was done by the Industrial Minerals Division on solution mining in the fifties.

Field surveys of Saskatchewan potash were made by the Bureau of Mines commencing in 1946 from wells drilled for oil, particularly in the intensive period of mine development in the mid-fifties, and samples were analyzed by the division.

Large Canadian production capacity contributed to the temporary over-supply of potash in the world markets. A quota system and price stabilization were introduced by the Saskatchewan government. In 1970 the average allowable quota was 45 1/2% of actual capacity. The gross production of potassium chloride that year was 5.7 million short tons or 3.5 million tons K_2O equivalent with shipments being 5.6 million tons valued at $116.4 million. Exports of potassium chloride in 1970 were nearly 5.5 million short tons valued at $121.3 million. Despite this there was 71,000 short tons of potash imported entirely from the U.S.A. valued at $2.2 million. In addition 9000 tons of potash chemicals valued at $1.9 million was imported.

By 1974 production had increased to 6 million short tons K_2O equivalent, with exports of about 6.4 million short tons K_2O equivalent. The price, which in 1969 was depressed at about $20 per short ton K_2O equivalent compared with $37.50 in 1965, was increased by the government of Saskatchewan to $33.75 per short ton in 1970. In 1974 the price was about $70 per ton K_2O equivalent, still much below the price in Europe. The largest producer in the world was the U.S.S.R.

At this writing there is every indiction that New Brunswick may become a second producing province in Canada as exploratory work has been promising.

Sulphur

In 1949, Canada produced a total of 262,000 short tons of sulphur equivalent valued at $2 million mostly for the manufacture of sulphuric acid. Of this quantity about 45% was derived from byproduct pyrite in mining metallic sulphides and 55% originated from smelter gases. Nearly 281,000 short tons valued at $5.2 million was imported in all forms to meet the total requirement of nearly a half million tons of sulphur per annum, the largest Canadian consumer being the pulp and paper industry. In this period studies and research were undertaken in the branch on the recovery of sulphur from sulphides and flue gases.

In 1951, the first plant was built in Alberta for recovering elemental sulphur from hydrogen sulphide contained in natural or sour gas. By the end of 1970 there were 30 such plants in Alberta and one each in Saskatchewan and British Columbia, with a combined daily capacity of more than 17,900 tons. In the same year Canadian production amounted to nearly 4.4 million tons valued at about $38 million of which sour gas provided 3.5 million including 53,000 short tons from the Great Canadian Oil Sands plant, the first commercial oil sands operation in Canada.

Thus the Canadian position was transformed from a serious deficiency to becoming the second largest producer in the world after U.S.A., and the largest exporter with 35% of the world market. Exports in 1970 were nearly 3 million short tons valued at about $43 million, with an additional $1.2 million in export of pyrite for sulphur production mostly to U.S.A. Imports from that country amounted to 53,000 tons valued at nearly $1.5 million. In 1970, Canadian consumption was nearly 1.6 million tons, of which 50% was derived from sulphide ores and smelter gases and the remainder from sour gas. In effect, the Canadian production of sulphur is largely involuntary, being a byproduct.

Other Minerals

Bartley was the commodity officer responsible for potash and sulphur and, as mentioned earlier, for several other minerals. He published a review of the Canadian fluorspar industry as it existed at the end of the 50's (121). The occurrence of fluorspar in Canada is widespread but the quality is not high; it is also commonly associated with other minerals. Many efforts have been made from time to time to recover this mineral, particularly during the two world wars. The Mines Branch then played a central role in devising the optimum beneficiation of the various ores as it did during the first war period. Following Newfoundland's entry into the Canadian federation, the sole continuous supply was derived from the low-grade deposits on the Burin Peninsula of Newfoundland. By 1970 production reached a record of 158,000 tons per annum used exclusively in aluminum metal production. Due to high costs and mine environmental problems, the future of the operations is uncertain at this writing.

Another mineral - barite - had received continuous attention in resource evaluation and beneficiation work. A review of barium minerals in Canada by Ross was published (122).

The Canadian resources of bentonite are limited and considerable effort was made in the early 60's to evaluate and beneficiate samples largely originating from Alberta and Manitoba. Bentonite was used for controlling the viscosity of oil well drilling muds and as a binding agent of foundry sands, but from the late 50's the largest consumer became the iron ore industry in pelletizing iron ore concentrates; thus Canadian consumption of bentonite in 1961 was 63,000 tons, rising to 278,000 by 1969. A review of bentonite in the Monograph series was published by Ross in 1964 (123), the last of the mineral commodity reviews to be published by the Mines Branch, a series started at the outset of the branch's history in Dr. Haanel's time.

The Non-Metallic Minerals Section had a tradition of promoting conservation by treating residues and materials that would be regarded as wastes. Some examples of this were: in the 50's barite was recovered for drilling mud use from base metal tailings, talc was recovered from discarded waste rock by improved grinding, and lime was recovered from carbonate sludge discarded from uranium ore treatment. In the 60's and early 70's a long-term project was undertaken to produce gypsum products like plaster, wallboard, etc., from waste gypsum residues derived from phosphate fertilizer plants. A beneficiation technique of sizing, washing, drying, grinding, calcining and chemical treatment was successfully developed: "Evaluation of phospho-gypsum for gypsum products manufacture" by R.K. Collings (CIM Bull, pp 41-51, Sept. 1972).

With greater official emphasis from the late sixties on conservation and pollution control, the section directed more of its research work to treating waste for recovering useful products, its name being changed in 1971 to Non-Metallic and Waste Mineral Section. The first to be re-examined were wastes from mining and metallurgical operations: "The utilization of mineral wastes" by R.K. Collings, A.A. Winer and D.G. Feasby (Journal of the Can Ceram Soc, vol 42, pp 61-67, 1973). A prior article was published in the October 1971 annual review of the Northern Miner by Brady, Collings, Bartley and Winer: "The wastefulness of wastes".

Collings succeeded Woodrooffe as head of the section in 1959. In 1974 staff consisted of R.K. Collings, head; C.M. Bartley (retired 1974), A.A. Winer and D.G. Feasby (1972-1975).

Before Reeves transferred to the Mineral Resources Branch in 1968, he published a general paper in this field titled "Factors of particular significance to the economics of industrial minerals" (MB IC 202, 1968).

Industrial Minerals Milling

When the Industrial Minerals Division was reformed in 1950, A.R. MacPherson was second in senior-

R.K. Collings

R.A. Wyman

ity in the Non-Metallic Minerals Section which included the function of beneficiation. Before he left the Mines Branch in 1951 he successfully completed a project on beneficiating gypsum by a dry method with the aim of removing the principal impurity - dolomite. This was reported in "Recent investigations into the beneficiation of Canadian gypsum" by A.R. MacPherson (Memorandum Series 111, 1950).

In the period prior to R.A. Wyman joining the Mines Branch in 1954, some processing steps were carried out in the ore dressing pilot plant. On Wyman's appointment as head of the Industrial Minerals Milling Section, beneficiation work was separated entirely from the Mineral Dressing and Process Metallurgy Division to avoid contamination from iron and other metals. A similar reason precluded any work being done on coal beneficiation in the Industrial Minerals mill.

Wyman joined the division when a major investigation on kyanite was in progress and he participated in beneficiating this mineral as will be mentioned under the Ceramics Section.

Lithium

In 1955 a major investigation was carried out on samples of spodumene - five from Manitoba and three each from Ontario and Quebec. A concentrating process was developed for each major occurrence: when heavy lithium minerals occurred in a disseminated state, recovery was entirely by flotation; on the other hand, where they were in large crystals, heavy media was used prior to flotation. On a pilot-plant scale, the concentrates were higher in lithium content than the 5% demanded by the market and the recovery was in excess of 84%. The Manitoba deposits, particularly those from the Bernic Lake occurrence, featured periodically in the history of the Mines Branch and are worthy of a condensed review. It will be recalled that under the subheading "Other Metals" an investigation of spodumene was described carried out by the Mineral Dressing and Metallurgy Division in the late 40's on a sample from Cat Lake in the Lac du Bonnet district that includes Bernic Lake. Also in 1961, the complex ore from Bernic Lake was studied by Nickel of the Mineral Sciences Division, followed by further research in 1962 of chemical extraction of cesium by the Extraction Metallurgy Division. In 1968 the Metallic Minerals Section of the Mineral Processing Division was involved with the development of a concentration process for tantalum. Wyman developed, improved and patented in Canada and U.S.A. in 1973 processes for recovering lithium from spodumene and amblygonite, the principal lithium minerals. Pilot-plant operations at the Bernic Lake mine proved successful, and the management termed the product "superconcentrates". However, financial constraints prevented the company from proceeding with commercial recovery of lithium.

The expectations of Canadian production of lithium were high in the 50's and a review was published: "Lithium" by V.A. Haw (MB Info Circular IM-1, 1955).

A statement was made in the 1959 annual report of the Department of Mines and Technical Surveys to the effect that "of fundamental impact and value was the long-term research started during the year on the flotability of non-metallic pure minerals". Wyman carried out this undertaking as attested by the three reports which are referred to together in the bibliography (124). This research entailed floating pure minerals with non-ionic, anionic and cationic collectors used with several types of modifiers in acid, neutral and basic systems. One of the important features of this research from a pollution abatement aspect was the use of degradable flotation reagents. The information contained in these and other publications received considerable international attention.

Before becoming part of the Mineral Processing Division in 1959, the section was composed of the following professionals: R.A. Wyman, head; G.A. Kent (1955 -) and R.M. Buchanan (1955 -). In the new division, Buchanan became head of the Ore Mineralogy Section. F.H. Hartman (1959 - 1975) joined the section in 1959, and K.M. Brown (1961 - 1973) in 1961. Some 500 processing investigations were carried out between 1955 and 1973, examples of which follow.

Kaolin

Because of the shortage of high-quality kaolin clay which has to be imported mostly from U.S.A. and United Kingdom, efforts were made at several periods to beneficiate the lower grades that are available in Canada mostly in the Western Provinces. In 1958, W.J.D. Stone (1957 - 1960) applied hydrocyclone and elutriation methods to a clay from Manitoba which was investigated jointly with Brady "Investigation of a clay from Arbog, Manitoba" by J.G. Brady and W.J.D. Stone (MB IR 58-214). This research continued in 1961 using chemical treatment and flotation. In 1971, the project was reactivated with the addition of staff. Synthetic mixtures of kaolin and silica were used as standard samples from which separation techniques could be developed.

Magnesite

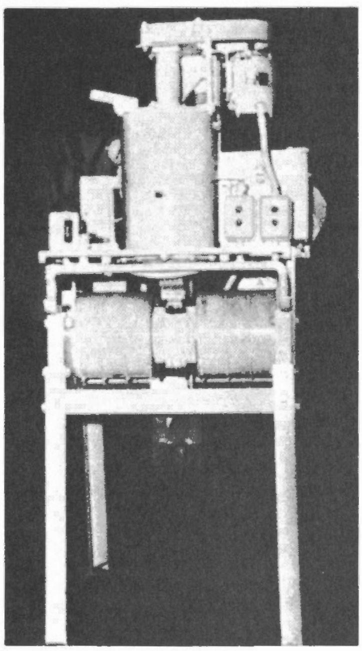
In 1963 a research project was started by Kent on beneficiation of magnesite from northern Ontario and continued for several years, resulting in a process that could also be applied to calcite ores. This consisted of calcining, followed by leaching with weak acid, evaporating and thermally converting the product to pure magnesia or lime that could be used for chemical as well as refractory applications. As an example, in the case of magnesia, the purity was 99.5% with only 0.03% silica and 0.006% ferric oxide. Patents were granted in the United States and Canada for this process described in "Production of high-purity magnesia" by G.A. Kent (MB RR 163, 1965). It will be noted that the above two projects were of direct assistance to the ceramics group.

Barite and Celestite

In 1967 an urgent project was carried out on the separation of barite from fluorite from a deposit at Lake Ainslie, Cape Breton Island, N.S. The concentration process was devised from data developed in the flotation studies and was patented in Canada. Pilot plant operations were successful both in-house and at the Nova Scotia Technical College carried out by Kilborn Engineering Company for a client. The project did not develop commercially because of financial difficulties of the entrepreneur.

Some years later the process was successfully applied to a celestite (strontium sulphate) deposit at Loch Lomond, Cape Breton, by the Kaiser Resources interests, after further pilot plant studies were made at the Nova Scotia Technical College. The commercial plant commenced operations in 1973. During the course of this joint work at the college, new degradable flotation collectors (taurates) were investigated at various concentrations and temperatures. The Mines Branch process was again tested at the Lakeview Research Laboratory in 1970 on a fluorite-celestite ore from British Columbia.

In 1971 Wyman presented a general paper on flotation research at the Mines Branch: "Solving industrial mineral flotation problems at the Mines Branch, Ottawa, Canada" (Trans AIME, vol 250, pp 231-236, Sept. 1971). Wyman and the section showed initiative in keeping abreast of innovations in equipment that would improve separation of economic and gangue minerals in the overall concentration process. Thus in 1959 the section noted the work of B.H. Jones in England on magnetic separation of weakly magnetic materials in



General view of Jones wet magnetic separator fine particle size, and acquired the first machine of that design to be used in Canada. After considerable testing the separator was found to be a useful beneficiation tool. "Wet magnetic separator for feebly magnetic minerals" by G.H. Jones and W.J.D. Stone (International Mineral Processing Congress, Preprint No. 34, London, 1960). A Montreal firm was subsequently encouraged to make it available in Canada. The investigations are described in "Illustrative applications of the Jones wet magnetic mineral separator" by R.A. Wyman, W.J.D. Stone and F.H. Hartman (MB TB 36, 1962). The study of magnetic properties of uranium ores was carried out over several years from 1963. To supplement the Jones magnetic separator, new equipment for stronger magnetic fields was installed in 1967. This is described in "Concentration of uranium minerals from Canadian ores by magnetic means" by F.H. Hartman and R.A. Wyman (MB TB 118, 1969).

Wyman was the second staff member of the Mines Branch to have pioneered automated mineral sorting. It will be recalled from Chapter 5 that some 15 years earlier Lapointe employed a sensing system based on natural radiation of radioactive ores. Wyman had to tackle a wider field in industrial minerals. In 1960, a Gunson electronic sorting machine used for agricultural products was purchased and adapted for mineral sorting. In these studies, reflectance of minerals and backgrounds and other variables causing acceptance or rejection of particles by the sorter were studied. Incidentally, the Canadian manufacturing firm benefited by this development and are now exporters of mineral sorting machines in world markets. The investigations are described in "Application of electronic sorting to minerals beneficiation" by R.A. Wyman (MB TB 82, 1965). The sensing system adopted depended on such properties of the minerals as radioactivity, conduction, etc. Industrial minerals generally are best differentiated by their optical properties - ultraviolet fluorescence, reflection and transparency: "Sorting by electronic selection" by R.A. Wyman, (Proceedings of the United Nations Interregional Seminar on Ore Concentration in Water-short Areas; New York, 1966).

In 1967, photometric sorting equipment was installed and it was found possible to apply sorting almost on a routine scientific basis: "Photometric sorting" by R.A. Wyman (Can Min Journal, vol 90, pp 79-80, May 1969). He also published in the Monograph series: "Selective electronic mineral sorting to 1972" (MB Monograph 878, 1973).

Research on physical properties of industrial minerals and on unit beneficiating processes was pursued by Wyman and his associates. Studies were carried out on grindability of non-metallic minerals in general and on fine grinding technology related particularly to the Humboldt vibrating mill used in conjunction with the Alpine "microplex" classifier and on transportation of ores and products by vibrating conveyors and feeders. This was described in "Operating characteristics of a vibrating mill" by F.A. Hartman and R.A. Wyman (MB TB 94, 1967), and in the companion study "Material-transporting characteristics of selected vibrating equipment" by R.A. Wyman (MB TB 95, 1967).

Experiments were carried out on drying of materials of various sizes and moisture contents using radiant heat as well as ultrasonics, dry fluidized methods and flocculation. Some of this work was carried out jointly with other sections of the division, particularly the Ceramics Section and described in "Experiments with radiant heat for drying minerals" by R.A. Wyman and T. Marshall (MB TB 183, 1973).

K.M. Brown was transferred to the director's office in 1971 and retired in 1973. He had joined the branch in 1961 after many years in metal mining in Canada and abroad. In 1974, Wyman was still head of the Industrial Milling Section with Kent and Hartman assisted by R.E. Atkinson (1972 - 1973).

CERAMICS

The systematic evaluation of clay and shale resources was pursued by Keele, first as an officer of the Geological Survey from 1910 and later as head of the Mines Branch Ceramic Division from 1915 to 1921. This was continued in the 20's through to the late 40's, but not on the same intensive scale as before for several reasons. There was a shortage and changes of staff, the general effect of the depression of the 30's and preoccupation with evaluation and other problems connected with structural bricks (see Chapters 4 and 5).

During the interregnum from 1946 to 1950 when the ceramics group was part of the Mineral Dressing and Metallurgy Division, a major activity was catering for the progressively increasing demand by provincial governments, clay producers and individuals for evaluating physical and firing tests for clays and shales. Thus in 1946, 95 samples were received, whereas in 1948, 240 samples were sent in, over half from Alberta and British Columbia and many of these were related to refractories.

Prince, who was in charge of the section, appreciated the importance of resource evaluation, though his appointment as head of the ceramics group was essentially directed to providing a stronger scientific base for dealing with the more demanding field of refractory materials. A survey of clays and shales in Prince Edward Island was carried out by A.R. MacPherson (1946-1951) as described by him in "Clays and shales of Prince Edward Island" (Memorandum Series 91, 1947).

Requests for solving problems related to refractory materials increased rapidly in this post-war period. An investigation was carried out at the request of the provincial government, in which silica brick was prepared from Nova Scotia quartzite for use in the steel industry as covered in Investigation Report 46-1 (Metallic Minerals Division, Ceramic Section, 1946). In other examples research was conducted on refractory brick made from brucite and magnesia and the effect of grain size variation and lime-silica ratio on properties of the brick described in reports 47-1 and 47-2 respectively.

Prince became increasingly involved in research with high-temperature-phase equilibrium systems of refractory oxides like thoria, berylia and zirconia in connection with the National Research Council atomic energy project. When the Industrial Minerals Division was reconstituted in 1950, Prince became head of the renamed Physical and Crystal Chemistry Section in the Mineral Dressing and Process Metallurgy Division. The engineers of the original ceramics group with some additions and Phillips as their senior engineer rejoined the Industrial Minerals Division in 1950.

Investigation of ceramic products that included common clays and shales for structural brick and tile continued at an increased pace. During the period from

1952 to 1959, nearly 2,000 such investigations were made. This work was in addition to in-house projects such as research on improving the qualities of Canadian fire clays for the production of "superduty" firebrick. In addition, a program was started in 1950 of testing all brands of firebrick, Canadian made and imported, to obtain the necessary data for drawing up specifications for the Canadian Government Specifications Board (CGSB). The aim was also to indicate how improvements could be made and to determine the type of brick best suited to a specific application. In 1951, at the request of the Royal Canadian Navy (RCN), the scope of the program was enlarged to include high temperature cements and plastic and castable refractories. By 1955 a total of 204 brands had been evaluated. The RCN prescribed in 1953 that all refractories used in its installations must pass the Mines Branch tests. The data were also given to the CGSB and to the manufacturers to assist them in improving their products.

H. Mercier fires brick in Remmey furnace with temperatures to 3500°F

To assist in sampling and examining clay and shale deposits, Phillips issued Information Circular IM-2 in 1954; he also published Information Circular IM-3 in 1956 on clays and shales of Eastern Canada from Ontario to the Maritimes. During this period the group was responsible for a complete evaluation of fire and semi-fire clay deposits at Shubenacadie, Nova Scotia, that resulted in commercial production of buff face brick and some refractories.

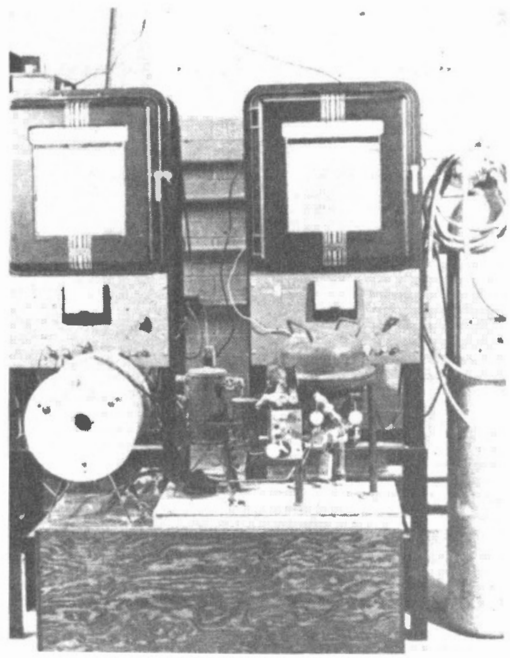
Another general resource report on some western clays was published by J.G. Brady (1952 -): "Nature and properties of some Western Canadian clays" (MB TB 21, 1961). While surveying the western resources, Brady carried out a detailed mineralogical study of the Whitemud Formation of southern Saskatchewan and southeast Alberta, which is a principal source of refractory stoneware clay (semi-fire clay). This is described in "Effect of the mineralogical composition of Whitemud Formation clays on their utilization" by J.G. Brady (MB RR 99, 1962).

It was with the coming of Brady (wounded in army war service) to the Mines Branch in 1952 that a systematic field and laboratory investigation and characterization of ceramic clays and shales was undertaken. It should be noted that high-quality clays - china clay, fire clay, ball clay and stoneware clay - are scarce in Canada, particularly in Ontario and Quebec where considerable glaciation and erosion in geological times no doubt caused the loss of many surface deposits. On the other hand, glaciation produced large deposits of common clay suitable for structural brick and tile, but many of these have a high content of lime and possess a short "firing range", i.e., range of temperature between vitrification and softening after firing. Selectivity and treatment allowed wider use of these clays. Brady collected a large number of samples starting from British Columbia and working east.

Improved evaluation methods such as differential thermal analysis were introduced: "Physical properties and differential thermal analyses of some Canadian clays and shales" by J.G. Brady (Journal of Can Ceram Soc, vol 26, pp 71-89, 1957).

Phillips retired in 1956 after twenty-nine years service with the ceramics group of the Mines Branch. S.M. Matthews became head of the group. Before resigning in 1959 he published a paper on the Mines Branch ceramics laboratory: "Ceramic research and facilities at Mines Branch, Ottawa" by S.M. Matthews, (Journal of Can Ceram Soc, vol 28, pp 35-38, 1959).

Clay mineralogy and X-ray diffraction were additional techniques applied in 1957 for the evaluation of clays and shales. This led to the formation of a separate Ore Mineralogy Section in the Mineral Processing Division, the successor to the Industrial Minerals Division in 1959, with R.M. Buchanan (1955 -) as head, Dr. R.S. Dean (1961 -) and Dr. J. Soles (1961 -). This group reported to the chief of the division as it gave support to all sections of the division as well as to other divisions of the branch, for example Fuels and



Differential thermal analysis equipment for study of clays

R.A. Buchanan

Mining Practice. A large proportion of its activities, however, were related to clays and ceramic and construction materials. Prior to the formation of the Ore Mineralogy Section, Vic Haw, being an accomplished minerologist, carried out numerous investigations for the divisions. He encouraged cooperation between those skilled in mineralogy and petrography and the mineral commodity officers.

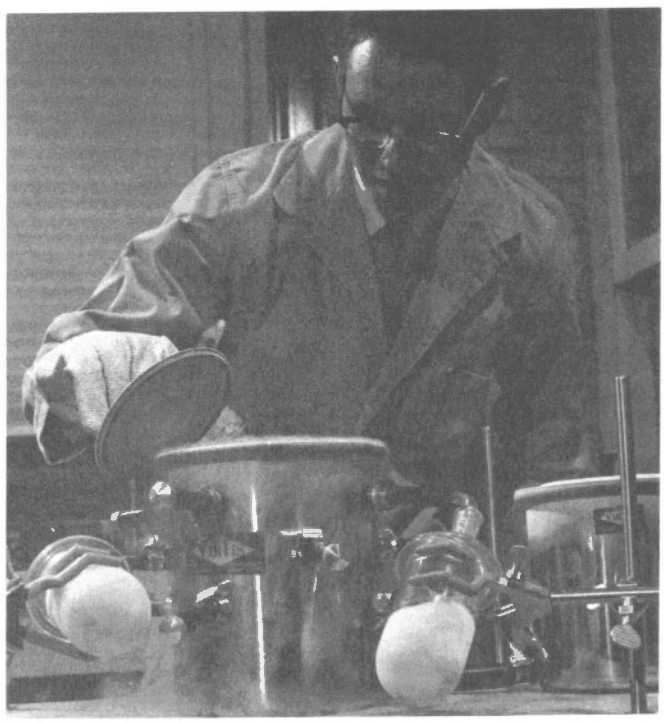
Brady, who became head of the Ceramics Section after Matthews left in 1959, worked closely with Dean on a cross-country survey of ceramic clays and shales. The effect of composition on unprocessed and processed clays was studied. The first of six publications (125) dealt with British Columbia; this was followed by the resources of ceramic materials in Quebec and Ontario. The Atlantic Provinces were covered in two separate reports and the Prairie Provinces in preliminary form. All the samples from the Prairie Provinces were collected but the analytical work was not completed. The evaluation tests included differential thermal analysis, thermal gravimetry, dilatometry, temperature gradient and firing.

Evaluating samples of clay and ceramic materials from various sources and assisting industry continued in the 60's and 70's when Ken Bell made an important contribution. The problems were more complex and specialized than before. For example, at the request of Atomic Energy of Canada Limited, a dense lithium fluoride shielding 83% of theoretical density, for a new type of gamma-ray spectrometer was developed by a 2-stage firing technique: "Dense lithium fluoride for gamma-ray-free neutron shielding" by V.D. Svikis (MB RR 119, 1964). Other examples were:

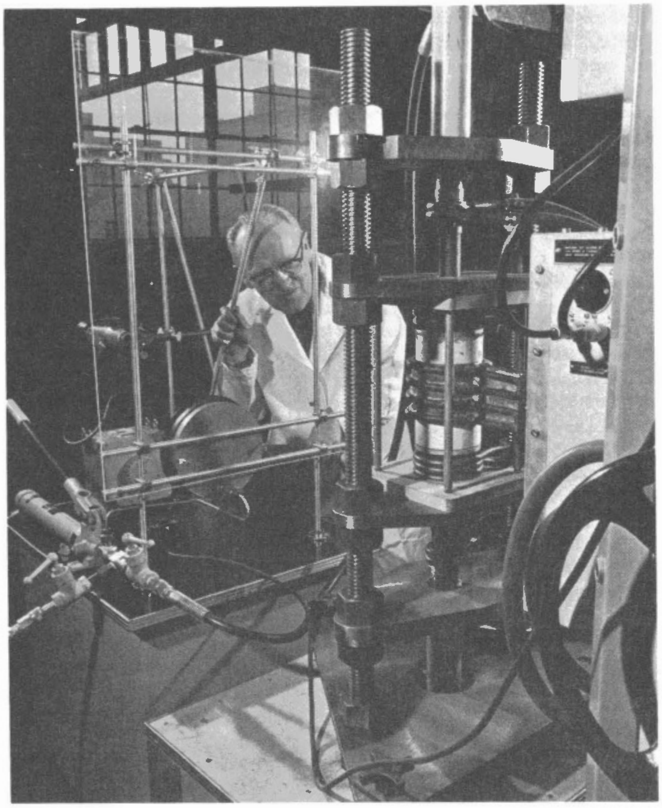
- studies of plasticity, firing properties and thermal expansion of local shale
- plastic clay mixtures were correlated with material preparation, kiln design and firing schedule for a new facebrick plant in eastern Ontario
- a method was developed to incorporate feldspar tailings from a deposit in Quebec in the manufacture of premium quality buff-faced brick
- the efflorescence on buff and grey facing brick was investigated for a Toronto company
- investigations were made of serious processing problems in forming, drying and firing sewer pipe made from local materials at a New Glasgow, Nova Scotia company and recommendations were made to overcome the difficulties
- firing schedules were established for a British Columbia sanitary ware manufacturer in using Canadian nepheline syenite in lieu of imported feldspar
- an investigation for a brick producer in the Maritimes was made using mixtures of glass slag, mortar sand and aluminum phosphate as additives to local shale.

Projects were inspired by the staff, for example, in the development of thermal storage ceramics that started in 1959. In the first phase of this research, the most promising materials incorporated calcined alumina and dead burned magnesia: "Non-metallic thermal storage media" by V.D. Svikis (MB RR 96, 1962). In the second phase of the research, materials with high specific heats were tested - silicates such as talc, olivine, and serpentine, and oxides like magnetite and hematite - and were found to possess high heating capacities and adequate mechanical properties: "Non-metallic thermal storage media for block-type electric space heaters" by V.D. Svikis (MB RR 206, 1969). In the present concern for energy conservation, interest has been revived in ceramic thermal storage in off-peak hours for use in peak hours in electric residential heating.

A project on hot pressing of ceramics was started in 1963. A facility consisting of special induction furnaces and a double-acting specially constructed press for "isostatic" pressing was installed. Research on a high-lime content shale from Dundas, Ontario, for production of sewer pipe was undertaken with this equipment. After considerable experimentation a satisfactory product was made from a mixture of 50% each of calcined and pulverized shale which was prepelletized and pressed under a vacuum at 10,000 psi: "Some experiences in isostatic pressing of high-calcine bodies" by K.E. Bell (Journal of Can Ceram Soc, vol 37, pp 38-40, 1968).



R. Dean uses freeze-drying technique to prepare clay samples for minerological examination (Photo - George Hunter)



J. Bond operates a ceramic hot press (Photo - George Hunter)

A high-temperature project was started in 1965 producing dead burned magnesia refractory from magnesite at Timmins, Ontario. A product of 92% dead burned hydration resistant magnesia was developed. The optimum calcining and dead burning temperatures, grain size, and percentage of additives were established: "Dead-burned magnesia from an Ontario magnesite concentrate" by V.D. Svikis (Bull of American Ceram Soc, vol 48, No. 7, pp 724-728, July 1969).

A project on thermal properties, particularly thermal conductivity of ceramic products, rocks and minerals was started in 1960 and continued for a number of years. "Round robin" testing with other laboratories using ASTM methodology was undertaken. The comparative method used was modified for improved reproductibility and standards were developed: "Comparative method apparatus and standards for measurement of thermal conductivity" by V.V. Mirkovich (MB RR 156, 1965). Thermal expansion and stability were studied and a thermal shock furnace was constructed.

Conductivity of heat as applied to thermal drilling of rocks in mining was jointly studied with Fuels and Mining Practice Divisions: "Experimental study relating thermal conductivity to thermal piercing of rocks" by V.V. Mirkovich (Int J Rock Mech Min Sci, vol 5, No. 3, pp 205-218, 1968). A companion mineralogical and petrographic study relating to the same project was carried out earlier by Dr. Soles, E. Hanes and V.D. Svikis in collaboration with L.B. Geller: "Experimental studies relating mineralogical and petrographic features to the thermal piercing of rocks" by J.A. Soles and L.B. Geller (MB TB 53, 1964). A quantitative relationship was established between pierceability of rocks and their thermal properties. Research on thermal diffusivity started in 1967.

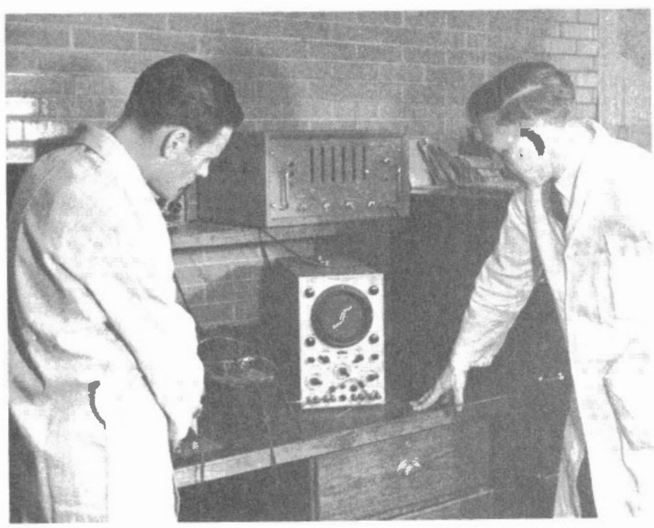
A project was started in 1971 to develop stabilized zirconia for fabrication into a solid state electrolyte for the oxygen probe which the Physical Metallurgy Division had invented. A cryochemical technique was used in producing a high-purity zirconia. At this writing, fabrication techniques have been improved, resulting in dense and shock-resistant ceramic bodies.

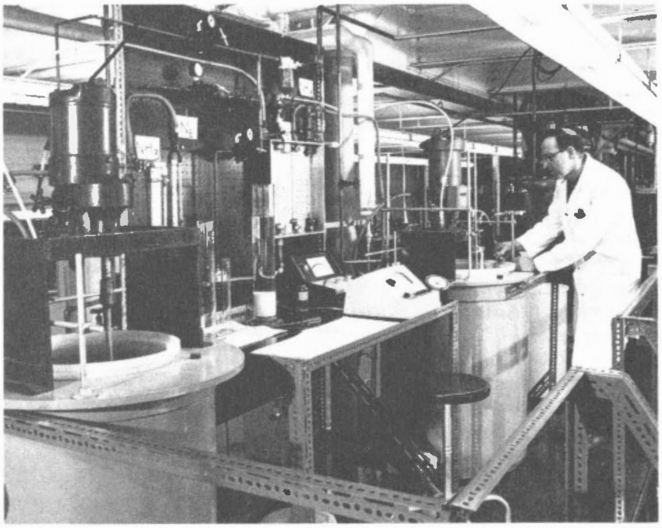
Because of the duration of the next two projects to be related and the importance then assigned to them, they are reported under their own sub-headings.

Electronic Ceramics

In 1950 an R & D project was started at the request of the Department of National Defence on the possibilities of preparing electronic ceramic materials possessing special dielectric properties. Special products were developed and supplied to DND. In 1952, at the request of the Defence Research Board, the development of piezo-electric ceramics for use in ultrasonic equipment was undertaken. The first ceramic tried was barium titanate and several thousand specimens were made for testing. In the early sixties further development work was done to improve the piezoelectric properties; lead zirconate and lead titanate were finely ground, then the two components were mixed, compacted and sintered: "Electromechanical properties of three experimental lead zirconate - lead titanate ceramic compositions" by T.B. Weston (MB RR 100, 1962). It was generally agreed that for optimum electrical properties the ceramic must be fine grained to sinter to a maximum density and without introducing impurities.

To achieve this aim, it was decided to set up a three-division group - Mineral Processing, Extraction Metallurgy and Mineral Sciences - aided by the Naval





L. Shaheen prepares ceramic hydrated oxides by co-precipitation (Photo - George Hunter)

Section. The Extraction Metallurgy Division produced by co-precipitation and spray drying a pure product first in one-pound batches followed by a pilot plant capable of making 15-pound batches. "The effects of some variations in fabrication procedure on the properties of lead zirconate-titanate ceramics made from spray-dried, co-precipitated powders" by A.H. Webster, T.B. Weston and V.M. McNamara (Reprinted from Journal of Can Ceram Soc, vol 35, pp 61-8, Reprint MB RS 32, 1966). The Mineral Sciences Division investigated the sintering characteristics. The pellets were finished off by the Naval Section with the Process Metallurgy Division making the electrical evaluation which showed improvement on commercial ceramics. Phase equilibrium studies of the $PbO-TiO_2-ZrO_2$ system were carried out by the Mineral Sciences Division. The program was continued to 1968, as many variables such as compositional change, effects of time and temperature of sintering, of slight excess or deficiency of lead oxide, etc., had to be evaluated: "Symposium on the preparation and properties of lead zirconate-lead titanate piezoelectric ceramics", Foreword by I.F. Wright (4 papers reprinted from Can Ceram Soc, vol 34, 1965, MB RS 8, 1966.) A company was to undertake commercial production of the ceramic.

In 1969 a review of this field indicated that less time could be allotted to piezo-electric ceramics and that more time should perhaps be diverted to dielectric ceramics. In 1972, one of the projects undertaken was the development of a suitable material for microwave dielectrics at the request of the Communication Research Centre. At this writing, barium tetratitanate appears to be a promising compound. Ian Wright, who joined the Bureau of Mines in 1948, was in charge of this project from 1950 to 1974 when he retired.

Kyanite

In 1951, kyanite and aluminum silicate were identified in one of the numerous samples that were continuously being sent to the Industrial Minerals Division for evaluation. The particular graphitic gneiss sample from Mattawa, Ontario, was submitted for an opinion as to its value as a source of graphite. Garnet and mica were associated minerals that were thought of as possibly providing byproducts that would add value to exploitation of the extensive deposit. Although efforts by industrial interests were made over a period of some years to bring the deposit into production, they did not materialize. Other deposits in Ontario were identified in the Sudbury and Clarendon Township (southern Ontario) districts as well as in British Columbia from where a "float" specimen was identified by the Mines Branch in 1931. To date no economical exploitation of any of these deposits has taken place. Vic Haw, who was with the industrial minerals resource engineers group at the time, presented a paper to the Canadian Institute of Mining and Metallurgy: "Kyanite in Canada" by V.A. Haw (CIM Bull, pp 27-35, Jan. 1954).

Kyanite is a source material for the production of mullite, a silicate high in aluminum content, and is considered a superior refractory. The ore has to be concentrated to high purity and the concentrate has to be transformed thermally to mullite. During the 50's, intensive research was conducted by the Milling and Ceramic sections of the division. Because of the disseminated character of Canadian kyanite which in the case of the Mattawa deposit was about 15% in kyanite content, beneficiation required magnetic concentration, fine grinding and flotation, followed by an acid leach to reduce impurities to acceptable limits. Laboratory and pilot plant flotation studies on kyanite ore from the Sudbury district were reported by R.A. Wyman (Industrial Minerals Division Research Report IM 189, 1955).

In the first phase of the research the porous kyanite concentrate was densified and stabilized by using phosphoric acid and aluminum phosphate as additives before compacting and calcining: "Processing of certain North American kyanite concentrates into volume-stable, dense and highly refractory aggregates" by V.D. Svikis and J.G. Phillips (Bull Am Ceram Soc, vol 35, No. 8, pp 305-308, 1956). In the second phase, research indicated that an addition to kyanite of 20% of aluminum oxide, making a body having an aluminum to silica ratio approaching a true mullite, would be beneficial. This provided a choice in some of the important process variables such as phosphoric acid content, compacting pressure, calcining temperature and the production of an aggregate with desirable properties: "Properties of improved, phosphate-stabilized refractory materials made from Canadian kyanite concentrate" by V.D. Svikis (Bull Am Ceram Soc, vol 38, No. 5, pp 264-268, 1959). These external publications were based on research reports in the Industrial Minerals Division - IM 168, 1954 and IM 212, 1956, both by V.D. Svikis.

Some revival of interest in kyanite arose in the 60's and an improved "mullite" refractory was prepared from a Temiskaming, Ontario kyanite and Alcan aluminum but this additional research did not lead to any industrial production of the refractory.

Source Materials for Ceramics

Most of Canada's clay deposits are of the common clay variety and are worked extensively in the manufacture of common and facing brick, various tile products, sewer pipe, etc. Finely-ground shale supplements the requirements of brick manufacture. High-quality or refractory-kaolin-type clays are scarce and occur in small deposits mostly in Western Canada. Ontario and Quebec are deficient in high-quality clays, thus there is a substantial importation of raw clay into these provinces to meet their requirements.

Since its formation some 60 years ago, the Ceramics Section had constantly aided the entrepreneurs to improve the refractoriness of clay products and widen the scope of their application.

The Canadian clay industry has grown into a sizeable one. Because of the variety of measuring units, it is simpler in reviewing Canadian clay production to speak in terms of dollar values. Historically, it is interesting to note that the value of Canadian clay products in 1886, the first recorded year, was $1.1 million, compared with $3.7 million for coal and $1.5 million for gold. These were the three leading mineral commodities in a total mineral production valued at $10.2 million. The peak production of clay products prior to World War II was in 1929 and was valued at $13.9 million.

In 1949, Canadian clay products were valued at $18 million from domestic production, and $14.5 million from imported clay, mostly from the U.S.A. and U.K. In addition, the value of imported clay products was $30.6 million, mostly from the U.S.A. and U.K. In 1949, bentonite was reported separately from clay production and manufacture. In that year the Canadian bentonite production was 17,000 short tons, of which about 8,000 tons was processed (ground and activated) and used in oil refining, oil well drilling and as a bonding agent in foundry moulding sands. There was some activated material imported from U.S.A. In 1969, bentonite was included in the overall Canadian clay production figures. On the other hand, imports that included fuller's earth, activated clays and earths amounted to 311,000 short tons valued at $4.6 million. Consumption was reported at 278,000 tons of which 211,000 tons were used in pelletizing iron ore. There were three Canadian bentonite producers but production must have been very small in comparison with the importation.

In 1969 the value of Canadian production of clays including bentonite and clay products was $51.2 million. Allowing for an overall inflation of 30-40% over 20 years, it would seem that the Canadian industry had doubled its production. However, imports of clay and clay products had apparently risen faster, as in 1969 they amounted in value to $76.3 million, although there was an offset of exports valued at $14 million.

Organization of Ceramics Section

The professional staff of the Ceramics Section in 1965 were: head, J.G. Brady, (1952 -), V.D. Svikis (1953 - 1970), T.B. Weston (1948 -), H. Mercier (1927 - 1967), K.E. Bell (1960 -) and Dr. V.V. Mirkovich (1961 -). Weston was one of the officers who worked with the Mines Branch uranium group in Chalk River. It is worth noting that no less than five officers in the Ceramics and Construction Materials Section were graduates of the University of Saskatchewan which was renowned for its ceramics engineering course.

In 1965 the Naval Section, comprising head, V.A. McCourt, (1947 - 1972), R.H. Moore (1948 - 1969), and W.A. MacDonald (1951 -), transferred administratively to the Mineral Processing Division, which was renamed Preparation and Properties of Materials Section. Ian Wright was given the position of head of Special Ceramics, as coordinator of inter-sectional and divisional work, in electronic ceramics. In 1968, Dr. T.A. Wheat joined the ceramics group and in 1970, Dr. M. Palfreyman was appointed to it but left in 1974.

In 1968 the Industrial Minerals Subdivision was officially proclaimed and Jack Brady became its research manager. Ian Wright became head of the Ceramics Section until his retirement in 1974, when Bell replaced him.

J. Brady

CONSTRUCTION MATERIALS

To repeat, this group in the past represented the continuation of the former Ceramics and Road Materials divisions founded in 1915 and 1916 respectively. These were combined into one division in 1922 and became a section of the Industrial Minerals Division in 1936, then part of the Mineral Resources Division in 1946, and finally recombined with the other sections in 1950 under the omnibus appellation of "Construction" in the resurrected division.

The latter name was appropriate in the light of the particular importance of all branches of the construction industry - roads, power dams, industrial, commercial and dwellings involved in the post-war construction "explosion". Once again the Mines Branch demonstrated its ability to respond to a current industrial and economic trend. The momentum of R & D in the Construction Section in the early period has largely been maintained to the present day.

A considerable effort was devoted to construction materials in the immediate post-war period between 1946 and 1950 in anticipation of a revival in construction. Some projects undertaken but not referred to earlier were:

- a survey of road materials along the Alaska Highway in the Fort Smith area at the request of the Surveys and Engineering Branch of the Department of Mines and Resources
- production of roof granules from Canadian slate and rhyolite
- initial experiments on lightweight aggregates
- use of syenite and diopside in the manufacture of rock wool (1947 rock wool production based on a

process developed by Goudge was valued at about $5 million)
- field surveys of raw materials for the construction industry in Eastern Canada.

As an index of Canada's utilization of concrete, cement production passed the one million barrel (175,000 short tons) mark in 1904, increasing to 12 million barrels by 1929, falling to three million barrels in 1933 and not attaining the previous high 1920 level again until 1947. In 1949 the demand had risen to nearly 16 million barrels or 2.8 million short tons; an additional 2.2 million barrels had to be imported. By 1967, the peak post-war year, production attained 8.0 million short tons with an exportable surplus of over half a million tons and an importation of less than 50,000 tons. In 1975, the last year of this chronicle, the annual production of cement was 9.7 million tons with a total potential annual capacity of about 16.6 million tons.

The natural or normal-weight aggregate component of concrete, to be economical in price, had to be located in proximity to construction or to inhabited areas. In this regard Canada was not endowed with large conveniently located deposits of sand and gravel close to major construction sites and hence these commodities had to be produced from crushed rock. In 1904 the production of sand and gravel amounted to nearly 400,000 tons, in 1929 to nearly 28 million, and in 1949 production was in excess of 63 million. By 1969 the production was 201.5 million tons after peaking in 1966 at 217.3 million, attributed to the effect of EXPO construction. Of the 1969 total, about 40% was crushed gravel of which the two largest users were: roads - nearly 147 million tons, and concrete aggregates - nearly 24 million.

The Mines Branch interest in construction materials during World War I with the appearance of the motor vehicle focused in particular on road materials and K.A. Clark who was renowned for his oil sands work, later of the Alberta Research Council, was responsible for a number of surveys for road material resources throughout the country. Clark was responsible also for the introduction of tests to evaluate road materials. One of Clark's associates was R.H. Picher, who conducted a large part of the field work referred to. He conducted the last area survey in 1950 and 1951 along the proposed Trans-Canada Highway in Newfoundland at the request of the Department of Resources and Development.

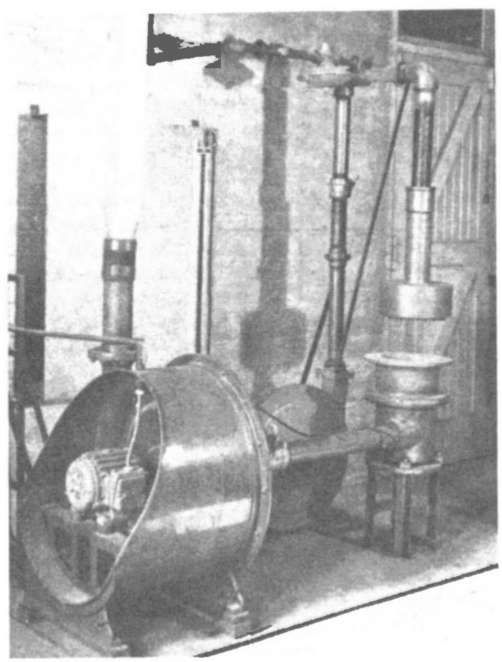
Picher was appointed senior engineer in the Construction Materials Section in 1950. He retired in 1954 with 37 years of service in the Mines Branch, and was succeeded by V.A. Haw who had joined the engineers of the Non-Metallic Minerals Section in 1950. Haw became acting chief of the Industrial Minerals Division when Monty Goudge left on retirement leave in 1958, thereafter taking up an appointment in industry. Monty retired in 1959 with 36 years of service. N.G. Zoldners (1947 - 1974) was appointed head of the section in 1959. Other professionals who joined the section were J.G. Matthews (1949 - 1952), R.A. Simpson (1950 - 1957), H.S. Wilson (1952 -) and F.E. Hanes (1956 - 1974).

Both sand and three categories of coarse aggregates were the subjects of Mines Branch R & D. The following account of this work is related in chronological order.

Lightweight Aggregates

A shortage of structural steel after the war was one of the factors that stimulated the evaluation of lightweight (LW) aggregates in the late 40's. A cubic foot of concrete mix using lightweight aggregate weighs 95-120 pounds. J.G. Matthews, later joined by H.S. Wilson conducted a survey of clays and shales that when heated rapidly below 2400°F in rotary kilns caused a release of gases, producing a "bloating" action which yielded rounded light strong particles with a vitrified skin or coating. One of the advantages of LW aggregate is the freedom from deleterious substances found in natural aggregates; another advantage is that it can be produced when natural aggregates or rock are not available. Research was also conducted with additives that could cause bloating when mixed with non-bloating clay. The alternative process required crushing followed by sintering in a pot or machine. A six-part report was published in 1952-54 (126). Later, further evaluation work was done by Wilson in Quebec and Ontario (respectively MB TB 48, 1963, in English and MB TB 51, 1963 in French). LW aggregates were produced from waste shale from coal stripping operations in New Brunswick and from coal washery residues and oil shales in Nova Scotia; they were also made from fly ash from coal-fired steam generating plants. This research work stimulated commercial LW aggregate production and some six plants were credited as having been commissioned on the basis of these investigations: "Development of the Canadian lightweight aggregate industry" by H.S. Wilson (MB IC 137, 1962).

LW stuctural concrete was cast in place, in precast panels or slabs, and to a lesser degree in prestressed building components. The first all-lightweight concrete 22-floor building was the National Trust Building erected in 1962 in Toronto. Over 13,000



Sintering pot for evaluation of raw materials for lightweight aggregates cubic yards of lightweight concrete of 115 pounds per cubic foot was used for columns, beams and floors. A further review of the LW aggregate industry was made by Wilson in 1968 (Canadian Pit and Quarry, vol 9, Sept. 1968) and a report for the United Nations Industrial Development Organization titled "Production and utilization of lightweight aggregate" by H.S. Wilson (Report ID/WB; 16/1, 1968). A study was undertaken recently in conjunction with industry to determine the feasibility of conserving some of the heat wasted in producing lightweight aggregate to offset increasing fuel costs. It was proposed that counterflow moving bed heat exchangers could save energy, both from exhaust gases and from shale to the extent of about 36%: "The recovery of waste energy in the production of expanded shale aggregate" by V.V. Mirkovich (MB TB 184, 1974).

In 1950, C.G. Bruce (1948 - 1950) identified fairly extensive deposits of vermiculite in the general area of Perth, Ontario. When heated this valuable mineral expands or exfoliates producing material for loose insulation, insulating plaster, concrete and other uses including horticulture. He reported on this resource at the annual meeting of the Canadian Institute of Mining and Metallurgy in Quebec City in 1951 (CIM Bull, pp 489-493, Aug. 1952). There were several attempts in the 50's and 60's by industrial interests to develop Canadian production of vermiculite. In this connection, beneficiation tests were carried out by R.A. Wyman (MB IR 64-66). However, it would appear that Canadian plants manufacturing exfoliated vermiculite as well as expanded perlite, which was also investigated by the Mines Branch, found that it is more economical to import the raw material from the United States.

In 1969, approximately 800,000 cubic yards or in excess of one million short tons of expanded clay, shale and slag was produced at a value of $3.8 million, and in addition about half a million cubic yards of expanded vermiculite and perlite, and a very small quantity of pumice were manufactured from imported material for a value of $4.4 million.

Normal-Weight Aggregates

Concrete using normal-weight aggregates weighs 140 to 150 pounds per cubic foot of mix. In 1951 a survey was started of rock suitable for making sand and gravel aggregates in the vicinity of the St. Lawrence River in connection with the proposed building of power dams and locks by the Ontario Hydro-Electric Commission and the St. Lawrence Seaway Authority. This was the general area where Keele and Cole carried out reconnaissance work some 30 years previously in the evaluation of virgin rock formations as sources of structural materials.

In the survey under review a large proportion of samples was derived from active or abandoned quarries mostly within a distance of 30 miles from the river. In addition, some samples were taken 50 miles from the river, and at the request of producers, samples were derived from several even more remote locations in southern and southwestern Ontario. Concrete specimens were made in the laboratory and durability tests carried out that combined freezing and thawing cycles until failure. Samples undergoing these tests were monitored for deterioration by the soniscope (ultrasonic pulse) and by compression tests. Two progress reports (Industrial Minerals Division Reports No. 101 and 102, 1951 and 1952) preceded the report "Durability of aggregates in concrete mixes (Final report)" by R.H. Picher (MB Memorandum Series 129, 1954).

Because of the shortage of natural sand and gravel aggregates in the Seaway area, the section continued to be involved for several years in this project which could be described as the national feat of the 50's. Samples of limestone, dolomite and sandstone each up to 50 tons in weight were crushed and the economics of producing aggregates for the large quantities of concrete required for the Seaway as well as for the hydroelectric power scheme were evaluated. The expertise gained generated requests for studies of manufactured and natural aggregates and how to beneficiate some of these by employing heavy media separation to strip deleterious materials. These requests came from the Hydro-Electric Commissions of Manitoba, Quebec and New Brunswick: "Concrete aggregate production" by V.A. Haw (Trans CIM, vol 60, pp 336-342, 1957).

In the sixties there was so much concrete building construction going on that an esthetic trend developed using "exposed" aggregate composed of pigmented gravel and chips of various Canadian rocks incorporated at the surface of concrete panels and slabs to impart some colour to the otherwise dreary effect of natural concrete. A collection of Canadian rocks was used by the industry. Materials also continued to be evaluated for road metal.

Heavy Aggregates

In 1956 and for some two to three years after, experiments were pursued to produce a heavy, dense concrete weighing 230 to 300 pounds per cubic foot of mix for shielding nuclear sources. Various materials were tried as aggregates including barite, ferrophosphorus and low-grade ilmenite. "An investigation into the use of ferrophosphorous as an aggregate for the production of heavy concrete" and "High density concrete with ilmenite aggregate" (MB IR 58-9 and MB IR 58-166) respectively, both by V.A. Haw. Eventually the latter was selected, producing a concrete weighing 240 pounds per cubic foot that was accepted for use not only in Canada but in the United States.

Concrete

In 1950 a shortage of cement-making capacity developed in Canada and this led to a study of mineral-based substitutes for cement including substances known as pozzolans, a term of Italian origin meaning related to volcanic rock: a leucite tuff. Pozzolan materials now include natural or calcined finely ground siliceous materials. They have important properties as additives in the reduction of heat of hydration, permeability and volume change of concrete mixes. During another study on the reactivity of porous cherts as a limestone aggregate component, pozzolanic materials were considered as additives to counteract this reactivity. In the period of the sixties and at this writing, pozzolanic materials were used in studies related to concrete mixes.

The period of the sixties saw considerable advances made on the evaluation and standardization of testing concrete and cement properties. A research program to study prolonged temperatures on the physical properties of concretes prepared from different types of aggregates used in Canadian construction was completed in 1960: "Effect of high temperatures on concretes incorporating different aggregates" by N.G. Zoldners (MB RR 64, 1960). A companion study using aluminous cement and different aggregates was carried out later: "High-temperature behaviour of aluminous cement concretes containing different aggregates" by N.G. Zoldners, V.M. Malhotra and H.S. Wilson (MB RR 109, 1963).

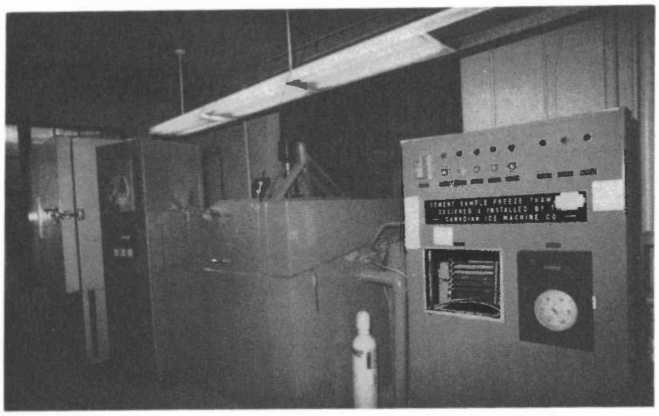
The curing of concrete is very time dependent yet an undelayed test for comparing strengths of various concrete mixes was an important desideratum. In 1963 research was commenced on an accelerated boiling water method for establishing the 28-day compressive strength in 28 hours. Statistical regression methods established a mathematical relationship between the accelerated and standard 28-day strengths (127). Further research work was done for the early prediction of the ultimate strength of concrete at 91 days. Considerable field testing of the method was carried out in the ensuing years; this method was used in the construction of power dams such as the Manicouagan Outardes complex and Churchill Falls. Many concrete firms, consultants and hydro-electric commissions accepted this test for concrete construction work. Both CSA and ASTM accepted the test method as a standard following "round robin" testing by cooperating laboratories. The five-year experience with this method was published in the Journal of the American Concrete Institute: "Some field experience in the use of an accelerated method of estimating 28-day strength of concrete" by V.M. Malhotra and N.G. Zoldners (Journal Am Conc Inst, vol 66, No. 11, pp 894-97, 1969, with a discussion in vol 67, No. 5, pp 424-434, 1970). A review of the prevalent opinions on the maturity of concrete as related to its strength was published in an Information Circular by Malhotra in 1971: "Maturity concept and the estimation of concrete strength - a review" by V.M. Malhotra (MB IC 277, 1971).

It should be noted for chronological sequence that in 1960 the cement testing program was originated by the Subcommittee on Physical Requirements and Test Materials of the CSA Committee on Hydraulic Cements, with the Mines Branch acting as coordinator of the program, which was carried on until 1973. There were three phases each comprising periods from 18 months to three years in which samples of commercial cements were distributed across Canada to participating laboratories which carried out an agreed program of physical and chemical tests employing mostly CSA and some ASTM methods. Reports were issued in the Mines Branch Investigation Report series CSA Cement testing program, Phase I and Phase II, (IR 62-102, IR 66-74, both by Zoldners and Malhotra, and IR 73-39 by G.G. Carette). Samples from the last phase (III) were studied for the effect of sand variations on the compressive strength of cement mortar (MB IR 72-21, 1972, by Zoldners and Carette).

In 1964 development work was started on the "ring" test for determining the tensile strength of 12-in. diameter moulded concrete for cylinders using three-quarter inch maximum size aggregate. "Ring test for tensile strength of concrete" by V.M. Malhotra, N.G. Zoldners, and H.M. Woodrooffe (ASTM Materials Research and Standards, Vol. 6, Jan. 1966). This research was conducted in cooperation with Ecole Polytechnique of Montreal and several universities abroad. Moulding equipment with accessories was loaned to the Ontario Research Foundation, Ontario Hydro and the Ontario Department of Highways. Drawings with some equipment were sent at the request of R & D organizations in U.S.A., U.K., and Mexico for an evaluation of the test. The ring test appeared to be a satisfactory method for measuring the tensile strength of concrete with aggregate up to a maximum of 2 in. size. Malhotra recognized the difficulties of measuring tensile strength of concrete: "Problems associated with determining the tensile strength of concrete" by V.M. Malhotra (MB IC 191, 1967). Comparison of ring-tensile with compression, flexural and splitting-tensile strengths were determined by V.M. Malhotra and N.G. Zoldners (Journal of Materials, vol 2, pp 160-199, Jan. - Mar. issue 1967, with discussion).

There was need to determine the durability and strength of concrete at the construction sites rather than having to wait for results from remote laboratories. Thus during 1962 to 1964 a cooperative project was carried out with Ecole Polytechnique evaluating durability of concrete using nondestructive methods of slow freezing and thawing and ultrasonic pulsing of 18 x 18 x 54-in. cast-on-site concrete test blocks at the Manicouagan dam construction. In 1968 Malhotra published a Monograph on nondestructive testing, (128). The on-site research on evaluating strength or durability of concrete was continued in a cooperative project in 1969 with the University of Ottawa in the building extension program. In the first phase of this project, large concrete test specimens in the form of slabs, blocks and columns were cast under summer and winter conditions, cored and examined for compressive strengths at various ages. Results were compared with standard test specimens. In the second phase, laboratory mixes of wide strength ranges were prepared and cured at 73°F and then transferred to a cold room at -31°F: "Effect of below freezing temperatures on strength development of concrete" by V.M. Malhotra and Carl Berwanger of Ottawa University (American Concrete Institute, Special Publication 39, pp 37-58, 1973).

At the end of the period of this narrative a project of evaluating strength and durability as well as improving environmental properties of cements and concrete, and designing concrete for specific uses was assiduously pursued. Here are some examples. Equipment for use at temperatures to -75°F was acquired and installed for studies of concrete at extreme climatic conditions. To raise heat resistance of portland cement, microfillers were investigated that included industrial mineral wastes such as fly ash, siliceous precipitated dust, etc.; a new pull-out test technique for determining in situ strength of concrete was developed by using a special ram to pull out a specially shaped steel rod whose enlarged end had been cast in the concrete; this was reported to the Second International Conference on New Developments in Nondestructive Testing in Roumania in 1974 and was published in the Proceedings and in the Organ of RILEM (Association of Test and Research Laboratories of Materials and Construction, Paris, France) with which the Construction Materials Section was in close contact from the early 60's as an international laboratory of repute: "Evaluation of the pull-out test to determine strength of in situ concrete" by V.M. Malhotra (RILEM matériaux et constructions, vol 8, No. 43, pp 19-31, janvier-février 1975). A high-strength concrete was developed from lean, low-strength two-day old portland cement using a sulphur infiltration technique consisting of immersing moist-cured then dried concrete into molten sulphur. A large increase in compressive strength was noted: "Development of sulfur-infiltrated



Automatic freeze-thaw equipment for concrete testing

high-strength concrete" by V.M. Malhotra (Journal Am Conc Inst, vol 72, pp 466-473, Sept. 1975). A new "no-fines" concrete without sand was proposed for economy of transportation costs particularly in the north, although additives might be required to resist freezing and thawing: "No-fines concrete - its properties and applications" by V.M. Malhotra (MB IC 313, 1974).

Stone

Stone is used principally in the crushed form for concrete aggregate, rubble and rip-rap, road metal, ballast, and in the chemical and metallurgical industries. In the pulverized form it is used principally in agriculture. A minor amount is used for building purposes. The following table shows consumption in 1960 and 1969, in thousands of short tons:

	1960	1969
Limestone	36,406	59,610
Marble	69	86
Granite	5,237	5,400
Sandstone	3,421	2,276
Shale	180	105
Total:	45,313	67,477
Value ($ million)	60.6	88.2

There were substantial fluctuations from year to year with 1966 and 1967 both exceeding $9 million in production value related to the construction boom resulting from EXPO 67.

Building, monumental, ornamental and stone for other uncrushed uses represented a very small percentage of the total. Thus in 1969 this category amounted to about 140,000 tons in all.

The term "granite" applied commercially to most igneous rocks including metamorphic. Heber Cole reviewed the granite industry during the 1930's but the Monograph on granite was prepared by Carr in 1955 (64).

Producers of dimension and ornamental stone were assisted by the construction group in assessing their products. Examples included black microsyenite from north of Lac St. Jean, Quebec, competitor to the internationally renowned "black sweet"; black granite from River Valley, Ontario, a quality building stone and potential curling stone; and a finegrained buff to red sandstone from near Trois Pistoles, Quebec. The division developed a display of representative building stones from various locations in Canada for the particular interest of architects and Canadian and foreign stone dealers. The display assisted EXPO authorities in selecting chips from the wide range of beautiful Canadian rocks in preparing coloured aggregate concrete panels. Polished concrete tile in terrazzo-containing aggregate of desired colours and textures in the concrete mix moulded under pressure made an appearance.

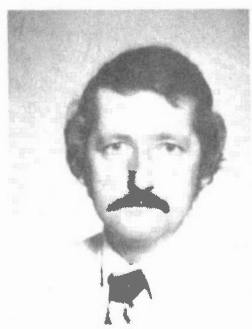
The division also assisted in obtaining from the stone industry large blocks of rock as part of the Geological Court in the Canadian Pavilion of EXPO 67. Rocks were selected on the basis of characteristic quality or economic importance.

In the late 60's, at the request of the Department of Indian and Northern Affairs, outcrops of lapis lazuli were investigated as a source of gem quality rock for producing table tops and other ornaments by the local Eskimos.

In 1965 the professional staff of the Construction Materials Section were: Dr. N.G. Zoldners (1957 - 1974), head; H.S. Wilson (1952 -), F.E. Hanes (1956 - 1974) and V.M. Malhotra (1962 -). At the time of writing V.M. Malhotra is head with H.S. Wilson, G.G. Carette (1966 -), and Dr. E.E. Berry, who joined CANMET in 1975.

V.M. Malhotra

H.S. Wilson



G.G. Carette

Industrial Waters

It will be recalled from Chapter 4 that a systematic industrial water survey was started in 1934 by Leverin, then in the Chemistry Division of the Mines Branch in the Department of Mines. In 1936 this section was transferred to the Industrial Minerals Division of the Bureau of Mines in the Department of Mines and Resources.

Although the industrial water survey was continued following Leverin's retirement in 1944, it was with the appointment of J.F.J. Thomas in 1946, an engineer with experience in the treatment and utilization of industrial waters, that this activity received a stimulus. A mobile laboratory was fitted out to permit various determinations on water samples as soon as collected, though some analyses were made in the central chemistry laboratories of the Bureau by Inman and Charette. The Dominion Water and Power Bureau of the Department and private companies cooperated by collecting and sending samples to the Bureau of Mines. The last report by Leverin (MB Rep 807, 1942) was revised, updated and issued in 1947 as MB Rep 819.

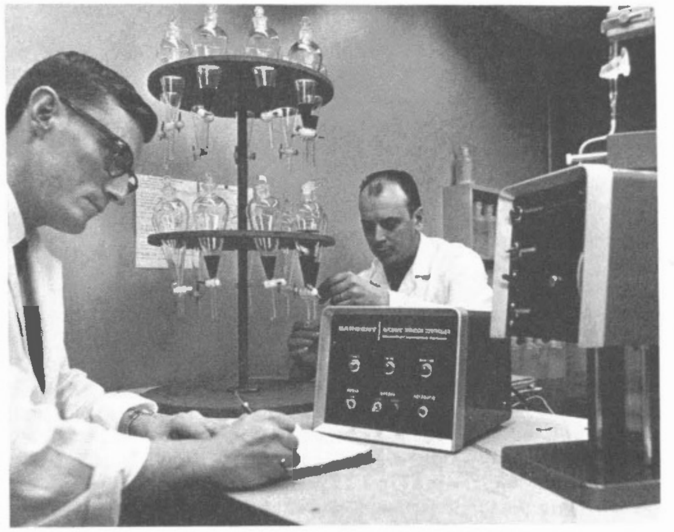
In 1950 the Industrial Waters Section was assigned to the reconstituted Industrial Minerals Division. A post-World War II survey was, however, more comprehensive, as the principal river drainage areas were investigated and covered in a series of reports (129).

Samples had been taken and analyzed prior to transfer of the laboratory to the Department of Environment.

With water sampling stations operating in the various drainage basins, the section continued detailed surveys of Canada's industrial water resources close to industry, as for example, in rivers and lakes near uranium mining camps. In some areas the section conducted surveys of municipal water supplies. At the request of the Department of Northern Affairs and National Resources, analyses of hot springs were also carried out. Similarly, groundwater samples were analyzed for the Geological Survey, as well as river water samples for the Geographical Branch.

A special report on water hardness was published: "Interim report on hardness of major Canada water supplies" by J.F.J. Thomas (Memorandum Series 132, 1956). A systematic water quality survey was made at military camps at the request of the Department of National Defence, and these results were reported in No.12 Report of the Water Survey Report Series: "Water quality at some Canadian military establishments, 1956-57" by J.F.J. Thomas (MB Rep 865, 1959) and in a supplement for the years 1959-62 by the same author (MB Rep 872, 1963).

In 1960, a five-year survey of major water resources of Western Canada was established to measure long-term variation in chemical quality with 35 locations set up for this purpose. In 1963 this project had to be slowed down because of other commitments - for example at the request of the Canadian Section of the International Joint Commission, data were obtained for future irrigation use of international river waters. The section also cooperated with the Department of Forestry in water conservation studies related to the eastern Rockies watershed and in the study of 15 headwater streams of the Saskatchewan River system.



W.J. Traversy and M.J. Malette carrying out spectrophotometric determination of calcium and magnesium in surface waters (Photo - George Hunter)

Simultaneously, considerable attention was given to aqueous corrosion and colouration of waters briefly referred to earlier in the section on corrosion. Requests for technical assistance on problems relating to water use by industry and government agencies increased, particularly on corrosion problems, as most Canadian surface waters are soft and corrosive. Suitable water treatment and controls were established at a number of government hot-water and steam-heating plants. Increased emphasis was also directed to the contamination of waters by industrial wastes. In this respect, treatment and control of waste waters from base metal mining operations received particular attention in a project carried out in cooperation with the New Brunswick Departments of Lands and Mines, and Fisheries.

In 1965 the Annual Conference of the Provincial Ministers of Mines requested a detailed study of pollution from mining activities across Canada. These developments were leading to the expansion of the long-term project on water quality variations into a national water quality network with a planned 150 sampling stations across Canada. The Maritimes led with 15 sampling stations and a temporary regional laboratory established at Dartmouth in 1965 which was later to be transferred to Moncton. Furthermore, a regional laboratory was planned for Calgary.

Liaison was maintained by the section with the American Society for Testing and Materials, American Water Works Association and the OECD in Europe in relation to developing methods for analysis of stream water, industrial water and waste waters. Increasing emphasis was placed on updating instrumentation for analysis of water and to meet the demand for information on minor and trace elements.

In 1951 the Industrial Waters Section was composed of two engineers, J.F.J. Thomas (1946 - 1965) and S. Romanchuk (1950 - 1952). In 1953 the latter was replaced by W.J.S. Craigen (1953 - 1956) who returned to the Mines Branch in 1973. In 1957 the professionals were: J.F.J. Thomas, J.P. Lively (1954 - 1965), W.J. Traversy (1954 - 1965) and J.J. Lynch (1955 - 1961). In 1961 Lynch transferred to the Geological Survey and R.M. Gale joined the group. All four officers were transferred with the laboratory in October 1965 to the new Water Research Branch of the department. In the government reorganization in 1970 the laboratory was again transferred to the Inland Waters Branch of the Department of Environment.

Ceramics Section - Industrial Minerals Subdivision - circa 1960

Left to Right - Standing - Jack Brady, Dave Svikis, Leo Vallée, Tom Weston, Joe Bond, J. Mirkovich, B. Hanson, K. Bell, G. Miller, Leo Zemgals; Seated - Doris Gibson, Hector Mercier

Recipients of the 25-year service pins, front row, l-r: J.T. Nevin, J.C. Sala, V.A. McCourt, H.M. Woodroffe, J.R. Reardon, J.G. Banks; back row, l-r: V. Sabourin, R.H. Moore, P. Vanasse, E. Gourgon

FUELS

In the decades of the 1950's and 1960's the Canadian energy economy, particularly in the most populated and industrialized provinces of Ontario and Quebec, was transformed from dependance largely on Canadian and imported coal (and its derivatives coke and city gas manufactured in Canada), to reliance on Canadian natural gas and Canadian and imported oil. The latter for the eastern section of the country balanced exports to the U.S.A. from Alberta.

There was wholesale replacement of solid fuel heating in houses, offices and factories by oil heating. City gas was wholly replaced by natural gas. Even some electric power generating stations in the Maritimes and Quebec started to burn imported oil. Railroads replaced steam locomotives with diesels by the early 60's.

There was a price to pay for the extended geography of Canada by the necessity of building transcontinental pipelines: a crude oil line (Interprovincial) from Alberta to the Sarnia, Ontario refining centre with pipelines twinned to Superior, Wisconsin for export to the mid-west States and a natural gas line from Alberta to Toronto/Montreal. Oil and natural gas lines were constructed to dispose of oil and natural gas surplus from Alberta and to a smaller extent from British Columbia to the hydrocarbon-deficient northwest States and even as far south as California. This supply and trade pattern arose from Canada's geography and the then world oil prices which were basically lower than those of Western Canada. The Maritimes, Quebec and eastern Ontario were supplied with oil from Venezuela and also from the Middle East, the bulk of which, other than requirements for the Maritimes, was refined in Montreal. This could be considered as a reasonable arrangement in a free world economy of the day; moreover, the relatively small reserves in the West would have been depleted at a faster rate had they supplied the whole of Canada's requirements of oil. Furthermore, no oil expert in the West forecast shortages from the "Third World" at that time. However, there were warnings such as the partial nationalization of oil in Iran and later in the Middle East, and in 1967 there was the Middle East war.

There was a general air of optimism in the land. By the end of the 50's refining capacity in Canada more than tripled. By the middle 60's the Canadian economy was solidly flourishing on an oil and natural gas base. In this period, glib statements were circulated that Canada possessed the world's largest resource of oil in its tar sands, with figures up to 700 billion barrels. There were also high expectations of a rapidly advancing nuclear energy industry that would replace fossil fuels in the electric power generation field.

Coal was popularly considered as outdated. The more sobering facts were not advertised such as that at no time were there recoverable reserves of conventional oil in Alberta in excess of 15 to 20 years even considering that about 50% of the requirements of Eastern Canada was imported. Nor was much said at the time about the proportion of natural gas discoveries in relation to oil discoveries being larger - for example, in a six-year period from 1951 to 1956 some 3700 exploratory oil wells were drilled that proved 67 oil pools of one million barrels or more each, whereas 134 gas reservoirs of ten billion cubic feet or more were discovered. This ratio of discoveries seemingly persists to this day. A paper outlining the Canadian fossil fuels position at the end of the 50's was published in 1960: "Fuel technology in Canada" by A. Ignatieff (presented to the Institute of Fuel by R.J. Brearley with discussion; Journal of the Institute of Fuel, London, vol 33, pp 223-237, May 1960).

The following table illustrates the rapid interfuel shifts in the Canadian energy source mix of fossil fuels in percentages during the 1949 to 1969 period.

In 1950 the total energy supply in Canada amounted to nearly 2.4 quads (1 quad = 10^{15} Btu, roughly equivalent to 40 million short tons of bituminous coal or 190 million barrels of oil). In 1975 the energy supply was 7.9 quads. At this writing the demand for energy, including some exports, matches the supply but the future is uncertain.

The quadrupling of oil prices by the Organization of Petroleum Exporting Countries (OPEC) in 1973 struck an unprepared and complacent society like a thunderbolt. An important factor in the public debate that followed was confusion over the difference between "resources" and "reserves" alluded to earlier in this narrative. Estimates of mineral resources are made on the geological evidence adduced to mineral occurrences, and estimates imply the quantity of mineral "in place". Mineral reserves, however, imply the amount of mineral that can be economically recovered from the ground and "concentrated" or "purified". These recoverable reserves depend on the availability of economic technologies at a given epoch. Mineable reserves of solid minerals in reasonably continuous deposits are usually easier to establish than fluid hydrocarbons which are dispersed in rocks of varying porosity and permeability that result in varying degrees of producibility.

The importance of energy to Canada may be seen from the comparison of the dollar value of Canadian production of fuels during the time span of 20 years from 1949 to 1969. In 1949 the value of Canadian fossil fuel production was $184 million, in 1959 it was

	Coal			Hydraulic	Natural Gas	Petroleum			Total
Year	Can. prod.	Imports	Total		(incl imports)	Can. prod.	Imports	Total	%
1949	23	31	54	8	4	6	28	34	100
1959	7	11.5	18.5	9.5	14.5	32	25	57.5	100
1969	3	6	9	6	31	35	19	54	100

Exports not deducted. Source: Dominion Coal Board. (Figures to nearest 0.5%)

$535 million, in 1969 it was $1,465 million, whereas in 1975 the value rose to $6,653 million, almost equalling the combined value of all other Canadian mineral products.

This was the general energy situation in Canada in which R & D in fossil fuels was pursued in the Mines Branch for some 25 years in the post-World War II era. Without the combined support of the director, the Dominion Coal Board and the coal industry, as well as the determination of the staff, coal research in the Mines Branch could have been in difficulties. As regards oil, most of the R & D in the branch was related to the Alberta bitumen and heavy oils which required considerable development of scientific and technological research with corresponding need for expensive apparatus and equipment and much of this requiring design and construction. The outlook at times was gloomy due to shortage of funds and staff. Only the tenacity and dedication of Dr. Montgomery and his associates carried through the program that is emerging as a success story at the critical time when Canada has to face the challenge of self-sufficiency in oil.

Organization of the Fuels Division, Post-World War II

The Fuels Division had a continuous history from its formation in 1910, undergoing no reorganization until 1967 with only two minor name changes from Fuels and Fuel Testing to Fuels Division in 1936, and to the Fuels and Mining Practice Division in 1959. In 1967 the fuels group and the mining group became separate centres.

In terms of scope of R & D programs of the division from 1950, coal included mining which at the outset related to problems in "deep" mining, hazards of electrical and internal combustion equipment in gassy atmospheres as well as respirable and explosive dusts; the qualitative evaluation of coal and heat resources by surveys and analyses, preparation (cleaning and briquetting), and utilization (carbonization and combustion). Combustion of coal was emphasized to assist a struggling coal industry, though some of this research was also conducted with hydrocarbons. Thus, as will be noted later, the R & D thrust on coal from the late fifties was directed to bulk use of coal in institutional heating, electric power generation, and metallurgical and other industrial applications. The R & D program on petroleum and natural gas included quality evaluation by surveys and analysis with some assessment of reservoir characteristics, fundamental research on the constitution of bitumen, bituminous substances and coal, and refining of Athabasca bitumen, heavy oils and residues. It should be noted in the case of hydrocarbons that the research was concentrated on lower-grade resources, whereas the currently used lighter oils and natural gas were featured only in the national surveys and analyses including that of helium in natural gas.

The immediate post-war position was presented at the 1950 British Commonwealth Scientific Specialist Conference on Fuel Research held in London in a paper on facilities for fuel research in Canada by R.E. Gilmore, and in one on educational and training facilities for research in fuels in Canada by Dr. Alan E. Cameron, President of the Nova Scotia Technical College. These were consolidated into a single paper in two parts and presented at the Annual General Meeting of the Canadian Institute of Mining and Metallurgy at Quebec City in 1951 (130). At the request of the London conference, a bibliography of published and unpublished reports of investigations of fuels research in Canada from 1950 to 1955 was prepared by Swinnerton (Report FRL 246, 1956).

In 1950 the number of staff was approximately 50, which increased by 1965 to about 130 including summer students, and this figure included mining. The budget for fuels and mining was about 20% of the total allocated to the Mines Branch.

At the end of World War II there were considerable retirements of key personnel as follows:

- R.A. Strong (1924 - 1945), head of the Carbonization Section, died in 1945 with 21 years of service, and was succeeded by E.J. Burrough (1927-1963).
- S.C. (Sid) Ells, oil sands and shales (1911 - 1945 - Fuels from 1936), retired with 34 years service.
- E.S. Malloch (1914 - 1947), head of Mechanical Combustion Engineering Section, retired with 33 years of service and was succeeded by C.E. Baltzer (1923 - 1965).
- J.H.H. Nicolls (1914 - 1949 and previously in joint McGill University-Mines Branch coal project), head of Coal and Peat Analytical Laboratory, retired after 35 years of service and was succeeded by W.J. Montgomery (1948 -).
- Dr. T.E. Warren (1929 - 1952), head of Hydrogenation Section, with 23 years of service and succeeded by Dr. D.S. Montgomery (1948 -).
- P.V. Rosewarne (1921 - 1954), head of Oil and Gas Laboratories, retired with 33 years of service and succeeded by H. McD. Chantler (1924 - 1958), who retired with 34 years of service, and was succeeded by R.G. Draper (1949 -).
- A.A. Swinnerton (1921 - 1958), head of Peat and Oil Shales Resources Evaluation, retired with 37 years of service, and was succeeded by T.E. Tibbetts (1952 -) for peat, and by Dr. D.S. Montgomery and R.G. Draper for oil shales consolidated with oil sands.
- R.J. Offord (1921 - 1958), officer in charge of Gas Analysis, retired with 37 years of service and was succeeded by A. Yates (1950 -).
- Walter Kritsch, coal laboratory technician whose father started in the division in 1910 and retired in 1936, retired in 1956 with 43 years of uninterrupted service from 1913, the then longest for a technician in the history of the branch.

The second chief of the division, R.E. Gilmore, also retired in 1954 with 36 years of service. He was one of the architects of the North American (ASTM) coal classification system and of the methodology characterizing properties of coal; on the human side he will be remembered for his modest and amiable character.

In 1960 the division sustained a loss through the untimely death of Ed Swartzman who had had 32 years of service and was a hard and methodical worker.

The comparatively rapid denudation of experienced staff caused by the restraints of recruitment during the depression and the war was rectified with some difficulty as much of the training had to be done on the job because of the relatively small reservoir of trained fuel scientists and technologists in Canada.

Ignatieff and D.S. Montgomery were appointed in 1954 as chief and senior scientist respectively. Attached to their offices in the Special Projects Section

Certificate of service presented by Dr. M. Boyer, deputy minister to R.E. Gilmore on his retirement; Mrs. Lillian Gilmore looks on

were consultants: H.A. Graves (1947 - 1958), mining adviser to the director from 1953, succeeded by M.A. Twidale, (1958 - 1971) following Graves' untimely death in the field; K.W. Bowles (1935 - 1975) Hydrogenation processes from 1958; Dr. W.A.O. Herrmann (1956 -) from 1960 synthetic liquid fuels specialist. Dr. John H. Walsh (1955 - 1974), advisor to the director on Primary Process Metallurgy from 1959, and Dr. H. Frisch (1960 - 1970) on foreign exchanges and information.

Before retiring, Swinnerton in 1957 prepared a brief history of the Fuels Division for the 50th anniversary of the Department of Mines that coincided with the period of continuous R & D in fossil fuels of the federal government (131).

Divisional Reports

Due to the diligence of A.J. Reynolds (1935 - 1971), administrative officer of the Fuels Division, with the longest clerical and administration service in the same division, the various series of reports published by the division were catalogued.

The last report in typeset printing in the Mines Branch series of "Investigations of Fuels and Fuel Testing" was MB Rep 737 for the year 1932.

Presumably on account of the depression and the increase in the number of industrial investigations, the results of which were privileged information, the practice of limiting circulation for this type of report was initiated. The following table sets out the various series that have been in use from 1930. Results of the completed investigations and research of wider interest to industry and the public continued to be published as Mines Branch reports and in the Memorandum series. Results were reported from 1959 in the Mines Branch Monograph, Research, Technical Bulletin and Information Circular series, and occasionally in the uncatalogued Investigation Reports. Analytical reports were numbered and issued by the laboratories concerned without cataloguing. It became the practice to prepare drafts in these divisional series of reports that were later published in the Mines Branch catalogued series. During and after World War II there were uncatalogued short series reports by the Carbonization and Combustion Sections as well as reports designated Fuels Division Reports or unpublished reports but these are omitted from the catalogued list that follows:

Series	First issue	Last issue	Total issued	Remarks
Report of Investigations of the Carbonization Section (RICS)	July 1930	Jan. 1945	199	All investigations on coal including physical and chemical surveys.
Fuel Research Laboratories Report (FRL)	Jan. 1945	July 1957	267	All investigations on coal and hydrocarbons.
Technical Memorandum (TM)	Jan. 1955	Dec. 1959	581	Some investigations, all visits, memoranda coded: number - year - section of the division e.g., 1/55-FP (Fuel and Power).
Internal Report, Fuels and Mining Practice Division (IR-FMP)	Jan. 1960	Dec. 1963	905	All investigations, visits, memoranda and translations coded: year - number - section e.g., IR FMP 60/1 - Min (Mining).
Divisional Report, Fuels and Mining Practice Division (DR-FMP)	1964	1966	565	All investigations, visits, memoranda and translations coded: year - number - section e.g., DR FMP 64/1 - SP (Special Projects)
Divisional Report (FD) Fuels Research Centre	Jan. 1967	Dec. 1970	430	1967 last year that included mining.

Reports after 1970 were listed in the semi-annual divisional reports to the director.

Note: The suffix identifying the section is omitted in the narrative.

Historical Reports: Requests were received from the director's office from time to time for project write-ups, in essence an accounting to the departmental heads or to the minister. In 1958, in connection with such a request, the division decided to prepare for the director's use a history of all research developments in the division. A supplement was prepared in 1963 in some cases and a number of copies was made up in consolidated form (IR FMP 63/205 Admin).

These historical reports expressed the continuity of the research which historically had been pursued in evaluating fossil fuel resources of Canada as they were explored and exploited and made suitable for economic utilization. The reports also represented the infrastructure of the division based on commodities over a long history. Interested readers are referred to these reports which are beyond the scope of this narrative. In the summary which follows, the year is underlined.

Peat

- "Development and progress of peat investigations conducted by the Division of Fuels" by A.A. Swinnerton (1921 - 1958) (TM 4/57 POS [Peat and Oil Shales]).

Coal

- "Summary of activities, Solid Fuel Analysis Section, 1907 to 1958" (TM 57/58 SF, [Solid Fuels]). Supplement of Summary of activities 1958-62 IR (FMP 63/10SF) both by W.J. Montgomery (1948 -).
- "Development and progress of major projects of Coal Preparation and Surveys Section" by T.E. Tibbetts (1952 -). This report consists of four parts: Physical and chemical survey of Canadian coal seams; commercial coal survey and analysis directory of Canadian coals; fuel and mineral briquetting; coal preparation, handling and storage (IR FMP 63/80 Prep [Preparation]).
- "Development and progress of the Carbonization Section" by E.J. Burrough (1927 - 1963) and J.C. Botham (1948 -) (TM 5/58-CG [Carbonization and Gasification]) and Supplement 1 to TM 5/58 (IR FMP 63/62 CG) by J.C. Botham.
- "Development and progress of mechanical engineering and combustion projects of the Fuels Division" - Part 1, 1907 to 1950, by C.E. Baltzer (1923 - 1965); Part 2, 1950 to 1958, by E.R. Mitchell (1949 -) (TM 89/58 Mech [Mechanical Engineering]) and Supplement 1 - Historical write-up of the Combustion Engineering Section, July 1958 to December 1962, by E.R. Mitchell (IR FMP 63/7 Mech).
- "Development and progress of thermal power investigations conducted by the Fuel and Power Section of the Division of Fuels, 1953 to 1958" (TM 88/58 FP [Fuel and Power]) and Supplement June 1958 to December 1962 (IR FMP 63/85 FP) both by C.E. Baltzer.

Oil Shale

- "Development of the oil shale investigations conducted by the Fuels Division, Mines Branch, Department of Mines and Technical Surveys, 1908 to 1942" by A.A. Swinnerton (TM 35/58, POS).

Petroleum and Natural Gas

- "Summary of activities - Petroleum and Gas Analysis Section, 1907 to 1962" by R.G. Draper (1949 -) (IR FMP 63/106 LF [Liquid Fuels]).
- "Developments and progress of Petroleum Reservoir Engineering Section" by R.P. Charbonnier (1954 -) (IR FMP 63/42 PRE [(Petroleum Reservoir Engineering)].

Long-term service staff recognized in late sixties

Front row, l - r: Dr. D.S. Montgomery (1948 -), chief, Fuels Research Centre (1967 - 1975), W.H. Harper (1927 - 1969), K.W. Bowles (1931 - 1971), H.P. Hudson (1921 - 1969);

Back row: A.J. Reynolds (1935-1971), L.G. Nadon (1949 - 1973)

Hudson and Harper were volunteers in World War II and rose to officer rank

Oil Refining

- "Summary of work of High Pressure Chemistry Section, 1929 to 1958" by K.W. Bowles (1931 - 1971) (TM 138/58 HPC, [High Pressure Chemistry]). This report gives particulars of work done in the old Hydrogenation Section on refining and on bitumen separation. Supplement 1 on summary of work of High Pressure Chemistry Section, 1958 to 1962 by W.H. Merrill (IR FMP 63/90 HPC).
- "A brief history of research in the catalysis project, 1956 to 1963" by B.I. Parsons (1955 -) (IR FMP 63/31 HPC).
- "Development and progress of the Petroleum Engineering Section" (TM 120/58 PET [Petroleum Engineering]) and Supplement 1 (IR FMP 63/71 PET) both by F.L. Booth (1945 - 1975).

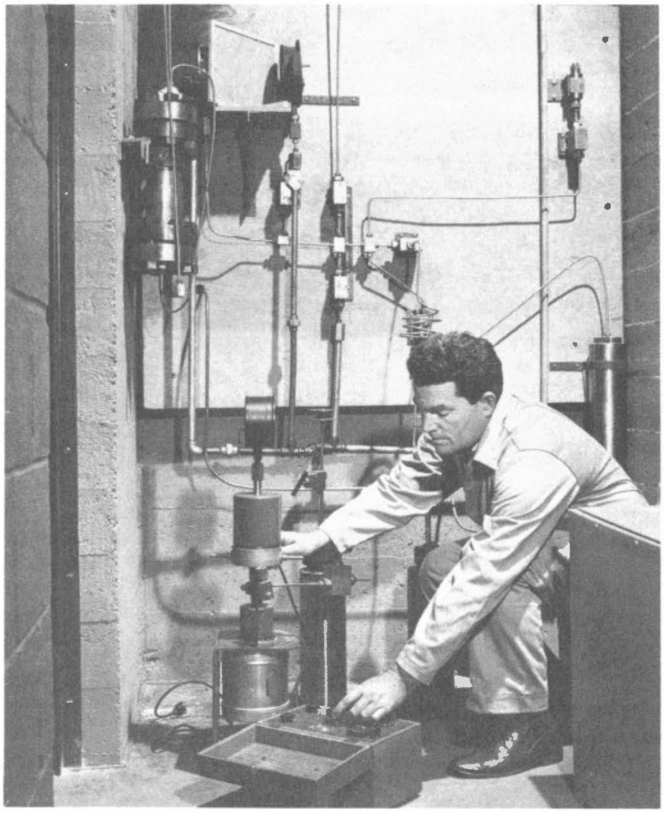
Fundamental Research

- "Historical development of the Fundamental Research Section" (IR FMP 60/205 RBS [Research on bituminous substances]). Supplement 1 (IR FMP 63/34 RBS) both by D.S. Montgomery (1948 -).

Engineering Services

As the division was considerably involved in pilot scale R & D, design and construction engineering capabilities were required and these were provided by H.P. Hudson (1921 - 1969), previously with the Mechanical Engineering and Combustion Section, largely for the coal R & D program and R.E. Carson (1948 -), previously with the Hydrogenation Section, largely for the hydrocarbon R & D program.

- "Survey of Fuels Division investigations on potential uses for coal in gas turbines in the Canadian metallurgical industry and miscellaneous methods of utilizing other solid fuels, 1946-58" (TM 141/58CE [Construction and Equipment]) and "Supplement 1" (IR FMP 63/60 CE) both by H.P. Hudson.



R.E. Carson checks high pressure porosimetry plant related to catalysis research (Photo - George Hunter)

- "Development and progress of the Engineering Design Section (TM 121/58 Engineering Design) and Supplement 1 (IR FMP 63/79 ED), both by R.E. Carson.

Peat

Due to an acute shortage of fuel in Quebec during the latter part of World War II, a joint project of the Quebec and federal governments was undertaken with technical financial assistance. Technical assistance was provided by the Bureau of Mines, which worked closely with the Quebec Department of Natural Resources. An effort was made to produce peat fuel near the city of Quebec and some 1500 tons was produced in 1943 but the results in the following year were disappointing and the project was discontinued.

In the post-war period under review, still another effort was made to encourage the use of peat in rural areas close to sources of fuel peat - a unit that could be attached to a standard coal- or wood-burning furnace was designed, constructed and tested. Results were successful and recommendations were drawn up for the user on the "effective" preparation of raw peat: "Preparation and burning of peat as a domestic fuel" by H.P. Hudson and T.R. Skerry (Mines Memorandum Series 127, 1954).

The general economic climate and the improved fuel supply discouraged the use of peat fuel. Hence the post-war thrust in the division was directed to continued evaluation of peat moss resources for agricultural and horticultural purposes. At that time the area of peat lands in Canada was estimated at 100,000 square miles with a potential of about 35 billion tons, but it was recognized that it was potentially probably even greater. It should be noted that sphagnum moss as a botanical species is dominant in Canadian peat bogs, and slightly humified sphagnum moss has been found to be better for soil conditioning compared with other moss species.

Swinnerton completed surveys of Eastern and Western Canada that updated previous resource surveys of peat bogs: "Peat moss in Canada" by A.A. Swinnerton (MB IC 104, 1958). There was a post-war international revival of interest in peat led by the Irish Turf Board, which because of the shortage of coal during the war had developed a large-scale mechanized operation for use as milled peat in electric power generation. The board organized the first international conference on peat in 1954, and Swinnerton prepared a paper "Peat in Canada".

Following Swinnerton's retirement in 1958, Tibbetts became responsible for this commodity. At this time there was considerable variation in the quality of peat moss offered for sale that included a high content of humified peat. He directed considerable effort toward establishing standards of analysis of both physical and chemical properties related to the use of peat moss in agriculture. Tibbetts was one of the founding members of the ASTM Committee D-29 on Peats, Mosses, Humus and Related Products in 1963; he became its chairman in 1971.

In connection with this standardization activity, Tibbetts established close cooperation with the peat producing countries that included Ireland, Britain, Scandinavia, Germany and U.S.S.R. The second international conference was held in Leningrad in 1963 which he attended, and largely through his efforts the third conference was held in Quebec City in 1968; the theme was peat and peat lands (muskeg). He was chairman of the conference and was assisted by B.P. McFarlane of the National Research Council, Building Research Division as vice-chairman. Tibbetts presented a paper entitled "Peat resources of the world - a review" (Proc 3rd Inter Peat Congr, pp 8-9, special volume published jointly by EMR and NRC). A spin-off of this congress was the creation of an International Peat Society, with Tibbetts as vice president and chairman of the Canadian National Committee.

At the request of the government agencies of the Maritimes, Tibbetts participated in a number of surveys; producers also sought his advice, and in cooperation with one of these - Grand Falls Peat Company of New Brunswick - a report describing an operation representative of a small bog was published: "Exploitation of a small peat bog" by T.E. Tibbetts and R.E. Kirkpatrick (MB IC 160, 1964). In Quebec, the Department of Natural Resources had a continuing interest in the exploitation of their large peat resources, the province being the second largest producer in Canada after British Columbia. Tibbetts continued the close liaison that was established with the Quebec department in the pre-war period.

In 1961, in association with R. Bruce Graham, consulting geologist, Tibbetts undertook the systematic evaluation of 14 peat bogs in southeastern Ontario.

The methodology used in the evaluation, from interpretation of topographical and aerial maps and terrain examination to sampling and analysis, was presented in a publication as a guide for future investigations, "Evaluation of peat moss as applied to some bogs in southern Ontario" by R. Bruce Graham and T.E. Tibbetts (MB TB 22, 1962). The association with Graham continued for several years due to his interest in stimulating the Ontario peat industry in competition with considerable imports from neighbouring states, particularly Michigan. A further joint study was made in the northwestern area of Ontario, "Evaluation of peat moss in some bogs of the Rainy River District, Ontario" by R.B. Graham and T.E. Tibbetts (MB TB 65, 1965).

A considerable flow of inquiries and requests for advice on peat and peat moss quality and modes of use were dealt with by Tibbetts during this period; some assistance in analysis was provided by T.A. Lloyd, who joined the Mines Branch in 1958 and was mostly concerned with R & D on coal preparation.

The production of peat moss in Canada was increasing slowly but steadily: in 1940 the production was 17,000 tons, in 1955 - 170,000 tons, and in 1965 - 267,000 short tons valued at about $8 million.

Coal

In the immediate post-World War II period, peak production of 19 million tons by the Canadian coal industry in 1949 came from a large number of mines with the highest proportion located in Alberta. About 40% of production was derived from four companies each producing annually one or more million tons, operating in Nova Scotia, Saskatchewan, Alberta and British Columbia. In 1950 there were still 356 individual mines in full or partial production with Alberta's total amounting to 207 mines employing a work force of 7999; most of these were small prairie mines providing the local domestic heating market with low-rank coal. By 1969 there were only 69 mines in Alberta with a work force of 1729. Other than in Nova Scotia many underground mines in the West closed to produce cheaper coal from strip mines. During the period to the end of the sixties government subvention assistance was provided through the Dominion Coal Board for moving the coal from the production centres in the Maritimes and Western Provinces to the markets in Ontario and Quebec.

Erosion of markets started in 1951 and continued throughout the decade with Canadian production by 1959 falling to about 10 to 11 million short tons per annum and remained at this level to 1964, recovering in 1970 when production was 16.6 million tons due to exports to Japan and to increased consumption by the Canadian electric utilities. In 1975 production was nearly 28 million tons.

At the end of the war most of the coal from the Maritimes was produced by Dominion Steel and Coal Corporation with over 5 million tons of coking and steam coal per annum, largely from their mines in Cape Breton but also from the mainland. With assistance from the Dominion Coal Board following promulgation of the Coal Production Assistance Act in 1949, some of the large producing mines were equipped for continuous mining with Dosco Miners with the aim of reducing costs by increasing productivity. Except when No. 18 Colliery was operating, the goal of lower mining costs was not generally achieved. Problems with the quality of these coals were a relatively high sulphur content usually in excess of 2%, and low ash fusion temperature of 2000°F which gave troublesome slagging on furnace grates. The large tonnages then available provided supplies to the corporation for metallurgy and for electric power generation and heating throughout the Maritimes including Newfoundland, as well as for markets as far west as the Ottawa Valley with some shipments to Toronto. For a short period the original company was owned by the Hawker Siddeley Company whereas in 1967 Dosco turned the enterprise over to the Cape Breton Development Corporation, a Crown company. Many of the old mines were closed on the mainland and on Cape Breton and the output was reduced to about 2 million tons per year but a new mine at Lingan was started.

In New Brunswick at war end about 40% of production was derived from underground mines and 60% from strip mines, all operating on a single seam 18 to 24 inches thick as most of the Carboniferous period coal measures were subjected to pre-glacial erosion. The largest producer was the Avon Company operating a strip mine. Sulphur content, usually over 5%, was substantially higher than in Nova Scotia. In 1969, coal mining in New Brunswick was put under a Crown company known as NB Coal Limited.

As for Ontario and Manitoba, the last production of lignite coal from Onakawana, Ontario, was in 1947 and from Turtle Mountain, Manitoba in 1944.

In Saskatchewan there were quite a number of producers at the end of the war, mostly located in the Souris district with one or two large mines like Western Dominion and Manitoba and Saskatchewan which accounted for about three quarters of the total provincial output, mostly from strip mines of about two million tons each. A low-temperature Lurgi carbonization plant produced about 60,000 tons per annum of briquettes for a heating market (see Chapter 3). The market for Saskatchewan lignite was for electric power generation and for domestic and commercial heating that included Winnipeg. The domestic market was almost entirely lost over a period of years mostly to natural gas but the production of lignite for electric power generation increased substantially in the early 70's to nearly four million tons, from three mines.

Alberta was the largest coal producing province with two distinct categories of mines: a small number of comparatively large mines known as steam coal mines in the inner foothills of Alberta which supplied a large proportion of its 5 to 5 1/2 million tons per annum output of high-rank coal to the railways. The remainder was supplied to industry in the West and to mixed markets even in the East with subvention help, and included some coke for foundries smelting base metals. In addition, a large number of relatively small mines on the Prairies and in the outer foothills produced about 3 million tons of low-rank coal for a widely scattered domestic heating market in the province with some shipments to neighbouring provinces.

A major problem of Western coals was the high content of fines - in the case of low-rank coals after losing about 25% moisture during storage, and in the case of the bituminous coal because of organic fragility arising from coal being sheared by tectonic forces. The hydroelectric resources of Alberta could not sustain the growing requirements for electricity. Thus large strip mines of sub-bituminous coal were developed over a period of years, and by 1970 output was again nearly as large as in the days of the numerous small mines. Whitewood mine in the Pembina district of Alberta was producing nearly 2 1/2 million tons a year for the Alberta Coal Company.

The loss of the railway market was felt quite severely by the bituminous coal producers, some of which were mining over one million tons a year. Most of the coals were of the coking type and an export market to Japan was gradually developed, though its full effect was not felt until the 70's. Major problems with bituminous coal was the production of fines as well as a high impurity content although sulphur content was usually 0.6% or less. The export specification of a 9% maximum ash required a higher standard of coal cleaning than the 15% accepted by the railways for a cheaper coal.

In British Columbia the centre was at Fernie in the southeast part of the province with similar coals but somewhat lower in ash. The Crows Nest Industries Limited, the original producer with over one million tons per annum disposed of its coal rights and plant at Michel-Natal and Sparwood to Kaiser Resources Limited in 1967. In 1949 there was also production of high-rank coal in the B.C. interior at Nicola and Telkwa and some sub-bituminous coal at Princeton but all these mines closed down.

The present-day Canadian coal industry is not unlike its counterparts in other branches of mining. Of the less than 20 active companies only six or so produce the bulk of the output, a substantial portion of which is for export. Most of the production is from strip mines using large equipment. At the Michel mine, Natal, B.C. a highly productive hydraulic mining method is being used underground at comparatively shallow depths. A problem may loom later in recovering valuable coking coals at depth when ground control becomes increasingly important. Sub-bituminous coals would not be subject to the same difficulties as they are mostly flat and at shallow depths.

Coal Surveys, Analyses, and Dust Explosibility

The evaluation of coal seam samples and of prepared or commercial coals was intensively pursued during the immediate post-war period to the late 50's when there were still a large number of individual mines. Swartzman was in charge of the coal surveys and preparation project and his first post-war assistant was D.C. Walsh (1951 - 1952) who was succeeded by T.E. Tibbetts (1952 -). T.A. Lloyd joined the division in 1956. This group was closely linked with the analytical laboratory with its long-term head, J.H.H. Nicolls, who retired in 1949 with 35 years service preceded by several years work on the joint McGill University-Mines Branch coal project (Chapter 3). Nicolls was succeeded by W.J. Montgomery who joined the laboratory in 1948. Montgomery's principal assistants were R.J. Young (1929 - 1957), G.C. Behnke (1945 - 1971), J.G. Jorgensen (1955 -), and G.C. Anderson (1950 -). Anderson first joined the division's administration office in 1950 and then transferred to the laboratory in 1958 for "on-the-job" training. He became Montgomery's principal assistant in 1971.

The physical and chemical coal survey series continued into 1955 with Report No. 153 (FRL Report 214) on the McBean mine, Nova Scotia, ending the original series. This coincided with the decline of the coal industry, but the practice of evaluating samples both from new seams and extensions of already exploited seams continued, the results being reported in the internal reports of the division. In the 60's, when prospecting and development of Western coking coal seams which were largely opened up for the export of coal to Japan, was in progress, private local laboratories were used to analyze the large number of samples involved.

Before Nicolls retired he collated the results of analyses of various samples of coal and peat that had not been included in previously published reports, and produced a 409-page volume he called his "swan song". This volume contained the widest collection of analyses of samples from diverse regions of Canada (132).

As the classification of coals by rank and the various analytical procedures for assessing physical and chemical properties developed by ASTM Committee D-5 on Coal and Coke had been in a large measure completed before the war, with considerable input from the Fuels Division, it was deemed necessary to produce an analysis directory of coal products including briquets as marketed by coal companies for use of commercial and governmental agencies. The first such directory was published on a restricted basis by Swartzman in the FRL series (FRL 1, 1945) in part related to the Carroll Royal Commission on Coal, 1946, for which R.E. Gilmore prepared a brief "Canadian coals and their classification, analysis and general characteristics" (FRL Report 2, 1945). An up-dated, official first edition "Analysis directory of Canadian coals" was published by Swartzman in the Memorandum Series in 1948 (MB Memorandum Series 100). In the case of Alberta, 50 coal areas were designated by the Research Council of Alberta (RCA) which were made official by the Alberta Coal Sales Act of 1925. Analytical data from limited production or non-operating areas reported by the RCA in their reports No. 12 and 35 by Stansfield and Lang were included in the directory as well as face samples from non-operating mines that Swartzman himself had taken. In the post-war period, the Alberta Department of Mines, through revision of the Alberta Coal Sales Act, accepted any Fuels Division analytical data relating to the province as official. Preceded by a sampling campaign of commercial coals at the mine tipples, a second edition followed in the Mines Branch series in 1953, with Supplements 1 and 2 in 1955 and 1960 respectively (MB Rep 836, 850, 868).

With the closure of mines, no further issues of the directory were published. During the years 1961 to 1968, analyses of coal and coke samples received by the laboratory were published in the Mines Branch series of Information Circulars by W.J. Montgomery and G.C. Behnke (MB IC 133, 147, 161, 173, 182, 193, 208 and 224) For the years 1969 to 1971 only analyses of coal samples were reported: (IC 249 by W.J. Montgomery and G.C. Behnke) and (IC 275 and IC 290 by W.J. Montgomery and G.C. Anderson).

Sampling of commercial coals at the tipples was revived in 1968 in the West and in 1969 in the East. Further sampling was done in 1970 and 1971 in the East and 1971, 1972 and 1973 in the West. The analytical data were published for each Annual Sampling Survey, the data for 1971 for the Eastern area (133) and for 1973 for the Western area (134) are given in the Bib-

W.J. Montgomery, head of Solid Fuels Laboratory

G.C. Anderson, analyst

J.Z. Skulski, analyst

liography. The chemical analysis of coal ash and occasionally of trace inorganic elements was done as a continuing project largely because of the usefulness of the data in the industrial applications of coal. The data were included in the original analytical directories. The analyses were made in his later years of service by J.W. Custeau (1929-1965) and then by the younger staff, particularly by J.Z. Skulski under the direction of Montgomery. A report on coal ash analyses was published in 1970 (135). To maintain a high standard of analytical accuracy in government, industrial and commercial laboratories, an interlaboratory scheme was set up in 1956 and continued for 10 years whereby samples were prepared and supplied by the Fuels Division to the participating laboratories which numbered up to 14: "The Canadian Cooperative Coal Analysis Exchange program" by W.J. Montgomery and J.G. Jorgensen (IR FMP 65/100).

Because of his expertise in properties of coal, Montgomery was requested to set up apparatus for studying the explosibility of Canadian coal dusts, with particular reference to mining hazards, and in this work he was assisted by Behnke: "Preliminary studies on dust explosibility of Canadian coals" by W.J. Montgomery, (CIM Bull, vol 53, pp 710-712, Sept 1960). With time, metal ores, particularly sulphides, and metal dusts were investigated at the request of industry: "Comparative explosibility of dusts" by W.J. Montgomery (Trans CIM, vol 55, pp 377-379, 1962).

Following Gilmore's retirement in 1954, W.J. Montgomery continued the active participation of the division in the ASTM D-5 Committee on Coal and Coke that had historically been carried on from the inception of the society. In 1971 he became secretary of the committee and in 1972 its chairman as well as being chairman from 1969 of the Canadian National Committee of the International Organization for Standardization (Committee TC 27 - Solid Mineral Fuels). At this writing he is still chairman of the D-5 Committee. Other members of the D-5 Committee at various periods were D.S. Montgomery, A. Ignatieff until 1967, Dr. B.N. Nandi - petrography; Swartzman and Tibbetts - briquetting; Botham - coke; and Visman - sampling.

Preparation

Towards the end of the war there developed a need to improve quality of various Canadian coals offered for sale. Mechanized mining was being introduced at an increasing rate both underground and in open pits. This resulted in the production of smaller sizes and more fines because of less opportunity for selective mining and hand picking of coarse waste rock. Increased use of stokers in industrial, institutional and domestic applications demanded clean sized coal without an excess of fines.

Reference has already been made in Chapters 4 and 5 to the negative properties of Canadian coals. These may be summarized on a regional basis. In the Maritimes, the ever present problems of high sulphur content and difficulties in combustion furnace grates due to low-ash fusion temperature had to be faced, particularly in the Quebec and Ontario markets where there was strong competition from better quality U.S.A. coals. In Alberta and British Columbia, the main problem was with the so-called steam coal mines which produced high-rank, friable and generally high-ash coals largely for the railway market and some industrial applications. The extent of the fines problem can be gauged from comparing the content of fine sizes (0 x 1/4 in.), between Maritime coals at about 25% and western coals at 50% and higher. The low rank, high-moisture coals of Alberta and Saskatchewan "slack" or break up in storage, unless they are treated.

Swartzman with his usual energy applied himself to encourage some of the large producers to install washeries. From his washability (sink and float) tests in the physical and chemical surveys he could give some prediction of results. An example of this effort was when the New Brunswick government gave consideration to a central cleaning plant for the Minto coalfield. Complete float and sink tests were made on various screen sizes of coal from eight mines (FRL Reports 33 and 36, 1946 by E. Swartzman); the first washery in the Minto coalfield was established in 1956 by the Avon Coal Company. Industrial- or semi-industrial-scale tests were conducted on processes that were new to Canada. Thus heavy media tests were made on a Lethbridge, Alberta, 1/4 x 3-in. size coal at the American Cyanamid plant at Stamford, Connecticut (FRL Report 119, 1949, by E. Swartzman); others were the Roberts and Schaeffer Company's hydrator and airflow processes for fine coal conducted on 0 x 1/4-in. slack from Greenhill mine, Blairmore, Alberta (FRL Report 159, 1951). Swartzman also conducted performance tests at some of the existing washeries by analyzing sink float samples from these plants, e.g., at the International mine, Coleman, Alberta, the main separation was being done by jigging (FRL Report 153, 1951) and at the Franklin mine, Nova Scotia, the main separator was an air-sand table (FRL Report 162, 1952).

There were good crushing facilities for handling various sizes of samples and several small-scale gravity separation units in the Fuels Division, but there was no integrated pilot plant. Consideration was then given in 1950 to equipping a full-scale coal preparation laboratory. In that connection Swartzman made a field survey in the U.S.A. (FRL Report 139, 1950) and prepared plans for a laboratory (FRL Report 150, 1950). However, there were higher priorities in the branch during this period and the project did not proceed.

Despite reaching a peak in Canadian coal production in 1949, the outlook was already becoming uncertain because of the rapidly improving outlook for hydrocarbons in Western Canada. The Western coal industry, accounting for about 55% of the Canadian coal production, was particularly vulnerable to competition from oil and natural gas. This was the principal reason for stationing Dr. J. Visman in Calgary when he joined the branch in 1951. In the initial period of 1951-2 he carried out a series of visits and investigations in a number of plants (Reports FRL 218 to 224 by J. Visman). Because most operators who were using air tables for cleaning coal objected to wet methods which caused winter freezing of fine washed products and drying was considered too costly, he studied the possibility of improving performance by doing preliminary work on the design of a centrifugal vibro-separator but this was terminated in favour of developing the "Compound water cyclone". Visman introduced the use of the "error curve" as an indicator of the efficiency of separating coal from refuse and the principles of statistical significance in sampling: "Sampling to pre-assigned accuracy" by J. Visman (FRL 212, 1955). His work on the cleaning of coals had to be interrupted in favour of briquetting because of complaints on the excessive amount of fines from coal supplied to the railways.

Swartzman had been making a continuous effort on briquetting coal both for the domestic heating and railway markets. Following discussions in 1945 with the Drumheller operators mining low-rank coal, in company with Dr. W.A. Lang of the RCA, a project was undertaken to produce suitable briquets for domestic heating. Various binders were used and the best results were obtained with 3% asphalt and 3% flour to reduce smokiness but there was risk of mould in the flour from prolonged storage. To obtain stability of the briquet in the fire, a minimum of 20% coking coal was required: "Report on the beneficiation of Drumheller sub-bituminous coals by briquetting using various kinds of binders" by E. Swartzman (MB Memorandum Series 92, 1947). The tests were repeated in 1953 with the coking coal admixtures to confirm the earlier tests (FRL Report 174, 1953). Low-rank coals from other areas of Alberta gave the same results except in the case of a coal from the Brooks area which yielded a

J. Visman in Calgary Office

reasonable briquet with only 3% asphalt due to the binding properties of soluble humates present in the coal.

Generally speaking, no binderless "green" briquets could be made from the Western coals including Saskatchewan lignites. On the other hand, the Onakawana, Ontario lignite was found by the Fuels Division during the war to be capable of being briquetted without a binder (Chapter 5). In 1956 a review of all low-rank coal briquetting done in Alberta was prepared at the request of the RCA (TM 9/56 by E. Swartzman), coincident with a request from the coal operators for an investigation of the Glomera high-pressure extrusion process. This was investigated by Swartzman at the Vancouver works of the licensee (TM 36/56). However, the rapid deterioration of the domestic coal market prevented the coal operators from proceeding further with binderless briquetting.

Briquetting of high-rank coals, which were supplied mostly to the railway market, coincided with increased mechanization and the mining of a larger proportion of coal from strip mines. This happened towards the end of the war and led the coal companies to build briquet plants, enabling them to supply both briquets and stoker coal. The railways were prepared to pay for an asphalt binder content of up to 4%. Swartzman became involved with determining the optimum quality of briquets in terms of maximum moisture and minimum binder contents. A summary report on the Crowsnest, B.C. coal was issued in 1953 (FRL Report 174 by E. Swartzman).

On becoming the resident engineer in the area, Visman was obliged to devote much of his time to the briquetting project. His studies of various factors influencing the strength of briquets led him to design an atomizing unit for increasing the wetting of the coal particles with the binder, a factor first noted by Swartzman in a paper presented to a briquetting conference in the U.S.A., "Study of the relationship of the quality of certain petroleum asphalts to the properties of the resultant coal briquets" by E. Swartzman, (Proc Coal Briquetting Conference - Natural Resources Research Institute, University of Wyoming, June 1949). The atomizing unit was tried in tests carried out at the Michel, B.C. briquetting plant in 1954, and showed an increase in compressive strength of 12 1/2% with a binder containing 2.9 to 3.6% asphalt and 1.0 to 1.5% of flour. Tests at the Canmore, Alberta plant confirmed that increases in moisture content were detrimental to the strength and stability of briquets. In this work Visman was assisted by C.J.F. Rozenhart and R.P. Charbonnier, who joined the Mines Branch in 1953 and 1954 respectively. This research was summarized in "Briquetting coal with binders and statistical evaluation of briquetting tests" by R.P. Charbonnier and J. Visman (MB TB 9, 1959). The atomizing unit which was patented was described in a report "Cyclone atomizer for briquet binder" by J. Visman (MB TP 17, 1957). Incidentally, both Visman and Rozenhart came to Canada from the Dutch State Mines, considered at that time one of the leaders in R & D on coal.

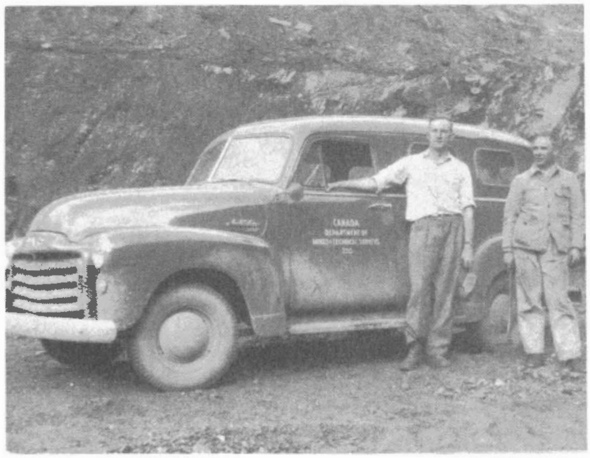
The research on binderless briquetting mentioned earlier related to the industry's concerns, particularly in the case of low-rank coals, was carried out mostly in 1958. This included application of scientific methods including microscopic study by Jacqueline Picard, who had joined the group in 1956: "Laboratory study of the binderless briquetting of Western Canadian coals" by A.R. McKenzie, Jacqueline L. Picard and J. Visman (MB TB 10, 1959).

Late in 1956 Charbonnier went on sabbatical leave to France where he earned a doctorate at the University of Paris. He also spent some time at the Institut de Pétrole in Paris as he had accepted a change of activities. In 1959 he transferred to Ottawa to undertake studies in petroleum reservoir engineering.

The Research Council of Alberta through its then director, Dr. N.H. Grace, and secretary, Dr. W.A. Lang, with the concurrence of the Alberta government and University of Alberta, suggested that the Mines Branch undertake coal preparation research on the premises of the Council's laboratories. Visman became responsible for this work. The Council offered rent-free laboratory and office space, and in 1956 Visman and his staff transferred from Calgary to Edmonton to form the Western Regional Laboratory (WRL). In 1966, with the construction of the Council's industrial research laboratory and pilot plant facilities at Clover Bar completed, much more space, particularly in the pilot plant, was made available to the WRL at a modest rental. This arrangement continues to this day. Dr. Grace died suddenly in 1962 and was succeeded the following year by Dr. E.J. Wiggins, who was equally cooperative. Dr. Lang maintained close liaison with the Dominion Coal Board and the Mines Branch as the principal federal agencies concerned with coal, participating from the start in the annual coal research meetings of the Board. Bert Lang retired in 1961 after 37 years service to RCA with tributes from the Alberta coal industry and all others aware of his contributions to the chemistry and technology of coal. Because of Grace's untimely death, Lang returned for several months as acting director until Dr. Wiggins took over. The University of Alberta, Lang's Alma Mater, awarded him a doctorate in 1966.

The space and other facilities provided by the Research Council of Alberta enabled Visman and his group over a period of several years, and particularly after moving to Clover Bar, to develop an integrated coal-cleaning and mineral-separation facility.

By 1959 Alberta's production, which supplied the largest share of the railway market in the West, had decreased to about 30% of the 1940 level. The briquetting program virtually terminated and the effort in the Western Regional Laboratory was directed to improving the cleaning of coal fines produced by the steam coal mines, which having almost lost the railway market by



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Founding group of the Western Research Laboratory: 1 - J. Visman and R. Rozenhart at Luscar Mine, 2 - R.R. Charbonnier, 3 - J.L. Picard

1959 turned to developing an export coking coal market. However, this market demanded an ash content not in excess of 9% as against the 15% accepted by the railways.

This narrative will return to the West after reviewing the technical assistance given to the Maritimes' coal industries. The problem of excessive fines was not as severe in the East as it was in the West. However, mechanization did increase the proportion of slack coal. Swartzman and Tibbetts carried out tests on Sydney high-volatile coals with and without binder to produce acceptable briquets. The binderless briquets gave encouraging results; however, a binder of 6% asphalt was required for durable briquets used alone. When used in admixture with coal, weaker briquets with a 4% content of asphalt were acceptable (TM 30/59 by Swartzman and Tibbetts). Swartzman and later Tibbetts participated in the work of the International Briquetting Association formed after the war. In 1957, a draft of the proposed standard for compression strength of briquets based on extensive testing was accepted with some revisions as a tentative standard (TM 43/57 by Swartzman).

As was the case during the war, briquetting was carried out on minerals alone or in blends with coal. These requests were particularly frequent during the 50's and came from industry or from other divisions, particularly the Industrial Minerals Division. Examples were: brucite, magnesite, dolomite, titanium slag and coal mixtures, calcined bauxite, iron borings, coke for the manufacture of an artificial abrasive, nickel-copper concentrates and argillaceous nickel ore. Swartzman published a general review article on the subject: "The significance of agglomeration in the mineral industries" (CIM Bull, pp 318-327, May 1954).

Nova Scotia was struggling to compete with the large imports of better quality coals from the United States into the Central Canadian market. Coal-cleaning facilities were introduced by the two principal producers in Cape Breton: Dominion Coal Company at Princess colliery, and the Bras d'Or Company at the Four Star mine. Similarly, New Brunswick was trying to develop markets in the adjacent New England states, and the division's, particularly Swartzman's, earlier work on coal cleaning was translated into establishing cleaning plants in the late 50's. In this connection, Swartzman and Tibbetts with assistance from Lloyd in the laboratory carried out performance tests at the Avon Coal Company's newly commissioned preparation plant on 1/4-in. x 2-in. and 0 x 1/4-in. sizes (FRL Rep 233, by Swartzman and Tibbetts, 1956), and on cleaning a carbonaceous shale and clay parting which is widespread in a single seam of the Minto coalfield. This was an important consideration as the parting could account for 25% of the seam, which varied in thickness from 18 to 24 in. and rock-to-coal ratios sometimes exceeded 20 to 1 (FRL Rep 239, 1956, by the preceding authors).

A performance test was also carried out at the plant of D.W. and R.A. Mills which started operations in cleaning strip mine coal in 1957 (TM 123, 1959 by the preceding authors). Investigations on cleaning coal from an underground mine using hand methods and from a mine with mechanized mining in the Minto coalfield were undertaken (IR/FMP 60/34 and 62/8 respectively, by Tibbetts and Lloyd).

In Nova Scotia, particular attention was paid to the smaller Bras d'Or company which opened up the 4-ft Tracy seam in the Four Star mine in the early 50's. Continuous mining on longwall faces was introduced with highly productive results. On the other hand, the high percentage of coal fines created a problem in cleaning. A performance test was carried out at Avon Coal Company's New Brunswick preparation plant in a Baum jig (FRL Report 251, 1956 by Swartzman and Tibbetts). Because of large amounts of fines not being cleaned satisfactorily, arrangements were made with the Deister Concentration Company of Indiana to carry out a test at their pilot plant on 0 in. x 1/4-in. fines which gave satisfactory results (TM 64/56, by Swartzman).

Size distribution and degradation of coal were monitored, particularly of that supplied to government buildings, with the introduction of continuous mining at the Dominion Coal Company from the early 50's. Tests were made on the effect of this method on size distribution of mine run coal at several of the company's collieries with their concurrence. At the Four Star mine, experiments with different types of continuous miners used in longwall as well as in pillar mining were monitored for size consist. Swartzman made an analysis of size distribution of Canadian mine run and slack coals in relation to size specifications (FRL Rep 203, 1955). Tibbetts also made a study of screen analyses of coals from Dosco mines in 1962 (IR FMP 62/164).

Storage of coal, sampling, analysis at user plants, specifications and government purchasing of coal were responsibilities shared with the combustion group and in this respect close liaison was maintained with Dominion Coal Board and Committee 18-GP of the Canadian Government Specifications Board.

In Western Canada during the initial period of revived interest in coking coals for markets other than railway, Swartzman and Tibbetts evaluated coking and other properties from newly developed seams such as Vicary Creek of Coleman Collieries (TM 77/57, TM 26/58 and 27/58 by Swartzman and Tibbetts). Studies of the Gieseler plastometer were made in relation to the reproducibility of test results (FRL Rep 252, 1956 by Swartzman and Tibbetts). This overlap with the Carbonization Section was due to the extensive research then being conducted by J.C. Botham on coal and gas outbursts in coal mines.

Swartzman and Tibbetts contributed a chapter on coal preparation to the volume "The milling of Canadian ores", published on the occasion of the Sixth Commonwealth Mining and Metallurgical Congress held in Canada in 1957.

Despite an earlier heart attack, Swartzman resumed his hard-working lifestyle and unfortunately died suddenly from a heart attack in 1960. Tibbetts assumed responsibility for coal and peat surveys and preparation. The Western Regional Laboratory remained autonomous but close liaison was maintained between the Ottawa and Edmonton groups. Resource studies through physical and chemical surveys were continued by Tibbetts and Lloyd but were no longer numbered in the series. On the other hand, Visman through Rozenhart, assisted the Ottawa group in collecting samples of commercial coals.

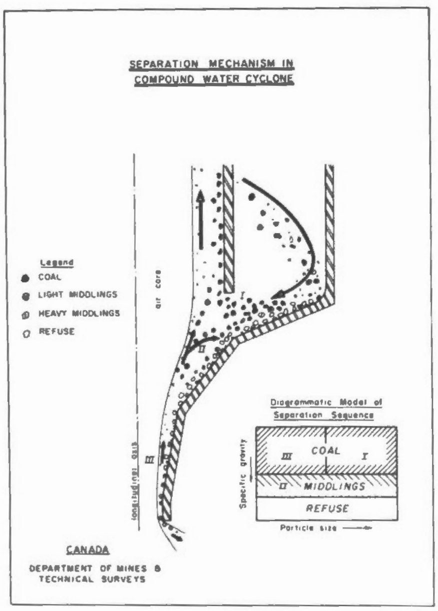
Compound Water Cyclones (Western Regional Laboratory)

Dr. Visman's motivation in developing the compound water cyclone arose from his assessment of the requirements of an industry that was severely cost-constrained in producing a competitive fuel with the allowable preparation cost limited to a maximum of about 15-20% of the total cost. He therefore looked to a high throughput separator of low capital cost. Following the evaluation of dry separation by pneumatic means, he turned to water separation using the Dutch State Mines hydrocyclone which he modified. A 2-ton per hour plant was constructed in 1959 with only five persons comprising the staff. Valuable engineering assistance was given by the Research Council of Alberta which sponsored the project on a joint basis. Bulk cleaning of 0 in. x 1/4-in. fines from mostly steam coal producing mines in Alberta and B.C. was carried out, though a Minto coal from New Brunswick was also tested with the hydrocyclone at the end of the period: "Cleaning fine coal in a 3-stage water cyclone circuit" by J. Visman (Trans CIM, vol 64, 273-277, 1961).

This preliminary work underscored the intrinsic properties of the high-rank Western coals: fragility resulting in degradation in the cleaning process, a sizeable proportion of intergrown coal particles, and the dissemination of a larger proportion than usual of fine mineral particles throughout the coal mass probably originating from upland storm water flow into the Lower Cretaceous lagoons. The practical implications were: the hydroclone was acting more as a classifier than a cleaner, the specific gravity of separation was limited with this cone to about 1.6, and higher separating gravities might be required for cleaning a wide range of coals to an acceptable ash content.

Visman was challenged by one of the more difficult problems of coal preparation practice of cleaning coals with the above characteristics, particularly if reliance is placed on the cyclone as the sole separator.

This led in 1961 to the conception, design and fabrication of a radically different cyclone which was patented in several countries and became known as the



Separation mechanism in compound water cyclone

N.E. Anderson operates a demonstration model of a two-stage water coal-washing cyclone using synthetic coal, Western Regional Laboratory (Photo - George Hunter)

compound water cyclone (CWC). The full development of this process became a major program of the division.

In this concept, Visman designed a vessel with an upper cylindrical section and a triconical lower section where coal particles were separated according to specific gravity in an unstable water medium in three successive steps using centrifugal acceleration and the principles of hindered settlement and classification. In preliminary tests, with simulated coal and natural 0 x 1/8-in. coal slack, the CWC was found to be an efficient bulk cleaner of fine coal at cut points higher than 1.6 specific gravity: "The cleaning of highly friable coals by water cyclones" by J. Visman (Proc of 4th International Coal Preparation Congress, London, 1962).

The principal associates in developing the process and many subsequent additions were Jacqueline Picard and Cor Rozenhart, with assistance from temporary employees, C.A. Blanchflower (1959 - 1960), L.S. Sims (1960 - 1969), N. Iflam (1966 - 1967) and J. Van Cruyningen (1967 - 1971). Blanchflower and Van Cruyningen were professional engineers.

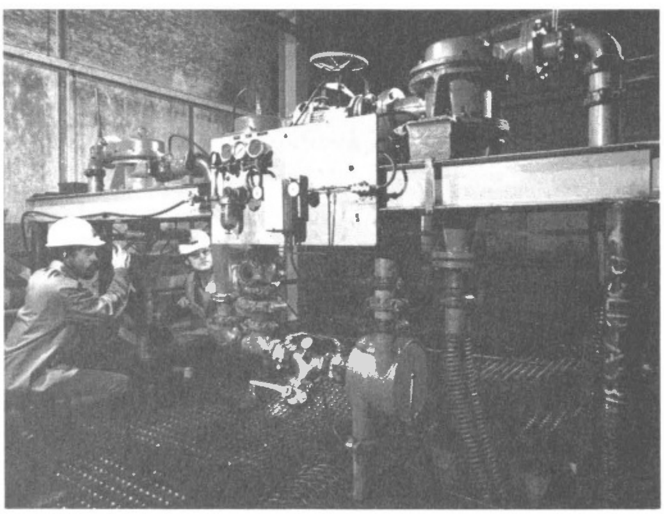
A licence for the manufacture and sale of the CWC was granted in 1962 to Cyclone Engineering Sales Limited of Edmonton, a company formed by P. Vinkenborg, engineer by profession, with Canadian associates; the choice of selecting this firm was made to encourage independent Canadian enterprise and to ensure vigorous development. Canadian coal companies required more convincing of the merits of the process than did companies in the U.S.A. and elsewhere, probably because of inability by small Canadian entrepreneurs to supply a performance guarantee.

Most of the initial research was done with 8-in. cyclones having a 2 to 3-ton-per-hour capacity, capacity being roughly proportional to the square of the diameter of the cone. Besides coal, the CWC was tested on various minerals including sand and ores of iron, barites, phosphate, etc. A paper on mineral beneficiation by this process was presented at the 65th CIM Annual General Meeting at Edmonton in April 1963 "Bulk processing of fine materials by compound water cyclones" by J. Visman. (Trans CIM, vol 69, pp 85-98, 1966).

By 1964, a range of five models of the CWC was developed for dealing with minerals from 2 1/2-in. to 0, cyclone sizes from 24 in. to 2 in.-diameter, and capacities from 70 tons per hour of coal and 160 tons per hour of ore to 6 tons per hour. Matching classifier cyclones were also designed to separate according to size; the lower compound section was made exchangeable with the classifier section. The small 2 in.-diameter multiple units were designed to operate at low pressure on slimes and sands and were tested and installed for desanding river water: "Low-pressure cyclone for desanding industrial water" by J. Visman and C.J.F. Rozenhart (MB TB 86, 1967). A successful application was made in beneficiating diatomaceous earth which required a separation at 10 microns. An automatic control for the two-stage CWC system was designed. A densifying or "slugging" cyclone was developed with the aim of obviating settling ponds and to prevent pollution of stream and river systems. The trend towards the use of the cyclone for de-watering, effluent treatment, clarifying water, and conservation of water in closed circuits, accelerated in the middle 60's, partly because of public emphasis on protecting the environment but due to a large extent to Visman's attitude from the start of the R & D work on the hydrocyclone when he said "Coal preparation should clean up its own dirt". A paper was given to the 5th International Coal Preparation Congress in Pittsburgh in 1966: "Two stage beneficiation of washing effluents with compound water cyclones" by J. Visman.

By 1966, when the laboratory was moved to Clover Bar, the CWC pilot plant was modified and enlarged with a capacity of 5 tons per hour consisting of integrated facilities for coarse coal cleaning, slime beneficiation and water clarification. A number of operational innovations were made and most were patented, including the addition of a pulp divider that enabled the cleaning plant to operate with a single circulating pump.

At that date the combined installed capacity in five countries including Canada of industrial applications of the CWC system was approximately 1500 tons per hour of dry raw feed.



Two-stage 8-in. cyclone system at Western Regional Laboratory in Edmonton operated by N.E. Anderson and representative of Cyclone Engineering Sales Limited (Photo - George Hunter)

During the foregoing period, Visman continued his interest in developing a theory of sampling. Such a theory was introduced which defined two variance components and was expressed in a general equation for practical use and application to incremental sampling: "Towards a common basis for the sampling of materials" by J. Visman (MB RR 93, 1962). The matter was pursued in the ASTM Sub-committee on Sampling of the D-5 Committee of Coal and Coke. In 1969 a paper was published in the ASTM Journal that provided the basis for standards for mechanical and manual sampling of coal: "A general sampling theory" by J. Visman (Materials Research and Standards, vol 9, pp 8-13, 51-56,62,64,66; Nov 1969). The extensive use of statistical methods in this analytical work led Visman and Jacqueline Picard to publish a useful reference: "Guide to engineering statistics" by J. Visman and Jacqueline Picard (MB IC 233, 1970).

Carbonization

In 1949 approximately five million tons of coal was carbonized in Canada, representing about 12% of the total coal supply of 41 million tons including 22 million tons of imports mostly from the United States. Somewhat less than 2 1/2 million tons of coke was produced by the Ontario steel industry from coals imported from mines largely owned by the industry. About 1.3 million tons of coke was produced mainly from Canadian coal, of which about one million tons of coke was manufactured in Nova Scotia and Quebec, and the remainder in the Western Provinces. About three-quarter million tons of coke was imported from the United States and about one-quarter million tons was exported to that country.

Twenty years later, in 1969, about 7 million tons of coal was carbonized, representing 25% of the total coal supply of 29 million tons of which about 17 million tons was imported. About 4 million tons of coke was produced by the Ontario steel industry, which still relied on imports of coal, often from its own mines in the United States. The coke rate for some blast furnaces had been reduced to almost half of the 1949 figure; hence the increase in coke consumption reflected the large increase in blast furnace productivity by the Ontario steel industry. The production of coke from Canadian coal was about one million tons and was almost wholly used in metallurgy. In 1969 the imports of coke had fallen to about 300,000 tons and nearly balanced exports. In that year there was already a sizeable export of 1.1 million tons of coking coal from steam coal mines of Alberta and southeast British Columbia to Japan.

An explanation should be given for the definition of the section responsible for the carbonization R & D program of the division as the Carbonization and Gasification Section with E.J. Burrough at its head from 1945 to 1963. The term "gasification" was related to manufactured or city gas in Canada, a product of carbonized coal with coke as a byproduct before natural gas became plentiful in the fifties. A study "Coke and Gas Industry of Canada" was prepared for the Carroll Royal Commission on Coal in 1946 (FRL reports 11 and 11a, 1945 and 1946 respectively by E.J. Burrough). The last paper dealing with manufactured gas by E.J. Burrough was published in 1953 (Canadian Mining Journal, November 1953). An international conference on complete gasification of mined coal was held in Liége, Belgium in May 1954 where a paper was presented on the limitations of gasification in Canada because of rapid developments of natural gas. "Gasification of coal relative to the Canadian fuels economy" by A. Ignatieff, E.J. Burrough and R.B. Toombs.

As will be seen from the narrative, the work of the Carbonization Section in the late 50's was directed to assisting the original coal companies and later the newcomers to develop a Japanese market as an alternative to closure. Equal attention was given to optimizing applications of coal and coke in the Canadian metallurgical industry with a considerable effort made to evolve significant methods that could predict coking properties of single or blended coals to be carbonized in industrial ovens.

At the end of the war, emphasis was placed on producing smokeless fuels, from indigenous coking and non-coking coals to compete with imported smokeless fuels, particularly for the Eastern domestic and institutional heating markets. In this connection, the Disco fluidized process for producing coke or char was investigated, not only for heating applications but as an additive to improve the strength quality of weak coke in metallurgical applications. However, smokeless carbonized solid fuel for heating was supplanted in less than a decade by natural gas that closed city gas facilities and attendant coke-making except in the Maritimes, and at facilities for foundry coke production in Montreal.

To improve the strength property of the relatively soft coke produced at the Sydney coke ovens, a study was started at the request of Dosco in 1948 blending Sydney coal with a volatile content of approximately 32% with mainland Pictou County coal from the Drummond mine with a volatile content of 24%. (FRL Report 164 by E.J. Burrough and J.C. Botham, 1952). Tests were also made with coal from Acadia, a Dosco mine in Pictou County with a volatile content of 28% (FRL Report 180 by E.J. Burrough and J.C. Botham, 1953). The preliminary results in the Bethlehem testing oven were encouraging but the oven was too small for standard ASTM shatter and tumbler tests for commercial evaluation. Hence, arrangements were made with the Montreal Coke and Manufacturing Company (now Gaz Metropolitain Inc.) to carbonize four 480-lb samples in their Russel moveable wall gas-heated, technical-scale oven at La Salle, Quebec. These tests demonstrated that a content of 25% Drummond coal increased the shatter index by 20% and the abrasion index by 10%. It was hoped that an in-plant transportation freight rate between the mainland and Cape Breton would allow delivery of this coal at reasonable cost; however, this was not achieved. Later, blends of 30% imported low-volatile coal from the United States became the practice at the Sydney Steel Works.

Technical- or pilot-scale tests were carried out at La Salle on several Western coking coals before the installation of an electrically heated moveable-wall oven at Mines Branch in 1962 (TM 51/58 by J.C. Botham and E.J. Burrough).

It is interesting to note that blends of up to 30% oxidized strip mine coal with underground coal indicated that sufficiently firm coke could be produced in the Curran Knowles sole heated ovens of The Crow's Nest Pass Coal Company, Limited, Michel, B.C. - at least for lead blast furnaces. In 1956, as the result of a complaint from the Vancouver Gas Works that some of the railway car deliveries appeared to contain non-

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coking coal, an investigation was made by Visman in association with Botham at the Luscar, Alberta, strip mines and preparation plant. Samples were taken of the in situ coal in the strip mine and of the prepared slack in the plant. This study that included statistical analysis of variability patterns as expressed by Free Swelling Index showed that the possibility of shipping entirely non-coking coals was remote. The implication was that strip mining of coking coal would be acceptable provided the delivery of oxidized coal from the mine was spread out and the coal streams were effectively blended in the plant. This was important as previously the opinion was generally held that only underground-mined coal should remain as the feed to coke ovens and retorts: "Coking properties as indicated by Free Swelling Index of strip mine coal from Luscar Coals Limited, Luscar, Alberta" by J.C. Botham (Fuels Research Rep 229, 1956) and "The pattern of variability of swelling indices of Luscar strip coal" by J. Visman (Fuels Research Rep 229A, 1956). At the present time a very large proportion of coking coals now mined in Western Canada is derived from strip mines.

The evaluation of coke for specific applications has been an important activity of the Carbonization Section. In 1947 the American Foundrymen's Association (AFA) requested the Mines Branch and the U.S. Bureau of Mines to develop a method of evaluating coke for cupola use in foundry practice. The Physical Metallurgy Division suggested that the Fuels Division evolve a method for indicating the reactivity of foundry coke. A method was developed which measured electrical conductivity of coke, indicating the degree of graphitization that had taken place during carbonization. Samples by the AFA were examined for three years and results reported to the Physical Metallurgy Division. Further work on reactivity was undertaken later in relation to coke used in blast furnaces.

At the request of the Fuels Division, N.C. MacPhee, chief of the Physical Metallurgy Division, visited the coke producers of Western Canada and explained to them the foundryman's concepts of the size and quality requirements of coal for foundry coke.

In 1954, a cooperative study was started with the U.S. Bureau of Mines wherein coals from three Canadian coking plants were carbonized in the USBM-AGA (American Gas Association) experimental retort as well as in the Bethlehem oven in the Fuels Division: "Sampling of coal and coke for FRL-USBM cooperative program re correlation of physical quality of coke of BM-AGA test with commercial coke" by E. Swartzman and E.J. Burrough (TM 17/56). The properties of these laboratory-produced coals were compared with the cokes made with the same coals in the industrial ovens referred to. Results were published by the U.S. Bureau of Mines.

In 1952, H.P. Hudson, who was then attached to the McGill coal-fired gas turbine project, conceived the idea of employing a modified cyclone combuster as a 2-chamber smelting unit for high-temperature, direct reduction sized iron ore by using coal fines. Bench-scale tests showed promise and the R & D work continued with the cyclone combuster furnace when it was released from McGill and was converted to a 2-chamber unit - the combuster producing heat only and a reduction chamber which had a charge capacity of about one ton per hour. Two progress reports were made on this process which was patented and eventually turned over to Canadian Patent and Development Limited: Reports TM 29/57 by H.P. Hudson and IR FMP 60/200 by J.H. Walsh and H.P. Hudson. Related to the cyclone iron ore reduction process, research was carried out on the high-temperature reduction of iron ores (Mineral Dressing and Process Metallurgy Report, 1958 by J.H. Walsh and H.P. Hudson). Because of the replacement in Eastern Canada of city gas and attendant production of coke by natural gas to encourage growth of the foundry industry in the West, a cyclone cupola using coal was proposed by Hudson and was patented (TM 3/57).

By the middle fifties, it was evident that the Canadian coal industry could survive only by the bulk use of coal in combustion and metallurgical applications. In 1956, a memorandum (TM 61/56) was addressed to the director with a proposal, which was approved, to establish a branch smelting panel with particular reference to thermal use of Canadian coal in metallurgical heat processes. At that date, specifications for fuels were established in many cases by long-standing practice, but changes were taking place in smelting techniques. Hence, it was considered appropriate to develop information on the specific role of the reductant and energy components in metallurgical applications as had been done over many years in the combustion of fuels in heat and power applications. It was proposed to work cooperatively with the Mineral Dressing and Process Metallurgy Division acting as principals on R & D projects such as the direct reduction cyclone project. Dr. Walsh, who had joined that division in 1955, was appointed to the panel together with Botham and Hudson from the Fuels Division.

This action inaugurated an intensive period of R & D with technical-economic studies by a small but dedicated staff. A liaison group was formed in 1957 between the Coal Research Committee of the Coal Division and the Iron and Steel Committee of the Metallurgy Division of the CIM. A paper reviewing potential use of coal in the Canadian metallurgical industry was presented by Walsh, Botham and Hudson at the Ottawa Annual General Meeting of the Institute in 1957 (Trans CIM, vol 61, pp 57-64, 1958). A companion paper "Fuels in the Canadian non-ferrous metals industry" was presented by J.C. Botham, J.H. Walsh and R.M. Ennis at the CIM Annual General Meeting in Toronto in April 1960 (CIM Bull, vol 54, pp 466-471, June 1961).

In 1959, Walsh was transferred to the renamed Fuels and Mining Practice Division in the Mines Branch reorganization of that year as a consultant metallurgist and advisor to the director on primary process metallurgy. Because of his capabilities in innovation, a small research group named Metallurgical Fuel Engineering was formed in 1964, but he also continued in his consultant's role and in his close liaison with the Carbonization Section.

By 1959, coal production in Canada had fallen to about 55% of that in 1949. A Federal Royal Commission was appointed in that year with the Hon. I.C. Rand as Commissioner and W. Keith Buck, Chief of the Mineral Resources Division, as secretary. The essential terms of reference of the Commission were to assess present and future markets for Canadian coal and the steps that could be taken to reduce the cost of production to ensure economic viability of the industry. The division prepared six studies for the Commission on topics ranging from mining to utilization and carried out R & D. Though the inquiry was Canada-wide, emphasis was placed on the operations of Dosco, which was facing rising costs despite mechanization of the mines. For the mining end the expert advice of W.V. Shepherd of the National Coal Board was sought, and he was assisted in his investigations by Alec Brown, head of the Mining Section of the division. Seven reports were prepared for the Commission by D.S. Montgomery, A. Brown, C.E. Baltzer, E.R. Mitchell, T.E. Tibbetts and A. Ignatieff. Commission Recommendation 14 confirmed the direction the Mines Branch had taken in pursuing R & D to extend the bulk use of coal in combustion and metallurgy. Additional funds were recommended for this work.

As a follow-up to the Commission's recommendations, the Maritimes Region Study Group (MRSG) was formed in 1960 with participation of the Mineral Resources Division and Walsh as secretary. Six reports (MRSG 1, and 3 to 7 inclusive) were prepared by Walsh and Botham during 1961 and 1962, dealing mainly with Dosco's metallurgical and fuel problems. These reports included studies on substituting 25 to 30% low-volatile coal from the United States in feed to the Sydney ovens to improve the strength quality of the resultant coke and to assess the weathering properties of the U.S.A. coals in storage. With formation of the Atlantic Development Board, this group's activity developed into a consultative activity mainly through Walsh to the technical adviser of the Board, Dr. G.C. Monture.

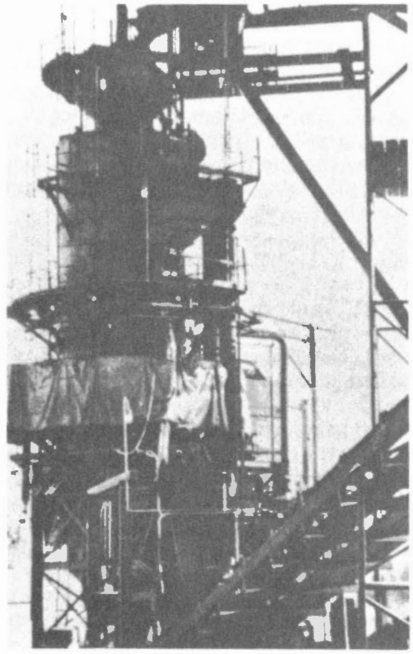
Because of the substantial importation of a large proportion of the coal tar required in central Canada, Dr. W.R. Horn, previously with the Domtar Company, was commissioned as a consultant to survey the plants including Dosco. He prepared a report "Present position and future prospects of the coal tar industry" by W.R. Horn (IR FMP 63/142). A research project on applications related to carbonization was carried out earlier by Montgomery and Frances Goodspeed in the late 50's in the context of the Research on Bituminous Substances program. In part, the project arose from the difficulty experienced by a Canadian supplier of coal tar pitch meeting the specification for electrode pitch. Infrared absorption spectroscopy was used to determine the structural features responsible for establishing the electrode compressive strength associated with various binders. Both coal tar and petroleum pitches were used. Two internal reports were issued: "The correlation of the infrared absorption spectra of coal tar and petroleum pitches with the electrode compressive strength" by F.E. Goodspeed and D.S. Montgomery (FRL Rep 213, 1956) and "Infrared spectroscopy as a means of evaluating pitches for use as binders in the preparation of electrodes for the aluminum industry" by the same authors (FRL Rep 262, 1957). The research earned Montgomery and Goodspeed the award of Bituminous Coal Research, Inc of U.S.A. for 1957.

A Western Region Coal Study Group was formed in 1961 to provide information to a group of high-rank coal producers in Alberta and B.C. and to government, transportation, dock and labour interests. This was coordinated by W.C. Whittaker, managing director of the Coal Operators' Association of Western Canada and member of the Dominion Coal Board. A preliminary survey was made by Botham of present and future markets for metallurgical coal in western U.S.A. (IR FMP 61/98), and this report was followed by a joint study by Botham and R.B. Elver of the Mineral Resources Division: "Coal and other carbon form requirements for the production of elemental phosphorus in the western United States" (IR FMP 61/156, 1961). A final overall report was issued entitled "Markets for metallurgical coal and coke in western United States and Western Canada" by T.H. Janes, J.C. Botham, R.B. Elver and J.H. Walsh (MB IR 61/131). A companion report was issued on pyrometallurgical processes: "The use of coal in pyrometallurgical processes in western areas of Canada and the United States" by J.C. Botham, J.H. Walsh, R.B. Elver and T.H. Janes (IR FMP 62/84). During this period of joint study with the Mineral Resources Division, a study on the choice of steel plant siting was published in the Mineral Resources Series: "Technical and economic factors in the choice of steel plant location" by R.B. Elver, T.H. Janes and J.H. Walsh (Min Information Bull MR 66, 1963).

Because of the substantial distances involved to many of the Western coal markets and in the light of the comprehensive program on pipeline transportation by the Research Council of Alberta and developments in other countries, a Working Party on the Movement of Solids (WPMS) was set up in the division in 1962 as an awareness project to evaluate the technical and economic feasibility of various transportation methods. Ten reports were issued from 1962 to 1964 by Brown, Charbonnier (the largest number), Mitchell and Walsh. Pipeline transportation from coking coal-producing centres to the West Coast was studied again in the late 60's and early 70's.

Aside from these studies, R & D work was vigorously pursued simultaneously to assist the Western coal industry develop markets for metallurgical applications. As will be noted later, the large coal companies such as Crow's Nest Pass, Coleman and West Canadian possessed large reserves of coking coals mainly of medium volatile rank. They were thus able to develop opportunities for exporting their coal to Japan. On the other hand, mines producing non-coking coals, either high-rank like Canmore or high-volatile sub-bituminous like Lethbridge, were not eligible for conventional coke markets. Canmore, with its low-volatile to semi-anthracite rank, had supplied the railway market and was the first in developing a small market with a Tokyo gas company through the efforts of W.A. Wilson, general manager, dating to 1953. Lethbridge on the other hand could aspire only to the production of char for a Canadian market.

A joint program with Canmore was carried out, first by small-scale tests in a vertical shaft constructed at the Mines Branch, in which briquets of blends of Canmore coals were carbonized to produce "form" coke. This was followed by a larger experimental furnace constructed at Canmore with a capacity of 2 tons per hour. Finally a plant of 30,000 tons per annum capacity with recovery of crude tar and surplus gas recovery was commissioned in 1963 and export was started to the United States for the phosphorus market.



Vertical shaft furnace developed jointly with Canmore Mines Limited

The work at Ottawa was reported in 1959: "Carbonization of Canmore (Alta) coal briquets in a vertical shaft furnace" by H.P. Hudson and J.H. Walsh (TM 84/59). A joint Canadian patent was issued in 1964 entitled "Method of treating coal" in the names of H.P. Hudson, W.J. Riva (Canmore) and J.H. Walsh. In 1965 a vertical shaft furnace, 3 1/2 ft in diameter and 14 ft high was erected at the Mines Branch, with interest shown and assistance given by two steel companies. Its purpose was to measure the many process variables for improving the coke produced to the standards required for the iron blast furnace, matters that time limitations in the early work for Canmore did not allow to complete. The more expensive briquetting method was replaced by pelletizing and later by extrusion using a binder of 1% each of tar derived from the process and bentonite. Extrusion offered possibilities of producing coal-iron agglomerates of varying cross section; a cruciform shape provided a high surface area and low bulk density. Several iron ore-coal blends were extruded including a large tonnage of ilmenite. Further research indicated that the coked iron ore agglomerates could be smelted in an electric "open-bath" smelter, the reduction time of the ore in close contact with the coke being very fast. This led to a patent being granted in Canada and the United States titled "Reduction in coke-combustion in slag-iron process" by J.H. Walsh, H.P. Hudson, J.C. Botham and J.E. Landon (1958-1970).

In the case of Lethbridge Collieries, a Canadian Pacific affiliate, a market for char was available in Cominco's electric pig iron furnaces at Trail if the product were satisfactory. Hudson, assisted by Landon who transferred in 1961 from the Technical Services Division, carried out trials in 1963 in the rotary kiln in Calgary and in the small vertical shaft reactor in Ottawa (IR FMP 63/160). As the position at the mine became urgent through loss of markets, the manager, R.D. Livingstone, decided in favour of a Wise Salem rotary hearth carbonizer that had just come on the market, following consultations and visits by Botham to the Wise Coal Company at Dorchester, West Virginia. This was one of the partners in the joint development with the Salem Brosius Company of Pennsylvania in 1961 of the Wise Salem oven. This oven incorporated the beehive principle with the rotating hearth used in roasting or sintering metal ores.

In 1964, M.A. Malek joined Walsh, enabling him to commence a research program on improving throughput of conventional vertical slot coke ovens by means of heat treatment of the coal feed. The selected method for study was the "spouted bed" gas-solid contacting method invented earlier by Dr. P.E. Gishler at NRC. Useful data for studies with the branch moveable wall oven that was installed in 1962 were quickly obtained in relation to the expansion properties of two low-volatile and one medium-volatile coals. Maximum expansion to about 150°C was noted, declining to about 200°C preheat with no change to 300°C, the maximum temperature studied. This suggested a minimum preheating temperature of 200°C. A second factor - bulk density - was also studied. It was noted that preheating of the coal reduced the bulk density within the full range of 300°C studied. Added moisture reduced bulk density whereas the addition of hot oil to the spouting bed increased bulk density. A related study was carried out of heat transfer in cold and preheated coals of varying bulk densities. The results of this research were presented at the International Conference on Coke in the Iron and Steel Industry honouring the 300th anniversary of Charleroi in Belgium, September 1966, titled "The treatment of coal for coking by the 'spouted bed' process" by M.A. Malek and J.H. Walsh. Malek suffered an untimely death in a car accident in 1966. Dr. B.H.P. Whalley transferred from the Extraction Metallurgy Division in that year.

With the request and financial support from the Dominion Coal Board, a research project was undertaken in 1966 by Walsh and Whalley to reduce to a minimum the pyritic sulphur of Cape Breton coals. Using a heavy liquid in their centrifuge as a separating method, the sulphur content was determined for various size ranges and it was established that the grinding of coal to below 100 mesh would be required for levels of less than 1% sulphur. As fine coal is not acceptable as feed for carbonization, an agglomeration step was required. A further requirement was dewatering of the fine coal as wet grinding would be used. Thus, a subsidiary study was made to dewater coal fines by centrifuging with a coke oven light tar. Meanwhile, the NRC had developed a similar approach for rock-coal separation of Western high-ash coals using the hydrophobic property of coal. Their technique, suitably adjusted to the Cape Breton coals, was used. In this project, besides Walsh as leader, the following also participated: Visman, Whalley and S.M. Ahmed who joined the group in 1968. A preliminary report was given at the Annual General Meeting of the CIM, Vancouver, B.C., in 1968 - "Study of pyrite removal from Cape Breton coals destined for use in metallurgical processes" by B.J.P. Whalley, S.M. Ahmed and J.H. Walsh. A similar report by J.H. Walsh, J. Visman, B.J.P. Whalley, and S.M. Ahmed was published in the Proceedings of the 9th Commonwealth Mining and Metallurgical Congress, London, 1969 (vol 3, pp 143-177).

Next, a continuous process was proposed consisting of agglomeration in an agitated medium of hot water

B. Whalley

with coke oven tar resulting in the separation of oil coated particles of coal from the hydrophilic particles, drying the agglomerates, preheating them not in excess of 350°C and then feeding the product into the slot oven. Patents on the process titled "Use of spherical agglomeration in the production of coke" were issued in the U.K., Canada and U.S.A. in the name of Walsh, Whalley, Botham and Ahmed.

Related to concern by the Dominion Coal Board of the large stockpiling of coal that would be involved at mines and ports in exporting, D.S. Montgomery and his Bituminous Substances Research Group carried out two projects on oxidation of coal. The loss of coking capacity as an indicator of oxidation of a coking coal was usually measured by determining physical properties such as dilatation or plasticity. Montgomery with B.S. Ignasiak (NRC PDF) and B.N. Nandi developed a more effective chemical method in which the coal was heated to 350°C and the gases analyzed for amounts of carbon monoxide and carbon dioxide, the results being compared with the dilatation data: "Comparison of dilatation and the chromatographic analysis of the pyrolysis gases as methods for studying coal weathering" by B.S. Ignasiak, B.N. Nandi and D.S. Montgomery (Trans CIM, vol 73, pp 70-74, 1970). In another project, the reaction of oxygen with coal was followed and it was found that the principal cause of loss of coking capacity was due to the formation of phenolic hydroxyl groups which undergo polymerization just below the normal melting point of coal: "Oxidation studies on coking coal related to weathering: (1) Chromatographic analyses of pyrolysis gases as a method for studying coal weathering" by B.S. Ignasiak, B.N. Nandi and D.S. Montgomery. [Fuel - the science of fuel & energy (U.K.) vol 49, pp 214-221, April 1970]

During the period under review, Walsh pursued an active role as consultant to the director in the broad aspects of process metallurgy and such projects as establishing the Canadian Metallurgical Quarterly in 1962. This was under the auspices of the newly formed Metallurgical Society of the Canadian Institute of Mining and Metallurgy and the Mines Branch which funded the publication of this scientific journal for several years. The successful launching and subsequent monitoring of this project required a considerable amount of his time.

Through studies and visits Walsh followed developments throughout the world in primary metallurgical processing of ferrous and non-ferrous ores. He was particularly interested in direct iron ore reduction and the possibilities of continuous steel production: "The present place of direct reduction processes in the iron ore and steel industries" by J.H. Walsh, presented to the Hamilton Branch of CIM, February 1964 (IR FMP 64/85). He developed an interest in the energy component of iron- and steelmaking, appreciating the large requirements and losses in the interrupted processing of iron and steel to end products. Thus he co-authored the paper with F.J. Pierce of The Steel Company of Canada Limited, titled "Energy requirements of the Canadian steel industry" (Proceedings of Sectional Meeting of the World Power Conference, Section IV A - Industry, vol V, pp 2370-79, Lausanne, Sept 1964). He conceived a process for producing steel directly from iron ore, utilizing the exhaust gases now largely wasted from an oxygen steel converter for the reduction of iron ore by injecting hydrocarbons such as natural gas and naphtha into the exhaust gases. This causes the gases to cool while achieving dissociation of the injected hydrocarbons to form a rich reducing gas-carbon monoxide and hydrogen - which passes through a bed of iron ore to produce a reduced and a preheated feed to the oxygen converter. This invention was patented in Canada and U.S.A. under the title "Process for utilizing hydrocarbon injection into hot reducing gases in iron ore steel making" by J.H. Walsh. Walsh's interest in industrial conservation of energy continues to the present day.

The most intensive development of the carbonization program occurred during the period from 1957 to 1965. An overview of this period suggests that it started with a consultation on petrography of coking coals by an integrated Canadian steel company followed by Japanese steel industry acceptance of Western coals as blending coals. This resulted in the establishment of comprehensive laboratory- and technical-scale evaluation facilities which were of interest not only to the Japanese but to Canada's own steel industry. The final step was formation of the Canadian Carbonization Research Association in 1965.

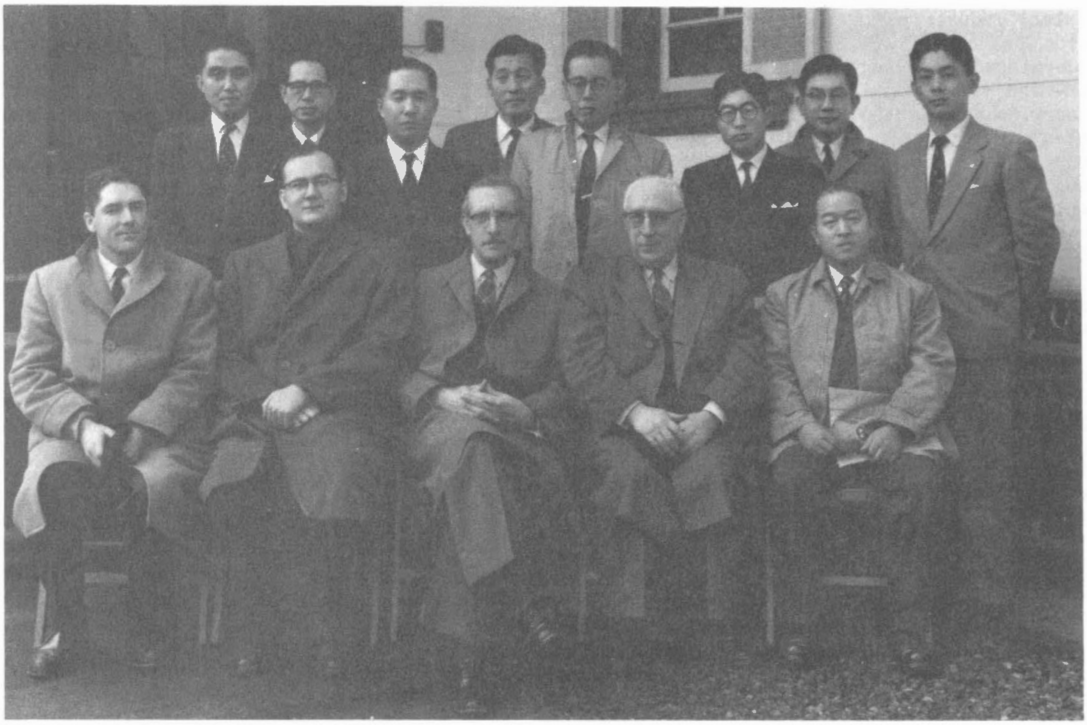
The Steel Company of Canada was the first integrated steel company to consult the division on coal petrography as a tool to aid the selection of coal blends for coking, and a meeting was held by Swartzman with the Stelco officials in March 1957 (TM 23/57). Swartzman, who started in a preliminary way to apply petrography in his coal preparation studies from 1946, had earlier visited the U.S. Steel Corporation which made the first industrial effort to use it in relation to carbonization (TM 16/57). In Western Canada the original "steam coal" producers of railway coal commenced negotiations in the middle 50's with Japanese steel interests through Japanese import companies; their steel mills had already started on major imports from the United States of premium low-volatile coals which they mixed with their own higher-volatile coals. In 1958 a decision was made by the coal operators of Western Canada to send a delegation representing the principal Canadian mines and W.C. Whittaker, executive director of the Coal Operators Association and member of the Dominion Coal Board. They requested that E.J. Burrough accompany the mission as technical advisor. A month was spent in visits and negotiations: "Technical report for Canadian Coal Mission to Japan, October 28 to November 22, 1958" by E.J. Burrough (TM 27/59). It became clear that the Japanese would be importing various coals to spread their sources. Following this visit, samples of Japanese, United States and Australian coals were obtained with assistance from the Dominion Coal Board.

A comprehensive program using various blends of Western Canadian coals with samples from the above countries was carried out on a technical scale in the La Salle Russell oven. On the basis of these investigations, the Coal Operators Association requested the Mines Branch through the Coal Board for a second mission to Japan. Whittaker led this mission that included Botham and Walsh as technical experts. The emphasis in this mission was on technical and not commercial matters: "Report of the Technical Coal Mission to Japan, January 19 to February 10, 1960" by J.C. Botham and J.H. Walsh (IR FMP 60/ 104). As a result of this visit, the Japanese contracted for 420,000 long tons of coking coal from the Crow's Nest Pass Coal Company, Limited, this being additional to the earlier contract for 100,000 long tons of semi-anthracite from Canmore Mines by a Tokyo gas company. It is pertinent to quote from the opening address by the Hon. J. Watson MacNaught, chairman of the Coal Board, at the 19th Dominion-Provincial Conference on Coal in Regina in 1967, who said in part "...that may have been the most useful trip made in the last decade by Canadian technical experts to a foreign country. I think it and the experiments in Ottawa which preceded it may be regarded as the turning point in the efforts to establish acceptance for our coal. The Japanese left no doubt that they were greatly pleased by it and the opportunity for direct technical discussions. They told Mr. Whittaker that no other nation having coal to sell had ever taken the trouble to send two such competent people as Dr. Walsh and J.C. Botham to visit them."

The price offered Canadian producers was lower than for the low-volatile coal of U.S.A. producers essentially because most Canadian coals are of medium-volatile rank, i.e., with a lower fixed-carbon content, and only a small proportion of the coals would qualify for low-volatile rank. Furthermore, Canadian coals were generally higher in ash and in the proportion of fines than those offered by U.S.A. and Australia.

Tests in the moveable-wall Russell oven at La Salle continued for a further two years. An example of the work done involved the development by Canmore of some of its low-volatile coking seams in the upper horizons of the stratigraphic column. Mixtures of blends of Canmore Stewart seam and U.S.A. high-volatile coals were carbonized in the La Salle oven and the cokes evaluated (IR FMP 60/212 by J.C. Botham). Another example resulted from the visit to the Mines Branch in June 1961 by a Japanese technical group which requested that samples of Greenhill No. 1 coal from West Canadian Collieries be investigated at the technical-scale level (IR FMP 61/132 by E.J. Burrough and J.C. Botham).

Interest in the potential of Canadian coals was also developing by some of the Ontario integrated steel companies. Thus in 1961, the Algoma Corporation requested a study blending low- and high-volatile coals the company was importing from its own mines in the U.S.A. with medium-volatile coal from the Crowsnest area, the tests being carried out in its own test oven at Sault Ste. Marie (IR FMP 61/11 by Botham and Burrough). Also in the same year, Stelco again approached the branch for an evaluation of a new low-sulphur coal which the company could substitute for a high-sulphur coal. This was in connection with use of a richer pellet feed to the blast furnace that would result in lower slag volumes which might not strip all of the sulphur from the hot metal. Preliminary tests in the sole heated oven and other physical and chemical tests including petrographic examination by Dr. P.A. Haquebard of the Geological Survey were carried out (IR



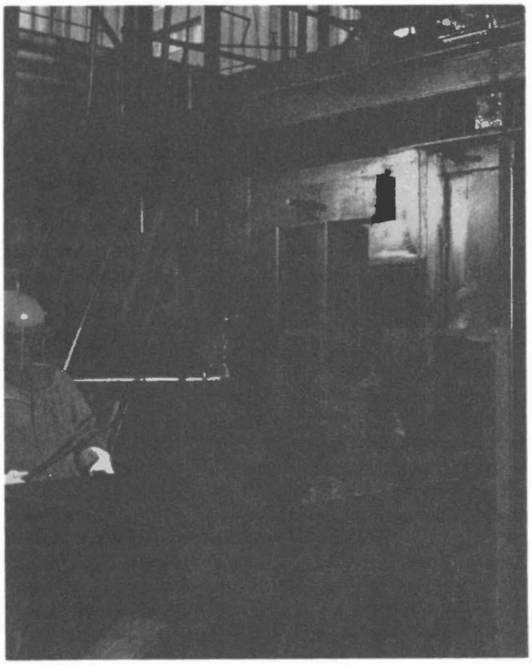
Technical coal mission visits Yawata Iron and Steel Company Limited in Japan. The Canadians in front row from left to right, are: J.C. Botham, J.H. Walsh, Canadian External Affairs officer, and W.C. Whittaker

FMP 61/180 by Botham and Burrough). This study inaugurated a long relationship with the Stelco research group in the persons of F.J. Pierce and H.N. Paulencu. A suite of coals was evaluated for the company subsequent to the installation of the moveable-wall technical-scale oven on Booth Street and the company supplied the services of Paulencu and a technician for assisting in operating the oven.

A letter was addressed to the Minister, Paul Comtois, by W.C. Whittaker in April 1960, and full support was given by the Dominion Coal Board in a resolution the same month requesting the provision of a technical-scale carbonization facility on Booth Street. A Butler building was purchased and erected in the space between 554 and 562 Booth Street. The oven and auxiliary equipment including electrics, most of which was fabricated by the Technical Services Division, were installed by Hudson's group, renamed "Construction and Equipment Section". The 12-in. slot moveable-wall oven was a modified version designed by Eastern Gas and Fuel Associates of U.S.A. It was uniformly heated electrically, power being supplied by a 75-kVA system. The coal charge was 500 lb and the coking cycle approximately eight hours. It was completed in February 1962, and the first charge was carbonized in April the same year. R.C. Guenette, who joined the division in 1950 and was attached to the Hydrogenation Section, was transferred to the Carbonization Section. He did all the brick work associated with the erection of the oven and was the first to operate it. C.H. Glaude, who was in the Coal Analytical Laboratory from 1929, was also transferred to conduct laboratory studies on coal rheology as applied to carbonization, becoming a specialist in plastometry. Laboratory equipment for evaluating properties of cokes from the oven and other sources was updated and included facilities for carrying out tests not only to ASTM but to Japanese standards.

Ed Burrough retired in 1963 after 36 years of service with the Mines Branch. He had been wounded in World War I, came to Canada in 1923 and worked at the Hamilton By-Product Coke Ovens Limited before joining the Fuels Division in 1927. He was the first staff member with industrial carbonization experience.

Coal and coke petrography as analytical tools for diagnostic and prognostic purposes and microscopic examination of coking coals and cokes made a significant advance through the work of L. Shapiro and his associates in the U.S. Steel Corp. who reported in the early 60's, that quantitative reflectance data of the reactive components of coking coal could be correlated with the strength of coke or the stability factor. This work was adapted and enlarged by Bituminous Coal Research Inc. with whom D.S. Montgomery was able to arrange for Nandi to spend an extended period in studying the latest petrographic techniques. Nandi, who was an NRC PDF with the Mines Branch in the 50's, rejoined the Fuels and Mining Practice Division in 1963 after a period of research with Domtar Company. As a coal scientist he joined Dr. Montgomery's research group on bituminous substances developing an expertise on petrographic methods and interpretation in the context of the complex chemistry of fossil fuels. Nandi was able to interpret the behaviour of the petrological constituents of coal, not only in carbonization but also in



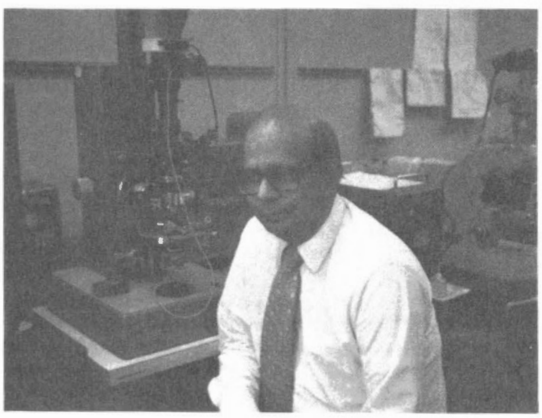
R. Guenette discharges a 12-inch moveable-wall oven installed at Booth Street and later moved to Bells Corners complex (Photo - George Hunter)

C.H. Glaude

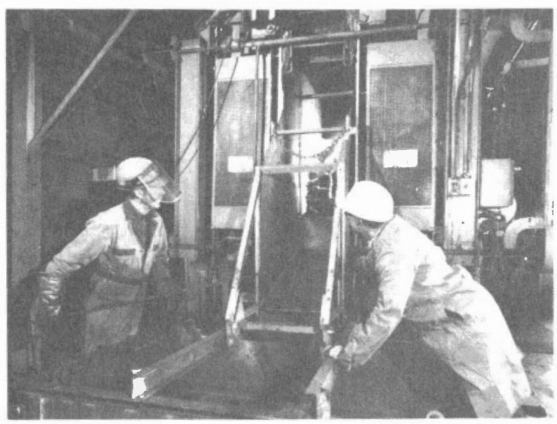
combustion and later in the complex processes like hydrocracking of bitumen. As Indian coals somewhat resemble the Western Canadian coking coals in their finely disseminated ash and inert particles compared with the United States Appalachian coals, a study was made of Indian coals, taking advantage of the presence of N.N. Chatterjee, a Colombo Plan Fellow. It was found that certain changes in the method of calculating the stability factor would be appropriate: "Petrographic studies of some Indian coals used for the production of metallurgical coke" by N.N. Chatterjee, B.N. Nandi and D.S. Montgomery, (CIM Bull, pp 615-625, May 1966). Over a span of years, considerable refinements have been developed by Nandi and contemporary petrographers in various countries, helping to enhance the value of coal and coke petrography as predictive and diagnostic analytical tools. Some of the more recent coal companies are now using petrography and had their analysts trained by Montgomery and Nandi.

Evaluation of the then recently developed coking coals by the original companies continued during the period of 1963 to 1967, such as the Stewart seam of Canmore, Vicary Creek of Coleman Collieries and Balmer of Crows Nest Industries as well as the U.S.A. coals from Stelco, Algoma and Dofasco. The 12-in. oven operated until 1972 on Booth Street and about 1,000 charges were carbonized during this period. In the seventies an 18-in. oven as well as a new 12-in. oven were constructed and put into operation at Bells Corners. Algoma Corporation donated a gas-fired Kopper's type oven which was installed at the Western Research Laboratories in Edmonton along with a British Carbolite type, adjustable to 18-in. to better serve the Western coal industry.

In 1963 Crows Nest Industries built three Mitchell horizontal-bed, internal combustion ovens, a modern version of the Beehive oven to evaluate the coke for the foundry market. This was at a time when prices for coal tar and oils were falling. A number of coal producers in the U.S.A. had turned to non-recovery ovens which could produce a cheap supplement for coke for foundry or even blast furnace use. Crows Nest Industries requested Botham's services and payment of travel expenses to evaluate the Illawarra oven in Australia, somewhat similar to the Mitchell oven, that had a two-direction heating system and operated at high temperatures up to 1500°C with a deep bed: "Technical



B.N. Nandi in Petrographic Laboratory



Z. Tazbir and D.K. Kelly discharge coke from 18-in. oven into a quench car (Photo - George Hunter) aspects in the manufacture of foundry coke with special reference to non-recovery ovens in Australia" by J.C. Botham (IR FMP 63/127).

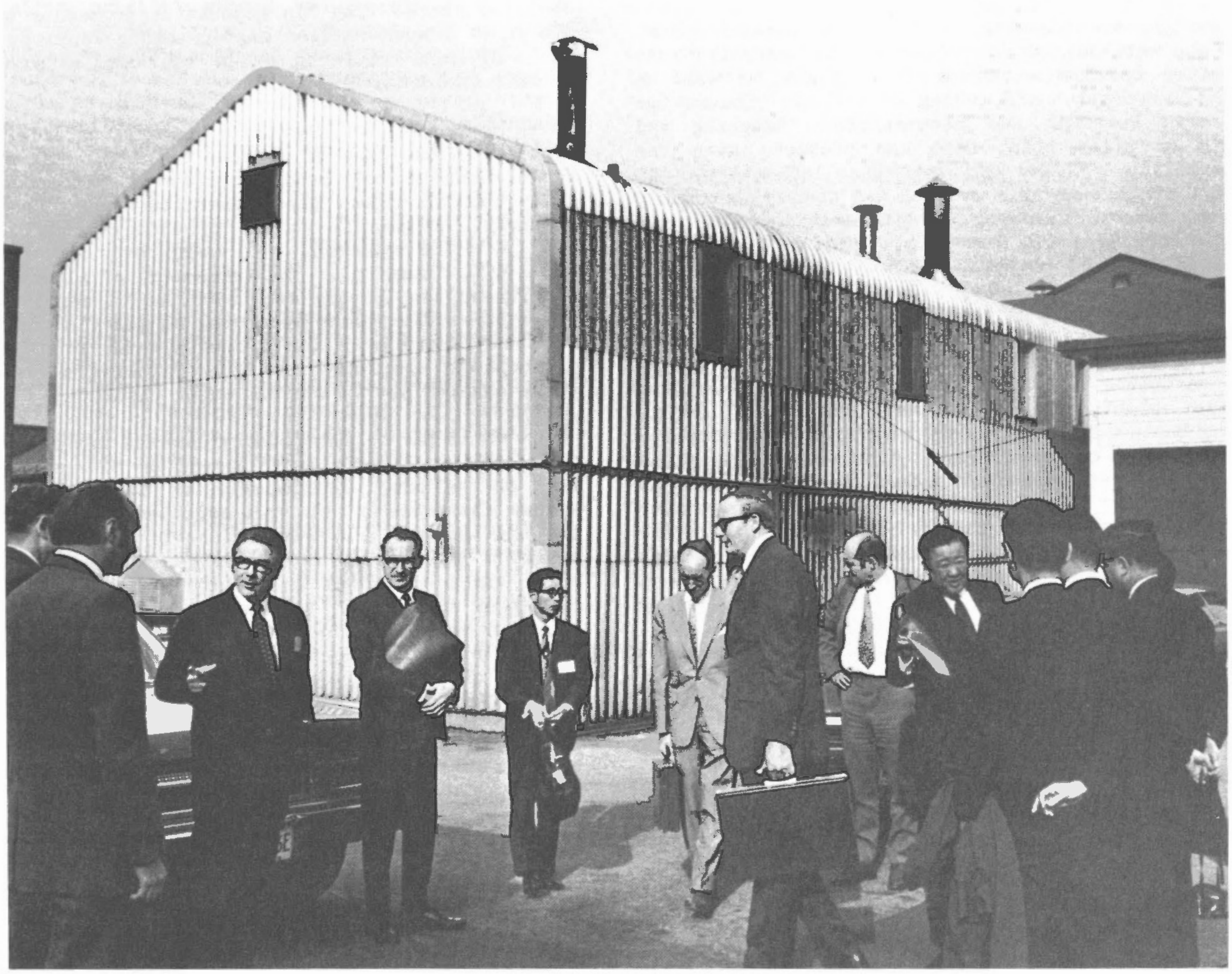
Space does not permit of reporting further details of the R & D work during the period under review except to refer to the Symposium on Science and Technology of Coal held in Camsell Hall on Booth Street under the auspices of the Canadian Institute of Mining and Metallurgy and the Canadian Advisory Committee on Coal Research. Aside from combustion, considerable attention was given to petrography and carbonization. Besides Canadian papers which included six from the department, there were presentations from the United States, United Kingdom, France and Germany (136).

Confidence by the industry in the carbonization research carried out at the Mines Branch was demonstrated by the formation in 1965 following informal discussions with Frank Pierce of the Canadian Carbonization Research Association. This was the first such organization of formal character with articles of association in this field in Canada: "Objectives of the Canadian Carbonization Research Association" by C.W. Drake and J.H. Walsh (Trans CIM, vol 70, pp 28-31, 1967). The inaugural board consisted of directors from Algoma, Dofasco, Dosco, Stelco, all integrated Canadian steel companies; Canmore and Crows Nest Industries, both Western coal mines, and Domtar doing high temperature tar processing. C.W. Drake of Algoma was the first chairman, and J.H. Walsh the first secretary. A technical committee composed of nominees from member companies and the head of the Carbonization Section, J.C. Botham, was also formed. The board met twice annually and the technical committee monthly or bimonthly. This structure continues at this writing. The board gives general direction to the R & D program, whereas the technical committee reviews projects in detail. Some of the projects were concerned with confidential studies relating to members' requirements, whereas projects on agreed themes of scientific or engineering interest to members and interested public were openly reported. The key to the success of the association was the intimate technical exchange of ideas and knowledge in the technical committee with some formality in the preparation of agendas and minutes. Annual contributions from member companies aside from assistance provided by companies' staff, accounted on the average for about one third of the cost of the Carbonization Section, exclusive of staff salaries.

It is appropriate to record an independent view of the activities of this group that appeared as a news item in the March 1969 issue of "Mining in Canada", which stated in part: "...There are stong indications now that the current Japanese contracts might not be in existence had it not been for the work of the Dominion Coal Board representing the Canadian Government and the technical work of a small group of men who courted the market over a period of years. ...The early association of the producers and handful of persons then with Fuels and Mining Practice Division became a base from which eventual negotiations could be carried out with the Japanese."

Board of Directors, Canadian Carbonization Research Association, 1966.

From left to right: John Walsh, Charles Drake, Frank Pierce, Stan Anslow, James Ludberg, Tom Cassidy, Jack Botham, John John, Rod Wallace, Ron Nicholson



Jack Botham and John Jorgensen on left with officers of Canadian Pacific Ltd. and visiting Japanese outside the Butler building erected for technical-scale acceptance tests of Western Canadian coals

HYDROCARBONS

Cold Water Separation and Preliminary Refining Bitumen

During the post-war period from 1945 to 1952, the original Hydrogenation Section was concerned principally with the Alberta oil sands in a considerable effort devoted to separation of sand from the bitumen and in some research work on refining of the bitumen. A brief recapitulation with some amplification of the events and circumstances which preceded launching of the post-World War II Mines Branch R & D program on Canada's low-grade oil resources based largely on Alberta bitumen may be useful.

As mentioned in Chapter 5, two war-time large-scale projects were undertaken on contract under auspices of the department with war-time allocations: in 1942 an exploration drilling campaign of the area to the north of Fort McMurray, with analyses of the cores by the Fuels Division, and in 1943, a demonstration separation plant at Abasand Oils Ltd. near Fort McMurray. The plant burned down in 1945. The cold water method had been tried with promising results and was repeated by H.L. Beer on a laboratory scale in the Metallic Minerals Division the same year. Further work was done on a laboratory scale by Rosewarne and Swinnerton (FRL Report 90, 1948).

In 1948, a decision was made to design a 200 to 300-lb per hour pilot plant to provide data for industrial-scale extrapolation. The plant was erected in the old power-house building which was to be demolished for erection of the Technical Services workshops. Hence, the work had to be rushed and test runs were completed in one year (1949-50). This project was directed by Warren with L.E. Djingheuzian being responsible for the ore dressing flowsheet and tests. Booth, Carson and Labelle, were involved in the assembly, some fabrication and commissioning of the plant, as well as with the dehydration and coking of the wet bitumen for which also Burrough was responsible. Sampling and analysis of pilot plant feed and products were the responsibility of the oil and gas laboratory. An important reagent in this process was sodium carbonate, acting as detergent in improving separation of bitumen from the sand grains. The pulp in the test runs was controlled at a pH of 8-9. In a parallel investigation on a laboratory scale, D.S. Montgomery and Pleet studied the action of some 50 wetting agents on the separation process. It was discovered that high yields could be achieved at a pH level of 5.5 without adding sodium carbonate but to obtain equally high yields in the pilot plant, sodium carbonate had to be added. However, Montgomery recognized the advantage in operating at low pH to achieve high clay settling rates which would permit faster recycling of the water. This aspect was left for later study if the opportunity arose. All the laboratory, both analytical and research data, as well as the research work on recuperation, dehydration, and coking of the separated bitumen were given in four reports noted in the bibliography (137). Montgomery also started research on the chemical constitution of the Athabasca bitumen.

On the refining side, as noted previously in Chapter 5, the emphasis on hydrogenation studies of bitumen on a laboratory scale dated from 1943. These small-scale experiments culminated with vapour-phase hydrogenation at 1000 psi, with fixed bed catalyst of the coker distillate from the cold water separation and coking studies mentioned above.

During the period 1943-1945 consideration was given by the government to establishing a hydrogenation pilot plant and laboratories on the present site of the GSC Building on Booth Street. Warren spent some time in Germany in 1945 studying coal hydrogenation which provided him with a broad understanding of the synthetic liquid fuels industry that was unequalled in Canada at the time. Early in 1946 a government committee of senior officials decided not to go ahead with a large-scale pilot plant project. Undeterred by this

Retirement of long-service personnel Leo Labelle with 40 years and J.W. Custeau with 36 years; Mrs. Labelle in centre

decision Warren with his associates proceeded with the design of a much smaller high-pressure facility in the Fuels Division building which was commissioned after he left the Mines Branch in 1952.

Meanwhile, in Alberta, a somewhat parallel situation as in the case of Abasand Oil Ltd. (Max W. Ball) arose when an oil sand property at Bitumount, some sixty miles down the Athabasca River from Fort McMurray, originally worked by International Bitumen Co. (R.S. Fitzsimmons), was taken over by Oil Sands Ltd. (L.R. Champion). The Government of Alberta, which had funded the company with $500,000 to complete a hot water separation plant according to Clark's flowsheet, was obliged to take the property over in 1948. The project was completed in 1949 following a program of tests carried out in the hot water plant.

World War II undoubtedly renewed interest in the oil sands of Alberta as a source of oil products for the war effort, particularly as Canada experienced severe shortages of its own supplies of hydrocarbons. The aim was not achieved because of the complex character of this resource, requiring time and skill to solve the problems of production and upgrading. However, in the early post-war period, the focus of interest was maintained because of the initiative of the Alberta government through the Board of Trustees of the "oil sands project" asking S.M. Blair, consultant and petroleum engineer from Toronto, to evaluate the technical and economic feasibility of commercial production of oil products from the bitumen.

On the basis of Blair's report to the Alberta government in 1950, a comprehensive conference with sessions on geology, mining, separation and refining, was conducted in Edmonton in 1951 (138). Members of the Department of Mines & Technical Surveys were invited as authors of papers and as participants. Dr. G.S. Hume, Dr. T.E. Warren and Dr. D.S. Montgomery each prepared two papers. Dr. R.T.D. Wickenden of the Geological Survey and L.E. Djingheuzian each prepared one. In addition to the papers on separation by Djingheuzian and on refining by Warren, et al., Warren contributed to the mining session and Montgomery to the geology and refining sessions. Warren's paper stressed the poor heat conductivity of bitumen in place related to the thermal methods for recovery of hydrocarbons from the bitumen. Montgomery's paper in the geology session indicated that the organic source material was not derived from lignin and cellulose; the distillation analysis and other data supported Hume's conclusion based on geological evidence, of the bitumen's Cretaceous origin. Montgomery's paper in the refining session on isolation and identification of Athabasca oil components was presented but not published as the large molecule asphaltenes could not be fractionated by the chromatographic method used on the other components. Full results that were available were also given to Blair for his report. Referring to the paper by Warren et al. there was not enough time before the conference commenced to provide a full evaluation of products and their qualities as well as of catalyst performance. The gasoline and diesel oil fractions were lower in quality than those produced from conventional light gravity crudes. However, the evaluation was completed after the conference and a report with an extensive bibliography was published later: "Low pressure hydrogenation of coke distillate from Athabasca bitumen" by F.L. Booth, R.E. Carson, K.W. Bowles and D.S. Montgomery, (MB RR 30, 1958).

Blair's original report was based on a daily production of 20,000 barrels of bitumen per day, but at the Athabasca Conference and subsequently the figure usually referred to was 100,000 barrels per day. Aside from the large capital expenditures required, there were the questions of disposing of the large tonnage of waste sand and the effect on the environment of the large quantity of sulphur effluents if the coking route were used in primary distillation. These matters were then of considerable concern to Montgomery and his associates and influenced their refining research.

Following the Athabasca Conference, was a period of hiatus for some years. Fortunately there was sufficient dedication by the Hydrocarbons Group and there was sufficient support within the department for Montgomery's opinion that Canada possessed a major portion of its hydrocarbon potential in low-grade resources, notably in the oil sands and heavy oils of Alberta and Saskatchewan. Modest funding was available to continue research.

Some interest by the larger petroleum companies continued, judging by the many visits of their representatives, both Canadian and foreign, to the Fuels Laboratories in Ottawa. During this period the ultimate reserves of bitumen recoverable by all known methods were estimated at 300 billion barrels, with six billion barrels available within the "economic radius" of the first large operation at Fort McMurray pioneered by the Great Canadian Oil Sands Company, which went on stream in 1967. The allowable daily production was 45,000 barrels but several years were required before this rate was attained. There was also activity by industry on experimental recovery by thermal methods in the heavy oil belt at Cold Lake, Alberta, during the late 60's, but this was suspended.

A principal reason for industry not pursuing further development of the oil sands earlier was of course rapid development of conventional oil production coupled with exaggerated expectations of reserves build-up as against the high capital costs required for an oil sands integrated recovery and refining plant. The following table shows the rapid increase in production of oil and natural gas that took place during the 50's, 60's and early 70's; exports are given for the years 1960 and 1970.

Canadian production and some exports of crude oil and natural gas for selected years

	Crude oil in millions of barrels (to nearest million)			Natural gas in billion cubic feet (to nearest billion)		
Year	Prod.	Imports	Exports	Prod.	Imports	Exports
1945	8	57		48		
1949	21	74	-	60		
1960	190	126	42	523	6	91
1970	461	208	241	2277	12	768

Warren resigned in 1952 to take up a position with the Cyanamid Company and later assumed the directorship of the Saskatchewan Research Council. He served the Mines Branch for 23 years. When he joined the branch in 1929 he was the only chemical engineer in it with a doctoral degree from the leading American university in engineering, the Massachusetts Institute of Technology. His training gave him the computational and design skills which permitted him to bridge the gap between bench-scale research and large-scale operation in an area of complex chemistry related to fossil fuels.

Organization of the Hydrocarbons Group

Montgomery became responsible for and participated in the three principal areas of hydrocarbon research: analytical, fundamental, and applied. He published a paper in 1956 outlining the scope of activities of the hydrocarbons group: "The Fuels Division" with the editor's caption "Our valuable research ally in Ottawa" by D.S. Montgomery (Canadian Oil & Gas Industries, vol 9, pp 37-40 Jan. 1956).

Montgomery's view was to develop a small corps of research chemists who would gain fundamental understanding of the chemistry of Canada's variable fossil fuel energy resources. The concept was that the analytical methods developed through research would provide a basis for process control and innovation in the refining R & D project carried on largely by chemical engineers. This concept of the early 50's continued for almost 25 years.

During the period under review the manpower allocation to this activity remained meagre. Thus in 1955, out of a total of 71 in the Fuels Division 19 members were exclusively allocated to hydrocarbons, not counting some research on combustion utilizing oil; in 1964 there were only 22 out of a total of 107 in the division. The competing urgencies of coal, specialized laboratories on safety of explosives and electrical equipment in explosive atmospheres, as well as mining deprived the hydrocarbon area of its fair share of staff, resulting in the necessity to conduct experiments only when they were not occupied by the custom construction of complex plants. Another reason for the manpower shortage was the dearth of available specialists, both professional and nonprofessional: most of the staff had to be trained on the job on the basis of their qualifications in science or engineering.

The founder of the Fundamental Research Section was Dr. D.S. Montgomery, who joined the Mines Branch in 1948. Dr. Mary L. Boyd (1948 - 1975) joined him in 1949, followed by Frances E. Goodspeed (1945 - 1965) in 1953 by transfer from the analytical laboratory, Dr. M.F. Millson (1954 - 1967), Dr. L.H. King (1957 - 1963), Dr. H. Sawatzky (1959 -) and Dr. B.N. Nandi (1963 -). These were individual researchers whose work attempted to elucidate problems related to the chemical constitution and properties of fossil fuels including coal. Montgomery, though discharging his duties as head of the Hydrocarbons Group and senior scientist of the division, carried out research in his own right in this group, which in 1954 was renamed "Research on Bituminous Substances" and continues at this writing.

The Applied Research Section was known as the Hydrogenation Section, but this was considered too restrictive to describe the various processes used not only in refining bitumen but also in heavy oils and residues. Some of the processes were carried out at atmospheric or low pressure. Thus, in 1957 the Petroleum Engineering Processing Section was formed with F.L. Booth as head (1945 - 1975) and his long-time assistant was Paul Mogan (1957 -). The Hydrogenation Section was renamed in 1958 High Pressure Chemistry, with its head being W.H. Merrill (1947 -). A.R. Aitken (1961 - 63) was his first assistant.

Catalysts play a very important role in the transformation of crude petroleum or feedstocks into products. Hence a decision was made to start a project on catalysts and the phenomena associated with their use. Dr. B.I. Parsons (1955 -) joined the Mines Branch to take charge of this project within the High Pressure Chemistry Section. Because of the increase in the amount of design required in the construction of pilot plants, R.E. Carson (1948 -) was separated from the Hydrogenation Section in 1958 and became responsible for engineering design. Though concerned primarily with the Hydrocarbons Group because of his versatile capabilities, Carson assisted other sections of the division in preparing designs for special apparatus in mining, coal preparation and carbonization. To allow for some flexibility in assisting Montgomery in his many activities, Bowles who had seen the hydrogenation work from the start in 1929, was transferred to the section known as Special Projects; similarly, Dr. W.A.O. Herrmann, who had joined the division in 1956 with considerable experience of the Bergius process in Germany, was first attached to Lorne Booth's Petroleum Engineering but in 1958 joined the Special Projects group to act as a consultant to Montgomery on synthetic liquid fuels and various transformations of low-grade oils and coals.

Analysis of Petroleum and Gas - Resource Evaluation

The analytical group was the oldest, going back to analyses of oil shales, producer gas from peat, and other gases including explosive and toxic mine gases before World War I, as noted in Chapter 3. Though Leverin was the chemist, the responsibility was Stanfield's. In 1921, this responsibility was taken over by P.V. Rosewarne (1921 - 1954). He was joined by R.J. Offord (1921 - 1958) by H. McD. Chantler (1924 - 1958) and by P.B. Seely (1930 - 1965). As previously noted, Rosewarne retired in 1954, followed by both Chantler and Offord in 1958. They were succeeded by R.G. Draper (1948 -) as head and by A. Yates (1950 -). Frances Goodspeed had joined the laboratory in 1945.

Dr. John Convey presents Mines Branch "Beaver" to H. McD. Chantler on his retirement while R.G. Draper presents the ubiquitous gift of luggage

At the outbreak of World War II, Rosewarne was seconded to the Oil Controller's office, and Chantler was in charge of the laboratory with Offord and Seely as principal assistants. The laboratory reported to Warren, who was virtually in charge of all the hydrocarbon area. After the war, Rosewarne resumed the general direction of the laboratory but acted principally as an adviser to the chief of the division before retiring in 1954.

The gasoline survey started by Rosewarne in 1922 continued after the war in the years 1947, 1948, 1950, 1952 and 1955 (MB Memorandum Series 98, 102, 112, 124 and 131), and the following members of the laboratory participated in the analysis of the samples: Chantler, Seely, Goodspeed, Draper and Yates. The survey of crude oil and natural gas occurrences continued throughout the period with samples sent in or collected by members of the branch. In this connection, H.N. Pickford, who was transferred from Ottawa to Calgary for the administration of the coal preparation and mining groups, spent considerable time in collecting oil samples from new fields or extensions of old ones. In the case of Ontario, the provincial authorities cooperated from the early days by providing samples including those they wanted analyzed. Natural gas was monitored for helium content and there was some activity in the early 60's in southwestern Saskatchewan where discoveries were made of helium which led to the formation of two companies intending to extract helium. However, no continuous helium production was established.

Under the auspices of the Canadian Government Specifications Board, exchanges were made with other laboratories in gasoline, lubricants and special products. A considerable number of samples of oil products were analyzed for National Defence and other government departments. Expert evidence was given in inquiry and litigation cases. Limited circulation reports in the FRL report series were prepared as shown on top of following page.

The analysis of mine air for toxic and explosive contents was the responsibility of the laboratory from 1964. When Offord retired in 1950, A. Yates replaced him.

A major project was undertaken in the late 60's. This included assembling for open publication, data on quality of Canadian crudes from samples collected and analyzed over several decades. Also assembled were data on some of the reservoirs, which were obtained and systematized for publication mostly by Dr. R.P. Charbonnier assisted by W.H. Harper following Baltzer's retirement in 1965 and the discontinuance of the Fuel and Power Section. This work resulted in seven separate publications according to province in the Information Circular series (139). Besides quality of Canadian crudes determined by analysis in the laboratory, the reservoir data provide comparative performances for some Canadian oil pools.

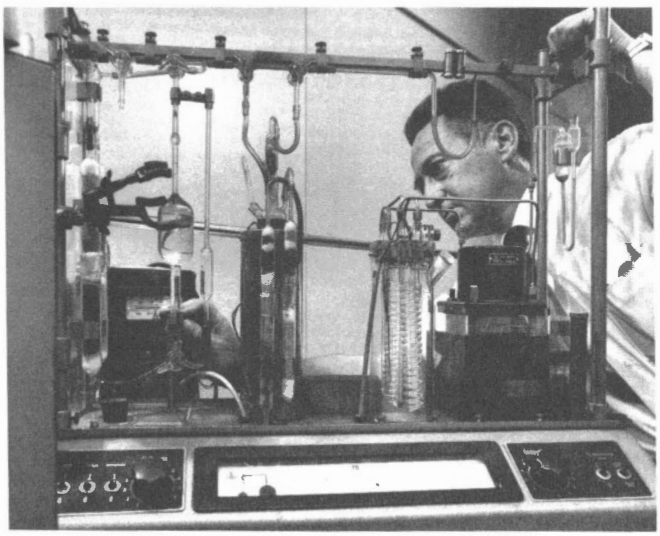
It had been hoped that hydrocarbon reserves would become a continuing study when Charbonnier relocated in Ottawa in 1959; however, this was not implemented due to shortage of staff and funds and Charbonnier remained in a consulting capacity in petroleum reservoir engineering. Studies were undertaken in under-

FRL REPORT SERIES

Report No.	Date	Crude oil	Natural gas	Authors
FRL 75	July 1947		Ontario 1946	R.J. Offord, F.E. Goodspeed
FRL 100	1947		Sask. and Alta. 1947	R.J. Offord, F.E. Goodspeed
FRL 138	Mar. 1950		Sask. and Alta. 1948	R.J. Offord
FRL 155	Mar. 1951		Ontario 1949	R.J. Offord
FRL 176	June 1953		Ontario 1950-51	R.J. Offord, A. Yates
FRL 177	June 1953		Western Canada 1949-52	R.J. Offord, A. Yates
FRL 215	Feb. 1953	Alta. 1951-52		H. McD. Chantler, P.B. Seely
FRL 184	Dec. 1953	Alta. 1953		H. McD. Chantler, P.B. Seely
FRL 206	July 1954	Canada 1954		H. McD. Chantler, P.B. Seely
FRL 235	May 1956		Ontario 1954-55	R.J. Offord, A. Yates
FRL 256	June 1957	Canada 1955-56		P.B. Seely, R.G. Draper, H. McD. Chantler
FRL 257	Jan. 1957		Western Canada 1954-56	R.J. Offord, A. Yates, R.G. Draper, H. McD. Chantler

ground storage of natural gas in southern Ontario and Quebec in view of the limited storage aquifers in these areas. A report was prepared with the cooperation of the Geological Survey: "Present status of underground storage of natural gas in southern Ontario and Quebec" by R.P. Charbonnier (MB IC 121, 1960, English text, and MB IC 144, 1963 with revisions, French text).

Other studies were made on optimizing the recovery of petroleum, particularly in regard to secondary recovery methods. In this connection, Charbonnier was of the opinion that the spacing of wells in Canada was too close. He kept in touch with the Alberta Oil and Gas Conservation Board which eventually widened the spacing. In situ combustion methods for heavy crudes were reviewed, including the Plowshare program of the U.S. Atomic Energy Committee. Oil well production methods were investigated such as cement uses in well completion and "down-the-hole" turbo, and electric drilling.



R.G. Draper checks a new Wörsthoff analyzer capable of determining traces of toxic gas in mine atmospheres (Photo - George Hunter)

As mentioned under Carbonization, Charbonnier was a member of the "Working Party on Movement of Solids". He kept in close touch with the major R & D project developed by Research Council of Alberta for the movement of solids in pipelines for the transportation of coal, water and oil slurries to Ontario thermal plants. Charbonnier was author of the following reports of this working party: IR/FMP 62/76, 62/166, 62/179, 63/20, 64/26 and 64/90. He kept in touch by communications and visits with the United Kingdom and French developments in pipelining and hydraulic hoisting in mine shafts. Charbonnier used the catalogue of cards published by the Institut de Pétrole which was cheaper than North American sources.

Fundamental Research on Bituminous Substances

As mentioned in Chapter 5, D.S. Montgomery joined the Bureau of Mines at a time when Timm and Parsons had decided that the scientific research base had to be strengthened in key areas of mineral and metals R & D by appointments at the doctoral level. Four such appointments were made in 1946 to 1948: Ceramics - Prince (1946), Extractive Metallurgy - Downes (1947), Physical Metallurgy - Convey (1948), and Fuels - D.S. Montgomery (1948).

Montgomery inaugurated the fundamental research in 1948 which in 1954 was formally organized in a section named Research on Bituminous Substances. The first project carried out was pressure combustion of coal related to the coal-fired turbine project (Chapter 5). However, events were moving rapidly in the hydrocarbons area and he was drawn into R & D on separation and refining of bitumen as mentioned earlier.

Despite his heavy commitments in the Hydrogenation Section and the division generally, particularly after Warren's departure in 1952, Montgomery retained during his entire career in the Fuels Division an interest and personal participation in the research he organized in this section. The research spanned the entire field of natural carbon-containing minerals from coal to oil. Bitumen and heavy oils were his main preoccupations, but he considered that any discoveries on the origin of bitumen, a mineral in some respects between coal and conventional oil, could contribute to the knowledge of coal and oils. Mention was made earlier to research on coal tar pitches for use as binders in metallurgy and to petrographic studies of coal in the subsection on carbonization. Some research related to coal mining will be mentioned later.

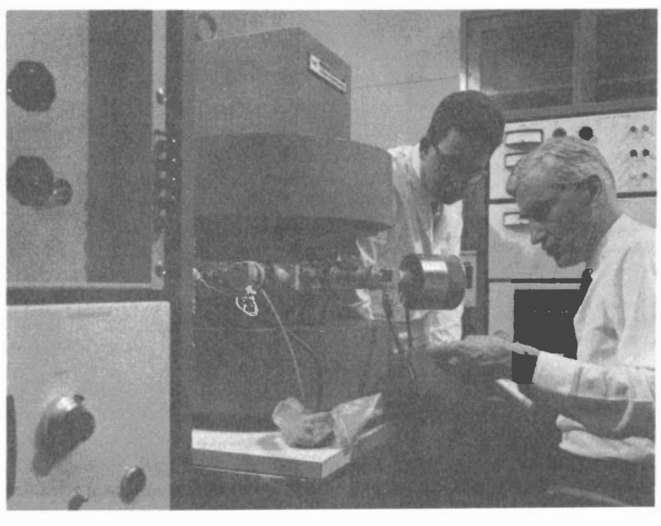
From the start, Montgomery expressed his concern on the paucity of knowledge of the chemical structure of the hydrogen-deficient bitumen composed of large and complex molecules in union with sulphur, oxygen and nitrogen, and the trace metals - nickel, iron and vanadium. The association of the organic matter and its various functional groups with the inorganic impurities including the clay, silt and sand, presented a continuing problem. Research in this area for several years was centred in two directions: the chemical constitution of bitumen to assist the refining strategies for producing acceptable petroleum products, and the study of the origin of bitumen and other naturally occurring hydrocarbon substances with the aim of evaluating the large low-grade hydrocarbon resources of Canada.

The Structural Group Analysis of bitumen can be counted as an important Canadian contribution, attested by the numbers of industrial and sundry research groups and individuals who consulted Montgomery over the years. Starting in 1955, methods of hydrocarbon structural group analysis were developed for pure compounds and for naturally occurring substances with a major effort being made on the constituents of the bitumen. The first method involved the measurement of three chemical properties - carbon and hydrogen contents and the number of aromatic carbon atoms, and two physical properties - molar volume and refraction. These properties were expressed in terms of five structural groups in a series of five simultaneous equations which where solved by the use of an electronic computer. This method was tested on 114 hydrocarbons, whose properties were determined under project 42 of the American Petroleum Institute, "New method of hydrocarbon structural group analysis" by D.S. Montgomery and M.L. Boyd (Analytical Chemistry, vol 31, pp 1290-1298, Aug. 1959). Next, the structural analysis technique was applied on the most intractable component - the asphaltene fraction of the Athabasca bitumen. This component has the lowest content of hydrogen, the largest molecular weight, and represents almost one quarter of the natural bitumen. This was followed by the lighter resins and oil fractions which could be separated by chromatography. All three studies were reported in a three-part publication entitled "Study of the Athabasca bitumen from the Abasand quarry" (140). It should be mentioned in passing that an attempt was made in 1949 to characterize the hydrocarbon constituents of bitumen using chromatography. The structural group techniques had wide applications for tracing metamorphic changes in naturally occurring hydrocarbons and in monitoring the thermochemical transformations in refining of bitumen, heavy oils and residues.

As an extensive literature had appeared on the subject of bituminous sands, Mary Boyd published a complete bibliography on the Alberta oil sands in 1960; it was her intention to revise this publication from time to time but this function was taken over by the Alberta Research Council who found her bibliography to be a useful "building block" (IR FMP 60/69).

An important analytical tool with this group from 1952 was infrared absorption spectroscopy, Frances Goodspeed mainly being responsible for the measurements. The Abraham's classification of bituminous substances used in the Fuels Division was considered inadequate for identifying the many petroliferous field samples submitted by the Geological Survey because of insufficiency of organic material. This led to developing a technique for samples weighing approximately 100 milligrams and also to the inauguration of a library of spectra of naturally occurring hydrocarbons. This work provided the organic geochemist with a basis for evaluating the economic potentials of organic occurrences. Dr. L.H. King joined the group in 1957. He was a geologist eager to relate geological evidence to the chemical composition of naturally occurring organic minerals. He assisted with one of the structural group studies and devoted much time to collecting and identifying field samples, e.g., he investigated the origin of anthraxolite and impsonite (coal-like, metamorphosed bitumens) and of New Brunswick oil shale and albertite. The results were published in two research reports in 1963 (MB RR 115 and 116).

As an example of the extreme complexity of substances associated with bitumen should be noted the research carried out by Dr. M.F. Millson. He joined the Fuels Division in 1954, and tried for several years to separate and identify individual vanadyl porphyrins, which are possible derivatives of the original chlorophyll in the flora that was the source material of bitumen. A non-metallic rhodo-type porphyrin was discovered spectrally and this was reported in Geochimica et Cosmochimica ACTA vol 30 pp 207-221, June 1965. Various fractions differing in solubility or spectra were obtained but definitive separation was not achieved. It was realized that to resolve these substances into compounds required the use of mass spectrometry for which funds were not available. A comprehensive report by the group to which Millson contributed was published in 1963 when King transferred to the Marine Geology group of the Geological Survey of Canada in Nova Scotia (141). At the opposite end to the naturally occurring species, the infrared spectra of pure hydrocarbons were determined in connection with projects of the American Petroleum Institute providing correlation between the natural processed fractions and pure compounds, resulting in an extensive



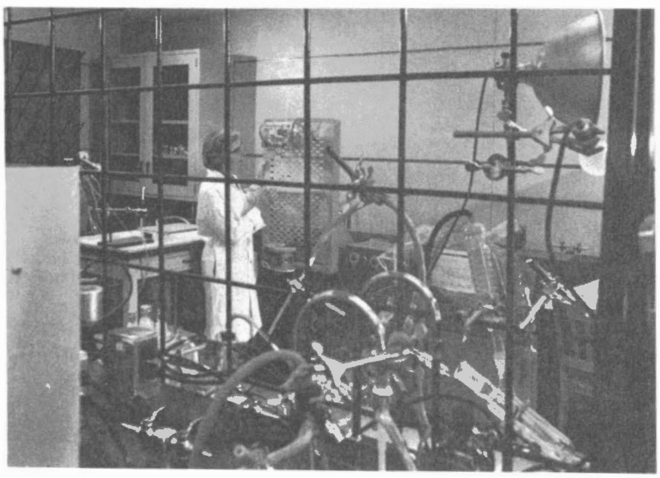
J.M. Denis and D.S. Montgomery working with mass spectrometer used for studying structure of complex substances (Photo - George Hunter) library collection of spectra. A mass spectrometer was acquired at last in 1967.

Infrared spectroscopy was used in identifying and estimating the quantity of various functional groups in the Abasand bitumen fractions, and the data were reconciled with the information from structural analysis. A report on the methyl and methylene groups in the oil and resin fractions of the Athabasca bitumen was published in 1962 (MB RR 98 by F.E. Goodspeed and D.S. Montgomery).

Considerable effort was made over the years by this research group to study asphaltenes by converting them to substances that could be analyzed by structural group analysis. Exhaustive hydrogenation of asphaltenes had previously been tried at 350°C, resulting in cracking and changing of the form of the molecule. A new reduction technique was followed at 150°C using ethylene diamine with lithium, but though full reduction was not achieved, physical property measurements were made of the completely hydrogen-saturated asphaltenes to enable standard structural group analysis to be applied. The research indicated that in the asphaltene molecule the aromatic clusters are linked mostly by sulphur atoms. The distillation of the saturated asphaltene showed that the greater part of the average asphaltene molecule was composed of fragments with a molecular weight of less than 370. Many interesting implications were indicated by this work that threw light on the reasons for coke deposition on catalysts used in refining and on the origin of asphaltenes: "The reduction of asphaltenes" by H. Sawatzky and D.S. Montgomery (Fuel, vol 43, pp 453-466, Nov. 1964).

Another approach was tried related to attempts to reduce refining problems of the high molecular weight asphaltene fraction by degrading the aromatic ring system with ozone. The results indicated that only a relatively small amount of low molecular weight ozonization products was produced.

A third approach was to use pyrolysis to reduce the molecular weight by employing a differential scanning calorimeter, measuring change in specific heat as a function of the hydrogen content of asphaltenes. A pyrolysis reaction was studied by Mary Boyd at the University of Ottawa under the direction of Dr. M.H.



Mary Boyd carries out research on pyrolysis of hydrocarbons (Photo - George Hunter)

Frances E. Goodspeed

Back to determine the kinetics in the initial stages of thermal decomposition of ethylene and ethylene-ethane mixtures. The results suggested the important role played by the low molecular weight polymers formed during the initial stages of this reaction: "Kinetics of the thermal reactions of ethylene. Part I" by M.L. Boyd, T-M. Wu and M.H. Back, pp 2415- 26 and ".... Part II. Ethylene-ethane mixtures" by M.L. Boyd and M.H. Back (Can J of Chem, vol 46, pp 2427-33, 1967). The pyrolytic studies mentioned in this paragraph were done in the context of the importance of pyrolysis as an important method in petroleum processing for the reduction of the molecular weights of hydrocarbons.

It was known that different samples of Athabasca bitumen differed in the ease with which they were separated by the Clark hot water process. Part of this was due to the nature of the mineral matter and part to dissolved gases. A new qualitative method of determining the dissolved gases was developed in 1969 so that this factor could be taken into account during processing, "Comparison of analytical methods for estimating the dissolved gases in Athabasca bituminous sand" by B. Ignasiak (NRC PDF), H. Sawatzky and D.S. Montgomery (MB IR 69-42).

The research officers involved in the foregoing program during the period 1954 to 1968 were: Dr. D.S. Montgomery, head; Dr. Mary L. Boyd (1948 - 1975), transferred to Fuels Division in 1952; Frances E. Goodspeed (1945 - 1965); Dr. M.F. Millson (1954 - 1967); Dr. L.H. King (1957 - 1963); Dr. H. Sawatzky (1959 -); Dr. B.N. Nandi (1963 -); and Dr. D.M. Clugston (1968 -). Frances Goodspeed was the first, and up to the present, the only woman president (1961 - 1962) of the Professional Institute of the Public Service of Canada.

Applied Research

For an understanding of the constantly recurring term "low-grade" resources in connection with refining R & D that has proceeded without interruption in the Fuels Division and its successor to this day, a comparison is given in the table below showing qualities of products that had derived from the laboratory distillation of a conventional high-grade oil from the Leduc Woodhead field and from separated Athabasca bitumen.

Products (% by volume)	Leduc Woodhead	Athabasca bitumen
Gasoline and light fractions	35	1
Kerosene and middle fractions	25	18
Lubricating fractions	18	16
Residuum and losses	23	65

The degree of additional refining required for bitumen compared with a light crude oil is clearly evident.

Applied Research Staff

The enlarged post-war applied research program was launched at a time when other priorities existed in the branch and Canada was experiencing her first "boom" in hydrocarbons resulting in a shortage of skilled manpower, both professional and technical. The achievements in the hydrocarbons area have to be measured by the performance of some 20 professional and technical personnel faced with difficulties such as the necessity of longer than average on-the-job training, shortage of funds for expensive equipment, etc.

In 1952, besides Montgomery as head, the applied research group comprised the following staff: K.W. Bowles (1931 - 1971), F.L. Booth (1945 - 1975), W.H. Merrill (1947 -) and R.E. Carson (1948 -) as professionals; and L. Labelle (1925 - 1965), J.G. Hinton (1925 - 1957), M.P. Pleet (1948 -) and R.C. Guenette (1950 -) as technicians. In 1955, Dr. B.I. Parsons (1955 -) joined, followed by Dr. W.A.O. Herrmann (1956 -), whose considerable professional experience in German synthetic fuels practice was helpful to the Hydrocarbons Group in relating R & D results to industrial feasibility; J.P. Mogan (1957 -) with prior student experience; J.M. Denis (1963) also with several summers' experience and D.H. Quinsey (1959 - 1971). Dr. G.T. Shaw (1946 - 1972) was transferred to the Fuels Division in 1950 and was attached to the Carbonizations Gasification Section, moving to the high pressure chemistry catalysis project in 1959. Among long service technicians only three started in the post-war period: M.P. Pleet (1948 -), who first worked in the Bituminous Substances Section and then in the High Pressure Chemistry Section, demonstrating considerable capability and versatility; R.W. Taylor (1954 -), a reliable performer, and M.A. O'Grady (1946 - 1970) who joined Booth's petroleum processing group in 1959. The foregoing in effect made up the steadfast core of personnel which provided continuity for the next 10 to 15 years. Though organized into sections the staff assisted each other when lengthy operation of pilot plants was required.

There were several professionals like D. Basmadjian, D.J.C. Rouleau, G.N. Fulford, A.R. Aitken, and some technicians who gave service for short periods. The catalysis subsection with many projects, particularly in the early period to the middle 60's, had to rely on summer students and NRC Postdoctorate Fellows such as Dr. Machin, Flitcroft, Mann and Bolton.

The safety record of the group was good. It should be remembered that a high proportion of research was done at elevated pressures and in the presence of hydrogen and substances of extreme flammability. The absence of accidents and serious injury bespeaks of the responsible attitude to safety of the entire staff in the plants and laboratories of the division. Even in an accident when hot pitch sprayed without causing serious injury, the staff had the presence of mind to shut off the plant.

These remarks apply to other hazardous locations in the division such as carbonization, particularly in regard to vertical reactors, explosive atmospheres laboratories, etc. The principal reason for relocation of the Fuels groups to the Bells Corners complex was realization by the authorities of the hazard of hydrogenation after turning down suggestions to locate the pilot plant in an isolated position on Booth Street prior to the departmental 1950-60 building program.

Petroleum Processing

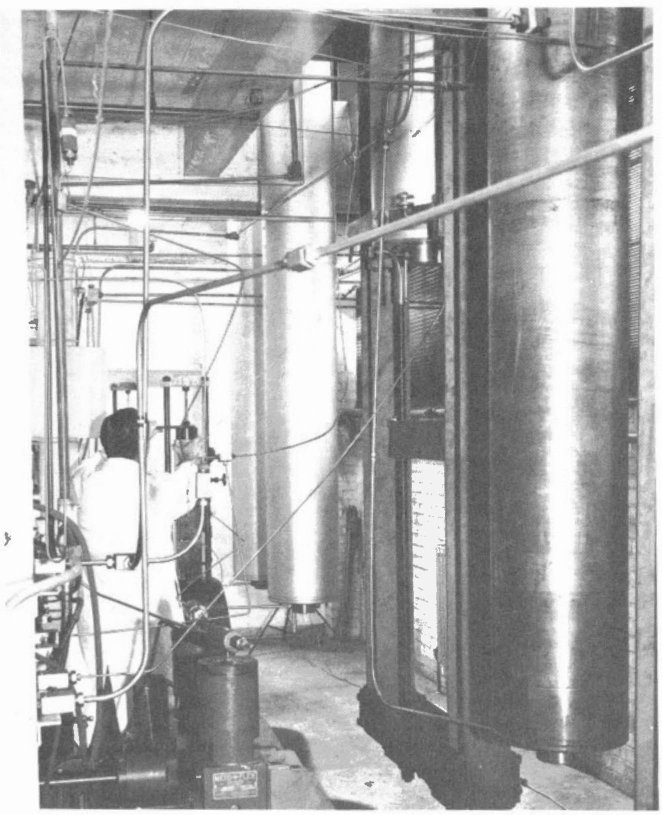
The Petroleum Processing Section was set up in 1957 with F.L. Booth as its head to provide a distillation facility in the Fuels Division to supply feedstocks for processing in the High Pressure Chemistry Section as well as dealing with its own research which included a lengthy design and construction project on fluidized-bed catalytic cracking. The first project that started in 1955 before the section was formed originated from the Excelsior Refineries of Edmonton, which was producing a high percentage of asphaltic residuum from vacuum distillation of Lloydminster heavy crude oil. Booth and his associates set out to produce by a cheap method a hard pitch that could be used in road construction and in the fibre-board industry or be stored for further refining into petroleum products. The flash inert gas dehydrator used in the oil sands separation project in the late 40's was used as a basis for this research. Modification was introduced and the results were successful: "The production of hard pitch from Lloydminster crude oil" by F.L. Booth, R.E. Carson, D.S. Montgomery (Interim Reports 1 and 2, FRL 200 and 204, 1955). These two reports were consolidated into a Mines Branch Research Report entitled: "Vapour-phase stripping of Lloydminster crude oil in a sloping-plate distillation tower" by F.L. Booth, R.E. Carson, D.S. Montgomery (MB RR 84, 1961). Further work was done during the next year or so and Interim Reports 3 and 4 were published (TM 56/59 and TM 157/59, by W.A.O. Herrmann, J.P. Mogan and F.L. Booth). Plant and operating costs for three methods - inert gas stripping, vacuum distillation, and vacuum distillation with steam stripping - were compared with the inert gas stripping method being cost-favoured in this study (TM 65/58, 1958 by W.A.O. Herrmann and F.L. Booth). An inert gas stripping distillation method was improved working on an intermittent basis, from 1960 to 1962, to enable combustion gases to be used directly and to avoid explosion or fire and contamination of a distillate: "Design and operation of a direct combustion heat source for vapour-phase stripping" by D.H. Quinsey, J.P. Mogan and F.L. Booth (IR FMP 62/17). This unit was used in producing feedstocks for the refining studies in the High Pressure Chemistry Section.

A vacuum distillation unit of 7 1/2-gallons per hour capacity was designed and constructed by 1965 to provide a facility for making deeper "cuts" than could be made by atmospheric distillation at the same temperatures.

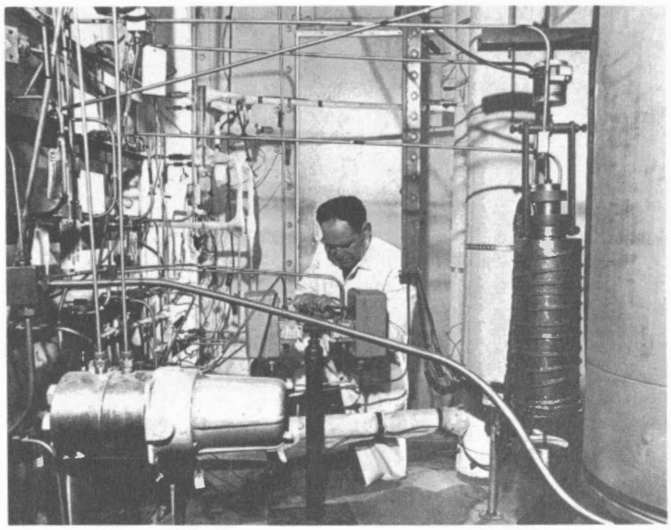
In the late 50's design was started on a catalytic cracking plant capable of operation with pressures up to 1000 psi using a fluidized-bed catalyst, the cracking reaction being carried out if necessary in the presence of hydrogen to provide flexibility for treating the wide variety of intermediate products, improve heat transfer and overcome some of the difficulties with fixed-bed catalytic systems. The unit was designed to operate with or without regeneration of the catalyst. Lack of funds and the scarcity of staff made progress slow. Meanwhile, a bench-scale unit was designed, fabricated and operated to provide a reliable design for the pilot plant relating particularly to catalyst behaviour. The unit was also used for testing and calibration of the fluid catalytic cracking plant which was commissioned in 1965: "Pilot plant for low and high pressure fluid catalyst bed reactions" by J.P. Mogan, R.W. Taylor and F.L. Booth (MB TB 78, 1965). It was the intention to use the plant for refining intermediate products from the hydrogenation project of the division to predict behaviour of catalysts as well as of commercial feedstocks intended for industrial fluid catalytic cracking units and for hydrocracking of feedstocks too heavy for their treatment in conventional plants. Following run-in tests, initial experiments were carried out in 1968 on Lloydminster light gas oils, heavy fractions and crude. The light gas oil was satisfactory but both the heavy fraction and crude gave rise to problems related to the feeding and circulation of the catalyst. At this point the plant had to be dismantled and was not recommissioned at the Bells Corners complex because the anticipated increase in staff did not materialize and the available staff concentrated on only one aspect of refining technology.

Vapour-Phase Hydrogenation

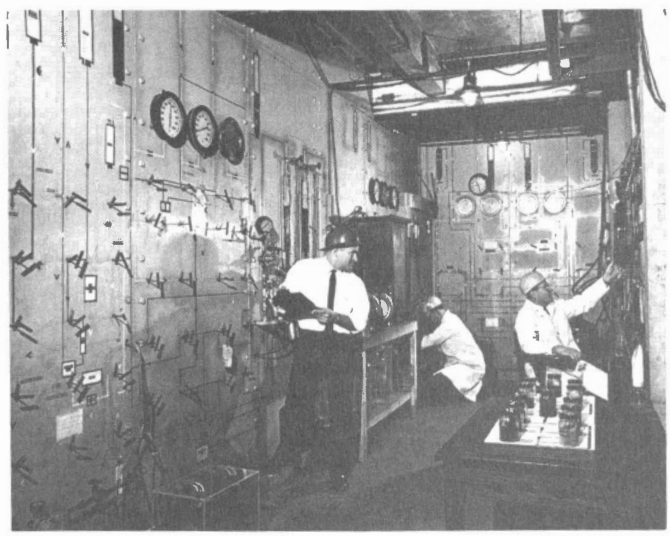
After completing the low pressure - 1000 psi - vapour-phase hydrogenation project on the coker distillate derived from the separated Athabasca quarry bitumen described earlier, most of the professionals and technicians were engaged in completing the high pressure hydrogenation plant designed to operate up to 20,000 psi. The design and ordering of parts and apparatus together with construction took place over a 10-year period from 1945 to 1955 with a very small staff, "Description of a high pressure experimental vapour-phase hydrogenation plant" by W.H. Merrill, K.W. Bowles and F.L. Booth (TM 167-59). The plant was commissioned in 1955. The high pressure experiments were conducted at 1000, 3000, 5000 and 10,000 psi, with a portion of the plant using the vapour-phase reactors and a fixed-bed cobalt molybdate on an aluminum base catalyst. At 10,000 psi, throughput was three times greater than at an operating pressure of 1000 psi. However the heat release at these high rates would be difficult to achieve commercially; a large amount of quench hydrogen would be necessary to control the temperature. The experiments showed that the reactor rate was diffusion limited and that catalysts with much larger pore diameters would be required to treat the heavy gas oils efficiently. The commercially available cobalt molybdate catalyst on alumina support tended to have small diameter pores to achieve greater mechanical strength. The recognition of this fact led the catalyst group in the division to experimental manu-



Pressure vessels originally designed for 20,000 psi for vapour-phase hydrogenation, Booth Street



M. Pleet checking the plant



F.L. Booth, J. Denis, W.H. Merrill on protected operating side of high pressure vapour-phase pilot plant (Photo - George Hunter) facture of catalysts with much larger pore systems. The rate of coke formation on the catalyst was pressure dependent, however the experiments were aimed at reducing the pressure to commercially acceptable levels and determining the rate of catalyst deactivation due to coke deposition. This work was discussed in: "High pressure hydrogenation of coker distillate from Athabasca bitumen - Part I, Feed A" by W.H. Merrill, K.W. Bowles and F.L. Booth (IR FMP 61/31) and "Part II, Feed E" (by W.H. Merrill, A.R. Aitken and M.P. Pleet (IR FMP 61/8). Several campaigns related mostly to catalyst behaviour with different coker distillate feeds and with catalysts of different morphology, following their evaluation in smaller-scale apparatus, were carried out in the period from 1955 to 1962. In 1962, a series of vapour-phase pilot plant runs of long durations of from 50 to 200 hours was carried out to determine the effect of pressures from 1000 psi to 3000 psi in the hydrogenation of bitumen coker distillate over a cobalt molybdenum catalyst. A high operating temperature was used to rapidly form coke on the catalyst. The rate of deactivation of the catalyst at 3000 psi was about ten times less than at 1,000 psi: "Hydrogenation of a coke distillate derived from Athabasca bitumen" by A.R. Aitken, W.H. Merrill and M.P. Pleet (Canadian Journal of Chemical Eng, vol 42, pp 234-238, Oct. 1964).

There was also an extensive project on the hydrodesulphurization of Weyburn heavy crude oil and distillates carried out at the request of the Saskatchewan Research Council. Three reports were issued - (1) on treating the crude oil (IR FMP 60/217 by Merrill, Bowles and Pleet), (2) on the distillates (IR FMP 61/49 by Merrill, Booth, Bowles and Pleet) and (3) on cost estimates of producing conventional refining stock and the production of gasoline and diesel fuels (IR FMP 61/170 by W.A.O. Herrmann).

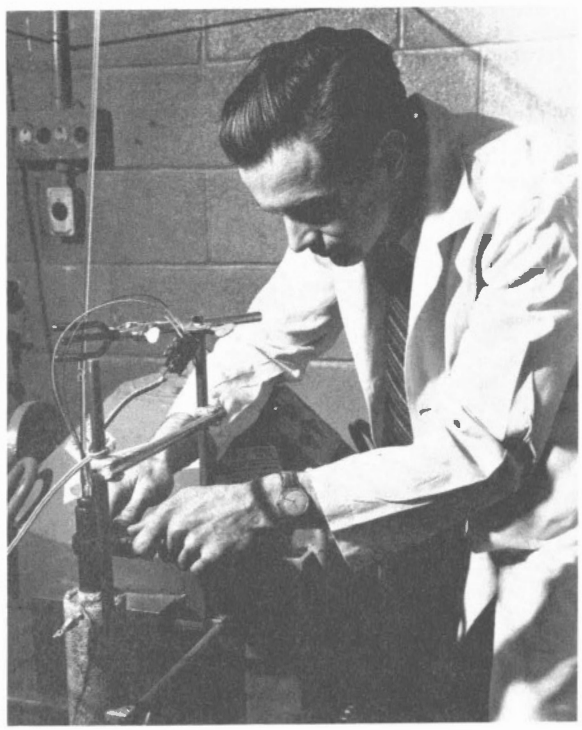
The general consensus by the early 1960's was that the vapour-phase hydrogenation of the bitumen coker distillate could not produce good quality gasoline, but that it could be reformed by catalytic cracking to yield a satisfactory gasoline. On the other hand a good yield of diesel and jet fuel could be anticipated. A paper was presented by Montgomery to a 1963 Chemical Institute of Canada symposium in Montreal under the theme "Hydrogen and its place in refining" entitled "The Athabasca tar sands as a source of crude oil" by D.S. Montgomery (MB IC 169, 1964).

At the request of various agencies, the high pressure facilities were used occasionally in testing cylinders, pipes and hoses. Studies on the embrittlement by hydrogen were made which indicated that stainless steel vessels showed no embrittlement, alloy steels showed about 25%, and carbon steels about 75% when exposed to 20,000 psi after 34 days in hydrogen. Restoration of the original strength and ductility after removal from hydrogen was achieved.

Catalysis

Montgomery recognized the Canadian weakness in catalysis compared with other countries and decided to build up an expertise to control the significant properties of catalysts and their supports thus promoting the most favourable environment for desulphurizing high content sulphur oils with minimum coke deposition. When Parsons joined the branch he was assigned to this project in the then hydrogenation group, becoming head of the catalysis group in the High Pressure Chemistry Section in 1958. The group was concerned with physical and chemical properties of catalysts and their supports and their performance in the refining processes; the most productive results were obtained in the study of catalyst morphology. Design and development of catalysts more suitable for refining low quality feedstocks than those commercially available were also undertaken. Studies were made on kinetics of catalytic processes and acidity of catalysts.

Various methods were tried of measuring the average pore radius, pore size distribution, total pore volume, and the surface area of catalysts. A version of the BET nitrogen adsorption apparatus was constructed for surface area and pore size distribution measurements. This method was found suitable for surface area measurements but was slow; however, by adopting a gravimetric apparatus modification using sensitive quartz spring balances, speed was considerably increased. Of several methods investigated for pore size distribution measurement, high pressure mercury porosimetry was eventually selected. The method was developed using equipment in the high pressure hydrogenation plant but later vessels and pumps for service up to 60,000 psi were acquired. This enabled the pore size distribution to be measured over the range from 100 microns to 40 Angstroms in diameter: "Porosimetry by mercury injection" by G.T. Shaw, B.I. Parsons and D.S. Montgomery (MB TB 45, 1963). Many measurements were made for research organizations and universities. In the course of searching for a technique for measuring pore size distribution, several rapid qualitative test methods were developed for measuring the total pore volume and average pore radius: "Rapid test methods for determination of the approximate average pore radius, total pore volume and

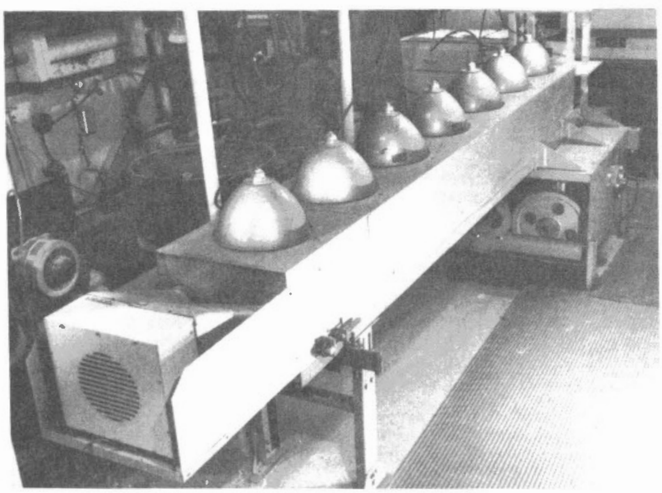


B.I. Parsons at work in cobalt 60 radiation facility surface area contained in porous materials" by W.D. Machin, B.I. Parsons and D.S. Montgomery (MB TB 16, 1960).

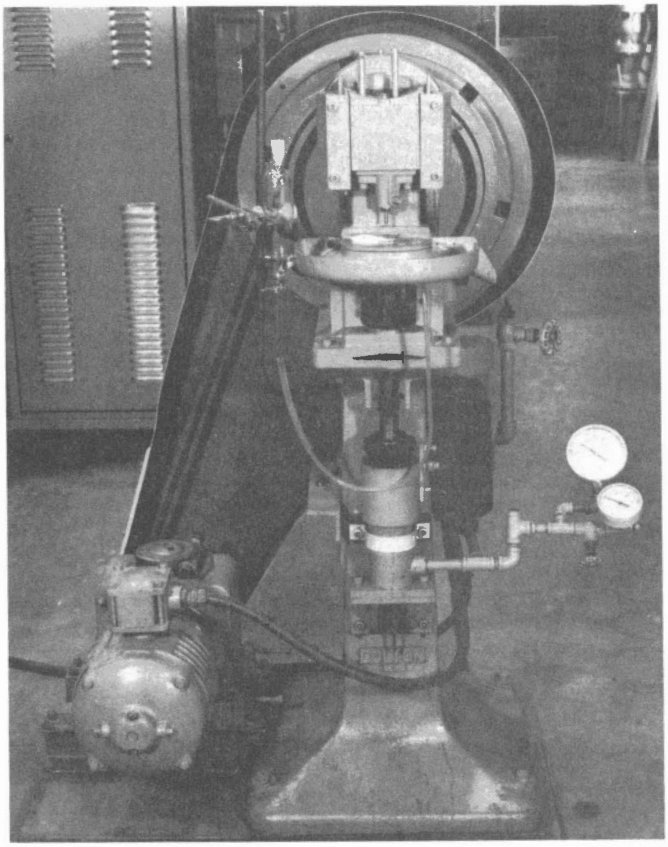
Research was then undertaken on the control of the pore structure in aluminum and silica-aluminum gel catalyst support. A method was developed for enlarging and controlling the pore volume in various pore size ranges by the addition of water-soluble organic polymers to the gels in the course of their preparation. The organic matter was eventually burnt out of the system in the final stages of dehydration and calcination. This resulted in the formation of pore volumes from five to twenty times larger than those obtained in conventional techniques: "The control of the pore volume and pore size distribution in alumina and silica gels by the addition of water soluble organic polymers" by D. Basmadjian, G.N. Fulford, B.I. Parsons and D.S. Montgomery (Journal of Catalysis, vol 1, pp 547-563, Dec. 1962). Canadian and U.S. patents by D.S. Montgomery and B.I. Parsons were issued on this process and, incidentally, these patents have been cited by 14 subsequent U.S. patents.

Because of the low activity of catalysts in dealing with low-grade feedstocks as demonstrated in the hydrodesulphurization research, the effect of gamma radiation on catalysts and catalyst reactions was pursued between 1957 and 1959. A fully protected cobalt 60 facility was designed and constructed under Carson's supervision between 1955 and 1957. It was thought that energy added to a chemical system at low temperature would improve the yield or improve the product. However, results of the preliminary investigation of hydrodesulphurization and cracking were disappointing, and staff shortage prevented further work: "The thermal decomposition of hydrocarbons in the presence of gamma radiation" by T. Flitcroft (TM 59/58). The facility, the first of its kind on the North American continent, was described in a paper by Parsons and Carson and was presented at the 1959 Nuclear Congress in Cleveland.

The kinetics of reactions such as catalytic desulphurization were studied in a pure substance - thiophene - and in pure unsupported catalysts of cobalt



Continuous drier for extrudates of aluminum hydroxide gel used in preparation of high porosity catalysts



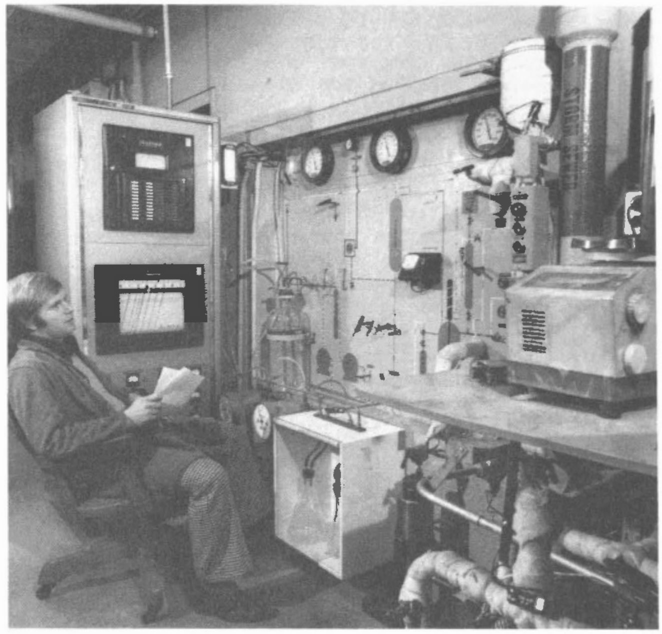
Constant pressure apparatus for pelletizing developed by R.E. Carson

and molybdenum oxides and sulphides. It was found there was a substantial improvement in the rate of desulphurization of thiophene with these catalysts compared with commercially available catalysts. Furthermore, molybdenum sulphide was much more active than the oxide, and cobalt sulphide was found to be less active than its oxide: "The hydrodesulphurization of thiothene over unsupported oxides of cobalt and molybdenum" by R.S. Mann, B.I. Parsons and D.S. Montgomery (TM 77/59).

Another chemical aspect of catalysts - the overall acidity and strength of acid sites at the catalyst surface - was studied, particularly in relation to catalytic cracking because the activity and coking rate are in proportion to the number of acid sites at the catalyst surface. With good feedstocks, acidic catalysts are actually desirable but this is not true for low-grade feeds. Several techniques of measuring surface acidity were attempted but staff shortage precluded reaching conclusions on the degree of surface acidity desirable for dealing with low-grade feedstocks, "Surface acidity of catalysts" by A.P. Bolton, B.I. Parsons and D.S. Montgomery (DR FMP 64/81).

The preparation of catalysts was commenced in 1957 with the purchase of a semi-automatic pellet press modified by Carson to operate at constant pressure instead of at constant volume to ensure that pellets contained a reproducible pore size distribution. The production of catalysts in the Fuels Division did not preclude the use from time to time of commercial catalysts, but it became clear within a few years that the majority of available catalysts were not specific enough for the particular reaction required for a low-grade feedstock and that the catalyst would quickly become unreactive by coke formation and impurities. Hence the comprehensive production and evaluation facility was in constant use, particularly through the sixties. Prepared catalysts were evaluated in a bench-scale unit and then as a second step in the pilot plant reactors.

As research on catalysts progressed it was found during the refining of low-grade residuals that catalytic reaction was almost entirely in the liquid phase wherein the pores were filled with residues and the effective catalyst surface reduced to a thin exterior layer. Accordingly, new methods were developed whereby the aluminum was produced as a highly porous material and pelletized into strong entities which could be impregnated to concentrate the active catalyst layer at or near the surface: "Low density catalysts and catalyst supports" by G.T. Shaw and B.I. Parsons, "Part I - Preparation of highly porous alumina" (MB RR 199, 1968), "Part II - The preparation of strong, low density pellets of alumina" (MB RR 230, 1970).



L.P. Mysak monitors control area for barricaded high-pressure stirred autoclave (Photo - George Hunter)

Combined Liquid- and Vapour-Phase Hydrogenation

By 1960 Montgomery considered that if coking of the heavy oils and bitumen were to be avoided, the primary step was to eliminate the extraneous metals - nickel, iron and vanadium - and particulate matter in a heavy pitch stream which could produce more distillate than by coking. The pitch could be burnt more easily than coke, and moreover, pitch was more marketable.

This philosophy led to autoclave and pilot plant studies on liquid-phase hydrogenation in which an area of some concern proved to be the selection of the most appropriate liquid-phase catalysts. The batch autoclave tests were particularly useful in these studies starting with the Weyburn residuum and continuing with extensive research work on Booth St. and in Bells Corners laboratories.

One principle which was recognized early by the hydrogenation group was that it was desirable to keep the oil hot and to keep it moving. This was due to the unsaturation in the oil tending to give rise to deposits unless thoroughly admixed with hydrogen, hence it was desirable to couple the liquid-phase reaction with the vapour-phase unit. This was the principle of the Combi plant which Herrmann had investigated earlier in Germany. The design was started in 1960 for the Combi plant by Herrmann, Bowles and Merrill. The plant was designed for an approximate throughput of one barrel per day operating at pressures up to 10,000 psi. Various pressure vessels, pumps, compressors, etc., were acquired as funds permitted. The plant was commissioned in 1965. Several hundred operating hours were achieved mainly on Weyburn residual oils. These tests were made to establish the effects of catalyst concentration and particle size, and the rate of hydrogen recirculation in the liquid-phase vessel on the yield and quality of the product but the results were not encouraging. Experiments were also conducted to determine the amount of recycle oil to be withdrawn continuously to eliminate sediment and polymer: "Combined liquid- and vapour-phase hydrocracking of heavy oil" by D.H. Quinsey, W.H. Merrill, W.A.O. Herrmann and M.P. Pleet (Canadian Journal of Chemical Engineering, vol 47, pp 418-421, Aug. 1969).

In 1968, work was suspended during transfer of the equipment and its re-erection at the Bells Corners complex. In the light of Herrmann's prior extensive experience with industrial coal hydrogenation in Germany he was invited by the Sinclair Research Co. of Harvey, Ill. to present a paper "Development and the economics of coal hydrogenation". The substance of this paper was incorporated in a review: "Oils and basic organic chemicals from coal by hydrogenation - a literature review" by W.A.O. Herrmann (MB IC 229, 1969).

Because of the apparent difficulty with catalysts in attempting to refine from the raw state such impure and complex minerals as bitumen, an alternative strategy of thermal hydrocracking was introduced. Exploratory experiments were started in 1968 on thermal hydrogenation of the Athabasca bitumen at pressures from 1000 psi to 3500 psi as an alternative refining strategy and to compare the effectiveness of refining with and without catalysts: "Comparison of thermal and catalytic hydrogenation as a preliminary step in the refining of Athabasca bitumen" by J.J. Cameron, M.A. O'Grady and B.I. Parsons (MB RR 217, 1969).

In later research there was evidence that by diluting the feed with selected gas-oil fractions, a reduction in the formation of sludge and pitch was possible due to a mild catalytic hydrogenation action, preventing the formation of undesirable material during cracking of the residuum.

In 1967 the Fuels and Mining Practice Division was reorganized into two centres: Fuels and Mining. Dr. Montgomery was appointed Head of the Fuels Research Centre. The professional staff of the Applied Research

Group was numerically largely the same as it had been 10 years earlier. The following were in the newly named Hydrocarbons Group consisting of Process Engineering and Catalysis Sections - Group Head: F.L. Booth, Process Engineering: K.W. Bowles, Dr. W.A.O. Herrmann, W.H. Merrill, P. Mogan, D.M. Quinsey (1959 - 1970) J.M. Denis (1963 -) Catalysis: Dr. B.I. Parsons, Dr. G.T. Shaw.

Combustion

The Mechanical Engineering and Combustion Section was the oldest applied research group in the Mines Branch. It started in 1910 with gasification of peat for power purposes and continued most of its research and development in coal combustion until the late post-World War II era when hydrocarbons came into universal use in Canada. The important role of combustion is the provision of energy in the form of heat.

It may be interesting to recall that just prior to the Klondike gold rush, coal was the principal mineral produced. Thus in 1896 the value of the 3.7 million tons produced was $7.2 million, compared with the $1.2 million for 727,000 barrels of crude petroleum and $270,000 for natural gas. Gold production was 133,000 fine ounces worth $2.75 million. The total value of mineral production was nearly $22.5 million at a time when the population was 5 million. There was some importation of U.S. coal and oil mainly to Ontario and Quebec. Considerable wood was also consumed. These statistics all reflect on the extent of Canada's dependence on energy even in that era of comparatively frugal living and limited industrial development.

The following remarks underscore the rapid changes that occurred in the period from 1948 to 1968 in the combustion field which was by far the largest consumer of coal. In 1948 the total coal produced in both Canada and U.S.A. amounted to 14 million tons for domestic, institutional and commercial heating applications, of which 6.3 million was of Canadian origin. By 1968 the combined consumption in this sector had shrunk to 1.4 million tons. In 1948, railways consumed 12.5 million tons of coal, of which 3.8 million tons were Canadian origin, but by 1968 consumption was only 132,000 tons, the market being virtually lost to diesel oil. On the other hand, the reduction in industrial coal consumption, although substantial, was not as drastic. In 1948 the combined Canadian and U.S.A. consumption was 12 million tons of which 4 million tons was of Canadian origin, whereas in 1968 the corresponding figures were 6.3 million and 2.6 million tons respectively. However, in the case of electric power generation, the position was quite different due mainly to new thermal-electric stations in Ontario and later in Alberta. In 1948, the consumption for this purpose was less than one million tons of Canadian coal, whereas in 1968, a total of 11 million tons was consumed of which 5.7 million tons was Canadian. Other losses in the combustion market were in the manufacture of gas and coke, but these were relatively small.

In considering the decline over a 20-year period in the use of coal in combustion applications, it should be remembered that this happened in a period of the largest increase in energy consumption in Canada, and the incremental annual demand was largely furnished by hydrocarbons with the exception of thermal-electric power, which was also growing at rates which in some cases exceeded 10% per annum over several years. In an estimate of total Canadian energy consumed in Canada in 1965 - 141 million metric tons of bituminous coal equivalent - the coal component provided 15% whereas hydrocarbons furnished 75%: "Fuels in a developing country" (The Melchett Lecture, 1965) by A. Ignatieff (Journal of the Institute of Fuel, vol 42, pp 51-58, 1969).

In the 50's and part of the 60's considerable effort by the Mines Branch group was directed to encouraging the use of stokers for fuel furnaces in domestic, institutional and commercial applications, and this was followed by research in improving the efficiency of combustion generally with renewed emphasis on the prevention of environmental pollution. Though the main thrust was on coal, there was also considerable research done on the use of hydrocarbons in combustion.

The close association of the Mines Branch Combustion Group with the Dominion Coal Board, successor to the previous Dominion Fuel Board, and more particularly with Lou O'Brian, the principal technical officer with the longest experience in both agencies, continued in the post-war era until dissolution of the board in 1970. Two major investigations were undertaken for the Board in the late 40's. The first dealt with the chemical and physical properties of 23 carload samples of coal used on the western lines of the Canadian National and Canadian Pacific Railways during 1949, with special reference to the size consist of the coal before and after passage through a standard locomotive stoker. This investigation was in connection with complaints by the railways about the excessive fines supplied by the mines referred to earlier in the narrative [FRL Report 130, 1949, by C.E. Baltzer, W.H. Harper and G.F. Stunell (1948 - 1949)]. A similar investigation for C.P.R. was carried out in 1950 on five carlot samples of coal used on its eastern lines (FRL Report 130A, 1951, by C.E. Baltzer and W.H. Harper).

The second study for the Dominion Coal Board was essentially directed to encourage the use of Western coals in Ontario and was carried out by Baltzer and E.R. Mitchell, who joined the group late in 1949. This was an engineering survey of all Ontario steam plants burning 5,000 tons or more per annum of coal and of all of the Ontario Government's heating plants. Four principal reports were issued (FRL Reports 146 and 146A, by Baltzer and Mitchell, 1950; and FRL Reports 146B and 147, by Mitchell and Baltzer, 1951). Baltzer, and later Mitchell and his associates, at the behest of the Dominion Coal Board, spent considerable time at government buildings and military camps on problems of coal burning and incremental costs in handling and maintenance, which compared unfavourably with petroleum or natural gas which many of these plants adopted.

Fuel and Power

A small group of only two officers - C. Baltzer, who had been with the division since 1923, and W. Harper, who came in 1927 - was established early in 1955 to evaluate the electric supply and trends in the electric power generating industry and to coordinate consulting services on fuel and power problems related to government agencies. A large number of reports, a substantial proportion being of a restricted character because of their advisory nature, was issued to various agencies, particularly to the Dominion Coal Board. The consulting function was always substantial in the Combustion Group, particularly from the start of World War II. Hence, Baltzer was the appropriate person to concentrate his efforts in this area. This allowed more time and scope to Mitchell to develop the combustion R & D program.

The fuel and power studies were on a nation wide as well as on a regional basis. The principal subjects of these studies were on characteristics and costs of fuels used in electric power generation, oil substitution in power and heating plants, forecasts of energy demand, elctric power statistics, etc. There was little official forecasting until formation of the National Energy Board in 1959, as a result of the recommendation of the 1955 Royal Commission on Canada's Economic Prospects. That commission forecast growth of energy requirements to be somewhat less than the increase of the gross national product. A report written in a popular style was published in 1957 wherein forecasts for the regions and Canada as a whole were made to 1975 from a 1953 base. An annual comparative growth of 4% was projected for Canada that forecast nearly 166 billion kilowatt hours would be required by 1975. This proved conservative, as in effect consumption in 1975 was 280 billion kilowatt hours: "Power and population" by C.E. Baltzer and John Convey (MB Memorandum Series 133, English and French texts, 1956 and 1957).

Close association with the electric power generation industry was maintained by Baltzer, and when he retired, by Tibbetts, through the Thermal Power Section (Eastern zone) of the Canadian Electrical Association. Baltzer was also responsible for linking this association with the Coal Division of the CIM.

When the Atlantic Provinces Power Development Act was promulgated in 1958, Baltzer prepared reports on the subvention paid on coal. Because of the rapid growth in electric power requirements in Canada, the section collated news items on power dams, thermal power stations and related items, and these were published in two editions: "Power briefs, 1st edition" by C.E. Baltzer and W.H. Harper (FRL Report 207, 1955) and "Power briefs, 2nd edition" by C.E. Baltzer and W.H. Harper (TM 58/58). In 1957 the 20th Annual Joint Solid Fuels Conference of the American Societies of Mechanical and Mining Engineers was held in Canada for the first time - in Quebec City - the CIM Coal Division being responsible for the arrangements. Several papers were given by Canadian authors including "The Canadian power situation with particular reference to thermal-electric power" by C.E. Baltzer (Trans CIM, vol 61, pp 32-39, 1958).

Baltzer prepared a memorandum on thermal electric power for the 1959 Royal Commission on Coal (IR FMP 60/65) and published a paper which brought up to date the coal requirements for Canadian thermal power generation which was growing fast in the late 50's and early 60's (CIM Bull, pp 841-46, Nov 1961).

Baltzer retired in 1965, having served the Mines Branch for 42 years, and was retained by the Coal Board for several more years because of his extensive expertise; he was one of the hard working breed of men. Harper joined Charbonnier until his retirement in 1969, also with 42 years of service which included army service during World War II, attaining the rank of captain. This section was disbanded on Baltzer's retirement, and some of its activities were taken over by Mitchell's group, though by then a large number of energy experts were appearing on the Canadian scene.

Coal

In 1951, at the request of the Dominion Coal Board, Mitchell, with the assistance of A. Yates on the analytical side, undertook a project on sulphur recovery from flue gases at several pulp and paper mills in Eastern Canada which were threatened with a shortage of elemental sulphur for processing. From this survey it was established that from 26% to 125% of the mills' requirements was available in flue gases which usually were exhausted to atmosphere: "Summary report of tests for the SO_2 and SO_3 contents from high sulphur coals used in pulp and paper power plants" by E.R. Mitchell and A. Yates (FRL Rep 158, 1951). Production of sulphur from a rapidly expanding natural gas industry in Western Canada quickly terminated the sulphur shortage.

Initial tests on the coal-fired turbine referred to in Chapter 5 were carried out during 1950-52 under Warren's direction in consultation with Dr. D.L. Mordell by H.P. Hudson, J.D. Robertson (1949 - 1953) and T.R. Skerry (1949 - 1956). Two aspects of the exhaust-heated cycle were investigated. The first was with the hot heat exchanger interposed between the combustor and the turbine so instead of the turbine blades being eroded and corroded, the tubes of the heat exchanger would be in the path of the hot gases and particles. This work was described in a special unnumbered Fuels Division report in 1951: "Heat exchanger experiments for the Mordell cycle coal-fired gas turbine" by T.E. Warren, H.P. Hudson, J.D. Robertson and T.R. Skerry. The second aspect was the cyclone combustor and secondary furnace designed and tested with a suite of Canadian coals with satisfactory results. This combustor was later used for a smelting application as mentioned earlier: "Canadian coals for the cyclone combustor" by H.P. Hudson and T.R. Skerry (special unnumbered Fuels Division Report, 1954). A paper was also prepared summarizing the foregoing work and developments for presentation at the Annual Meeting of the Mining Society of Nova Scotia in July, 1952: "Coal-fired gas tubines" by T.E. Warren, H.P. Hudson, J.D. Robertson and T.R. Skerry. Hudson assisted in the set-up of the pilot plant in the Gas Dynamics Laboratory of McGill University at Ste. Anne de Bellevue, and W. Foster-Pegg (1953 - 1957) and A.W. Haddon (1953 - 1958) were hired specially for the project. Professor J.W. Stachiewicz was the project manager for McGill, responsible to Professor Mordell. The plant was commissioned in 1953 and at its longest run of 270 hours, corrosion of the tubes of the hot heat exchanger was discovered.

Mitchell took over Mines Branch liaison with the Mordell project in 1955 and organized a corrosion panel in the branch, issuing four Fuels Division reports (TM 1A, 1B and TM 17 all in 1955, and TM 31 in 1956). Major modifications to the furnace and heat exchanger were made and the plant operated nearly 1000 hours with individual runs up to 200 hours. In November, 1956, a symposium was held at McGill to stimulate interest in the development of a turbine stationary power unit. At that time the railways had shown no interest in the development of turbine motive power but despite this Dr. O. Solandt, then head of research for Canadian National Railways, was present at the symposium. Mitchell prepared a report: "Techniques employed in heat exchanger corrosion investigations for the Mordell coal-burning gas turbine project" as well as a review of European work on solid fuel turbines (FRL Rep 255, 1956). The latter was based on a visit to Europe in the summer of 1956 which included attendance at the World Power Conference in Vienna and visits to several research establishments. In an effort to broaden the scope of the turbine by linking it with steam, a study was made jointly with Burrough: "An analysis of coal gasifier-gas turbine-steam boiler combination for generating power" (TM 24/57). A Canadian patent was granted to Mitchell. As there was no positive reaction from industry, the project was terminated early in 1958. A report on the project and the symposium was published in the Mines Branch Monograph series: "Experimental coal-burning gas turbine exhaust-heated cycle" by J.W. Stachiewicz and D.L. Mordell (MB Monograph 867, 1960). A separate volume with the same number was published as "Proceedings, conference on coal-burning gas turbines" unauthored. Mitchell became specialist correspondent for gas turbines through the chief of the division, who represented Canada in the Commonwealth Committee on Fuel Research (CCFR) formed in 1947.

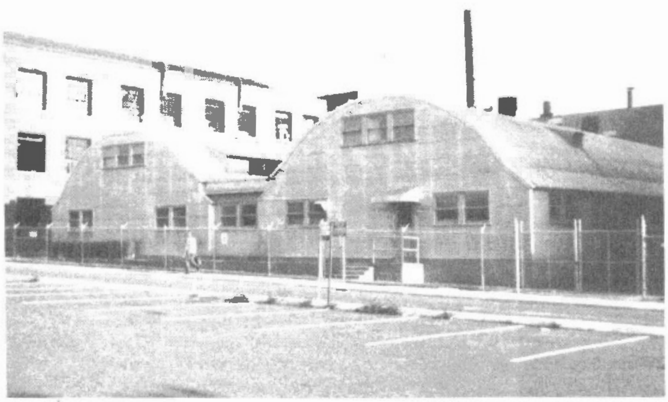
Stoker Development

A sustained effort was made in the period from 1950 to 1955 to popularize the burning of Canadian coals in small stokers essentially for domestic and small building use. Most of these stokers were of U.S.A. design for use with good quality coals. Mitchell carried out tests in 1952 on five Alberta coal groups from low-volatile to sub-bituminous rank and compared the results with an automatic oil burner which favoured the latter. Promoting coal was attempted through instruction cards illustrating the burning of different types of coal. Dominion/Provincial Coal Research Conferences, the forerunner of the present Coal Conference - starting in 1949, encouraged the Coal Division of CIM to promote the use of equipment types best suited to burning given Canadian coals. Accordingly, a domestic heating forum was organized in 1951 at the Western Annual General Meeting in Calgary. A more ambitious program was arranged at the 1952 Western Annual General Meeting in Winnipeg, comprising not only the presentation of papers but a display of stokers in operation at the University of Manitoba, burning high and medium-rank coals from Alberta and lignite from Saskatchewan in three types of stokers, described by E.R. Mitchell, Dr. W.A. Lang of Alberta Research Council and J.E. Rougeau of Great West Coal Company with Baltzer as the moderator: "Forum on the automatic burning of coal" (CIM Bull, pp 242-49, Apr. 1953). One may conclude that by the middle of the 50's attempts to retain domestic coal firing, particularly in the urban areas of Western Canada became a lost cause because of the rapid inroads of oil and natural gas.

With renaming of the section in 1955 to Combustion Engineering, and the appointment in 1954 of Mitchell as its head, emphasis was shifted to institutional heating with coal in Central and Eastern Canada, mainly in government departments. Mitchell built up the section with some difficulty, partly because of the shortage of engineers specializing in combustion in Canada but he did have the services of Skerry until he left in 1957. In the same year, F.D. Friedrich (1957 -) was recruited, followed in 1958 by G.K. Lee, (1958 -) G.R. Fouhse (1958 -) and a technician, M.H. Weatherall (1953 - 1964). This group, as its predecessors, was very productive, and it is fair comment to say that any success achieved in improving the efficiency of combustion of Canada's heterogeneous coals was due largely to the historic guidance and advice given by the successive generations of combustion engineers and scientists of the Mines Branch. Long before atmospheric pollution became a public issue, "smoke abatement" was a principal aim in this laboratory and in progressive industrial plants.

Mitchell was a good organizer and he assisted the office of the chief of the division in acting on a number of committees and at meetings such as being program chairman of the 12th Annual Dominion/Provincial Coal Research Conference held in Ottawa in 1960, for which he was commended by the Conference Advisory Committee. He was also secretary of the Canadian Advisory Committee on Coal Research formed in 1961 on the proposal made by Dr. Lang at the 1960 conference, and CCFR specialist correspondent on combustion and new methods of power generation, etc. His services were in considerable demand by Canadian and U.S.A. professional and industrial organizations such as the American Society of Mechanical Engineers, the American Society of Heating, Refrigerating and Ventilating Engineers, and he was founder of the Institute of Combustion and Fuel Technology of Canada. The section was moved to the west Quonset hut at 30 Lydia Street in 1959 after transfer of the staff of the dissolved Radioactivity Division to 555 Booth Street.

A major effort, started in 1957 and continued to 1962, was the attempt to improve the burning of Cape Breton coal in conventional institutional stokers installed in the heating plants of federal buildings in Ottawa and elsewhere in Central Canada. The first request was from the Department of Public Works in 1957 regarding heavy smoke emission and heavy maintenance cost at the central heating plant on Cliff Street, Ottawa. This was a spreader-fired travelling grate stoker. Experiments indicated that the grate clips should be redesigned and that modifications should be made to the stoker and the overfire turbulence system in the boiler. These changes were successful, resulting in similar changes being made in the other two boilers in the subsequent season (TM 39/58, Mitchell and Friedrich). There followed requests for diagnosis and resolution of difficulties, and for advice on new



Quonset huts, 30 Lydia Street occupied by Radioactivity Division until 1959 and thereafter by Mining Research at left and by Combustion Engineering at right installations including equipment acceptance tests at many federal establishments using various types of stokers, mainly the underfeed type.

The principal difficulties with Maritime coal were due to their highly caking nature, the low fusion temperature of their ashes, and the practice of burning thick beds of coal on the grates. In 1959 the Dominion Steel and Coal Corporation entered into a cooperative research agreement with the Mines Branch to study the effect of additives and the improvement of clinkering characteristics as well as continuing the improvement of conventional stokers to better suit the combustion characteristics of Dominion coal. This agreement provided funding for hiring a technician, J.Z. Skulski who had good prior chemical training and who continued until the end of the project in 1964 when he joined the Solid Fuels Laboratory as analytical chemist. The first part of the Dominion program on additives indicated that several additives increased the ash softening temperature but they were not considered economical to use. A formula was developed from the ratio of acidic and basic components of the ash to predict ash softening temperature of coal-additive mixtures. It was also established that an oxidizing atmosphere in the furnace increased the ash softening temperature but carbon in the ash reduced the temperature: "Index of ash clinkering and the influence of additives on eastern Canadian coals" by G.K. Lee and J.Z. Skulski (MB TB 19, 1961). The second part dealt with blocking of air passages in the grate bars with molten ash, resulting in excessive heating and damage. A whole series of bars and links with better air openings to improve heat transfer and cooling of the bars were designed and patented for the various stoker types. A more resistant alloy was introduced after consultation with the Physical Metallurgy Division. Two foundries, one at Merrickville, Ontario, and the other at North Sydney, Nova Scotia, were licensed to produce these bars and links. Improved combustion was achieved and smoke emission was reduced through improved air distribution. For worm feed stokers a patented smoke abatement device was designed. The conclusions of this comprehensive study were summarized in a publication: "Research on the application of Eastern Canadian coals to large stokers" by E.R. Mitchell, F.D. Friedrich and G.K. Lee (MB TB 14, 1961).

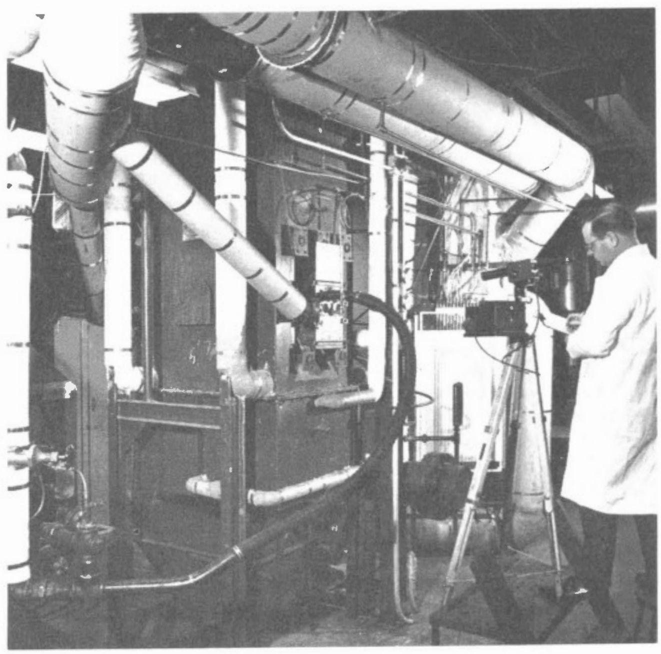
The concept of a distinct stoker for burning Eastern Canadian coals was born early in the project. During the 1958 heating season, experiments were carried out on a spreader-fired oscillating grate at the Dosco mill in Etobicoke, Ontario. Valuable information was derived from these tests which gave promising results: "Combustion of eastern Canadian coal in thin fires on a spreader-fire air-cooled oscillating grate" by E.R. Mitchell, F.D. Friedrich (Fuels Division) and G.A. Gauthier (Dominion Coal Company) (MB TB 1, 1959). This report had some influence on the installation of oscillating grates at a veterans hospital and at both an army and an RCAF camp.

For the next five years the design was improved by incorporating a vibrating grate and means for preheating the coal to render it non-caking. The laboratory model was tested extensively and provided the design criteria for a commercial model of a stoker-fired package boiler which was eventually purchased for the heating plant at the Mines Branch Bells Corners complex: "Development of a model vibrating-grate stoker for strongly caking coals" by F.D. Friedrich (Jour of Institute of Fuel, London, vol 38, pp 102-110, 1965). However acceptance tests indicated that further adjustments would be required and because of the high cost of coal compared with oil, the final decision was to heat the complex by oil.

Industrial Combustion

By the end of the 1950's the general view in the division was that the future of Canadian coals with their widely varying characteristics lay in power generation and large industrial applications which would employ the cheapest bulk-produced coals. This was one of the principal reasons for the decision by the Combustion Group to develop a research rig using pulverized coal or residual oils as fuels. In the course of time this unit made a substantial contribution to the Canadian thermal power industry. A design was prepared which incorporated a pilot-scale pulverized coal-fired water tube boiler with a slag tap furnace rated to burn 200 pounds of bituminous coal or 16 gallons of oil per hour, corresponding to a steaming rate of 1500 pounds per hour at 15 psig. The firing was done by two opposed burners tilted downwards over the slagging chamber. The combustion gases passed from the boiler into a test air heater with interchangeable stainless steel tubes for studies of high temperature corrosion and then to a conventional air heater before entering the stack. The steam for the boiler was dissipated in an air-cooled condenser.

The principal components were supplied at reduced cost by Foster-Wheeler Limited of St. Catharines. The auxiliaries were in part purchased and in part retrieved from discards in the branch. Construction was assisted by the division's Construction Equipment Section and by the Technical Services Division. The rig was commissioned at the end of 1962 and was "run



E.R. Mitchell records data from study of turbulent diffusion flames in a pilot-scale coal-fired boiler (Photo - George Hunter) in" with oil and, in some preliminary tests, with coal.

In 1963, four tests with low temperature ash fusion coking coals from Eastern Canada were conducted, followed in 1964 with Saskatchewan lignite. This rig provided research facilities for studying the aerodynamics of burner design, combustion reactions, the mechanism of fireside ash deposits, corrosion, heat transfer, and the sulphur dioxide-sulphur trioxide acid dewpoint relationship. A paper was prepared for the 1967 Centennial Symposium on Science and Technology of Coal on the influence of various factors on the corrosion potential of boiler flue gases from burning two high-sulphur Eastern Canada coals and a Saskatchewan lignite. Results indicated that the continuous deposits from the gas stream vitiated the equilibrium data that could be applied to the corrosion rate. A principal observation was that corrosion was minimal at less than 1% excess oxygen and the corrosion was high with an oxygen content of 3% in the flue gas: "Effect of fuel characteristics and excess combustion air on sulphuric acid formation in a pulverized-coal-fired boiler" by G.K. Lee, F.D. Friedrich and E.R. Mitchell (Proceedings of Symposium on the Science and Technology of Coal, Special Centennial Volume, EMR, published by Mines Branch, Department of Energy, Mines and Resources, Ottawa, 1967).

Two high-ash lignites from Onakawana, Ontario and Bienfait, Saskatchewan were tested. The results indicated fouling of high temperature heat transfer surfaces due to superfine alkali particles which condensed from vapour and effectively cemented fly ash particles into massive sintered deposits: "Combustion and fouling characteristics of two Canadian lignites" by F.D. Friedrich, G.K. Lee and E.R. Mitchell (MB RR 208, 1969).

The section was traditionally sensitive to the necessity of controlling not only smoke but emissions of toxic gases and particulates. Mitchell was appointed in 1958 as chairman of the City of Ottawa Air Pollution Appeal Board. In 1960 a literature study was undertaken to assess the physiological effects on plant life caused by flue gases containing sulphur dioxide and trioxide and the contamination of soils by fly ash. The study deduced that emission of sulphur oxides became dangerous to plant life in the immediate vicinity when a steam generating plant using high-sulphur coal reached a steaming capacity of 1.4 million pounds per hour [IR FMP 61/135, G.K. Lee and A. Laur (1960)].

In 1960 also, at the request of the Nova Scotia Light and Power Company, an investigation was carried out on emission of agglomerated fine dust from the stacks of the company's cyclone-fired furnaces at Halifax. The agglomerates were found to be spheres from 17 microns to sub-micron in size and to consist of coal ash with ferric oxide as the main constituent. The particles were coated with a water soluble sulphate of sodium, calcium and aluminum. The conclusion was that the latter was derived from residual oil which was also used in the plant. Low velocity electrostatic separation was recommended: "Agglomeration of super fine fly ash in high-velocity streams" by E.R. Mitchell and G.K. Lee (Trans CIM, vol 65, pp 380-384, 1962).

Over the years, considerable confidence in the section was built up by the combustion engineering constituency, both governmental and industrial, with requests for equipment acceptance tests and combustion problem-solving. Probes were developed for measuring temperatures in large, not easily accessible furnaces and for taking dust samples. In the early 60's the section undertook the monumental task of preparing a series of volumes on combustion data of Canadian fuels and heat loss data for various fuels commercially used in Canada; all the data were derived from extensive records of the Combustion Engineering Section from almost its inception. The combustion data were aimed to help equipment designers, and the heat loss data were aimed to enable operators to determine efficiency without the need for elaborate measurements. Three volumes were eventually published starting in the late 60's, with coal in two parts. Mitchell gave full credit for authorship to his associates though he participated in developing the data (142).

Hydrocarbons

Early in 1958 the Royal Canadian Navy requested advice on how to remove slag from superheaters in naval boilers using Venezuelan oils, for which mechanical means or the use of acids had not been successful. Many specimens were examined and the section determined that the bond between the superheater tubes and fuel oil was caused by sodium salts of the acids in the heavy components of the oil. Though the slag was dense it was porous and the recommendation was made to use steam containing a wetting agent until the slag was softened, when it could then be removed with water or mechanical means (TM 103/58, G.K. Lee). This initial investigation led the RCN in 1959 to sponsoring a fuel oil combustion project to study the mechanism of ash deposition on boiler heating surfaces and to determine preventive measures. An evaluation was made of 14 fireside deposits produced in 100-hour runs in a rig constructed in the laboratory to simulate superheater slagging conditions of marine boilers. The oil was high in sulphur and vanadium. The deposits were examined chemically, optically and by X-ray diffraction, the last method with the advice of the Shell Company's British laboratory. In the next phase, 44 test runs of 100 hours each were made in which 20 fuel oil additives including proprietary brands were evaluated. The additive finally selected was a special formulation of magnesia and alumina in an oil carrier with a suitable dispersant. Shipboard trials were proceeded with, giving encouraging results. This additive was found to reduce corrosion at the cold end of the boiler: "Investigation of fuel-oil additives to prevent superheater slagging in naval boilers" by G.K. Lee, E.R. Mitchell, R.G. Grimsby and Lt. Cmdr. S.E. Hopkins, the last two from the RCN. (Reprint from Proceedings of American Power Conference, vol 26, pp 531-552, 1964; MB TB 66, 1965).

The long period of experimentation furnished a better understanding of the oil ash chemistry at high temperatures; the mechanism of deposition was considered as one of vapour diffusion. Reduction in excessive combustion air showed desirable results: the dewpoint temperature was increased because of reduced formation of sulphur trioxide and formation of lower oxides of vanadium with higher fusion temperatures.

By controlling the thermo-physical properties of the fuel ash with an additive, the ash deposit structure could be controlled as a light fluffy easily removable material. A final report on the additive was given at the 1966 American Power Conference: "Formation of oil ash deposits on boiler surfaces and control by additives" by G.K. Lee, E.R. Mitchell, R.G. Grimsby and D.H. Benn, RCN, (Proc American Power Conference, vol 28,1966). A report on this research was given by Lee and Mitchell to the Naval Tripartite Meeting on Fuels and Lubricants in Ottawa in May 1967.

The industrial world was interested in this additive patented in several countries and as early as 1965 two U.S.A. companies were producing the special formulation on a commercial scale.

Burner Development

In 1957 a propane heater with a low burning rate was developed for use with river gauge wells to prevent freezing of the water level recorders. Four units were fabricated for the Department of Indian Affairs and National Resources and 18 units for the Hydrographic Surveys Branch. This unit had a heat rate of 2500 Btu per hour (FRL Rep 267, 1957, by Mitchell and Friedrich).

In 1959 and for the next three years the section was concerned with high intensity or resonant combustion, and one of the projects was in connection with the Linde Company, which was interested in developing a jet piercing method of drilling rocks in open pit mines using oxy-fuel burners. L.B. Geller was the company's representative for a short time and he was assigned to the Combustion Engineering Section for the burner time project of this research. As the Mining Section and Mineral Processing Division were involved in this project, M.A. Twidale who joined the Mines Branch in 1958 was appointed as coordinator by the director. Geller joined the Mines Branch in 1960.

It was found that failure of rock was caused by a mechanism of spalling - some rocks spalling easily and others not. However, an important fact determined was that spalling occurred at temperatures considerably below those produced by oxy-fuel jet burners. A number of air-fueled jet burners were then built and operated. A stable flame was developed for an air kerosene burner with a high air-to-fuel ratio, releasing up to 61 million Btu's per cubic foot per hour. Rock tests with this burner were pursued and patents were applied for in the U.S.A., Canada and South Africa and were granted in 1964, both for method and apparatus, in producing air fuel flames of sonic and supersonic velocity, the authors being L.B. Geller and E.R. Mitchell. Altogether, 13 divisional interim reports were written, mostly by Geller, with others from the Mineral Processing Division. These were consolidated into a 611-page volume containing a summary by Geller together with 20 appendices by him and others. This volume was edited by one of the best editors in the department's history, D.A. Shenstone (143). Though this project did not attain the practical objective of designing a universal rock piercing machine, considerable information was developed on thermal properties of rocks when heated to failure which could eventually lead to the design of combined mechanical and thermal drills and possibly to continuous mining machines.

The air kerosene burner was adapted to submerged operation and was tested on the ice cover of the Rideau River in Ottawa in February, 1962. The penetration was approximately 50 feet per hour for a 9-inch diameter hole. The burner proved to be stable and reliable: "Destruction of ice formations and penetration of ice by air-fuel jet burner flames" by L.B. Geller (IR FMP 62/187).

L. Richards drills rock samples in connection with jet-piercing research project at Uplands

Jet piercing equipment; in foreground are electric pump and flowmeters; at left centre is automatic-feed blow pipe

D. Savignac and L. Geller carrying out ice-cutting tests on Rideau River, Ottawa

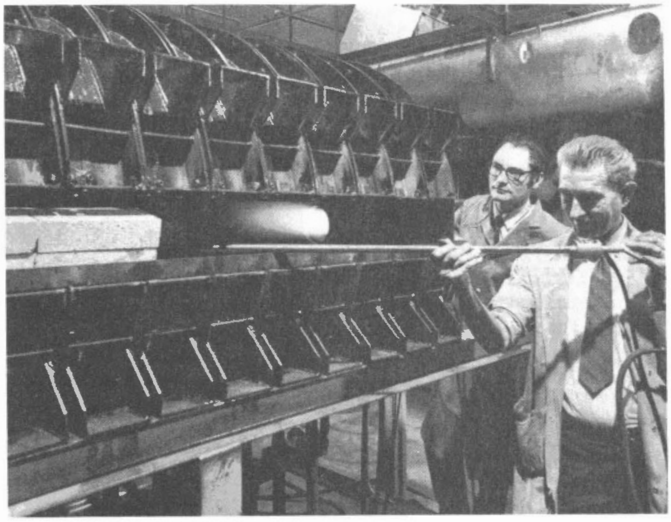
In 1962, Green Steel Industries of Winnipeg requested assistance to suppress excessive noise of a patented domestic gas-fired hot water boiler utilizing pulsating combustion to achieve high heat release rates. The unit was assembled in the section's soundproof chamber and tests were made to establish sound level distributions. NRC loaned a precision sound level meter and a frequency analyzer. It was found that the air inlet and exhaust mufflers were ineffective and these were redesigned. New mufflers were fabricated in the branch and the unit was demonstrated to the manufacturer in Winnipeg in 1963.

A conference - the first fossil fuel technology conference held in this period - is worthy of mention. It was jointly sponsored by the department and the Institute of Combustion and Technology of Canada under the patronage of the Governor General of Canada, General Vanier. Mitchell, as president of the Institute and chairman of the Program Committee, was assisted by his immediate associates Friedrich and Lee in organizing the conference which was held in May 1963 at Ecole Polytechnique of the University of Montreal which was the alma mater of Dr. Marc Boyer, the deputy minister of the department from 1950 to his death in November 1962, it being named the "Boyer Conference" in his memory.

The papers by Canadian authors from various parts of the country included one that had two authors from the Combustion Engineering Section: "A pulsating combustion system for space heating" by J. Alebon, G.K. Lee and L.B. Geller, and were published in one bilingual volume. Dr. Charbonnier was responsible for supervision of the French tests, many of which he translated from English himself. D.A. Shenstone, V. McBride and J.P. Couture were responsible for the editing and production of this unique volume (144).

In 1966 the combustion group became a member of the British Flame Research Committee and through it, the Mines Branch Combustion Laboratory became associated with the fundamental studies of the International Flame Research Foundation IFRF at Ijmuiden in Holland. Friedrich participated for several months in one of the studies where he developed expertise in the use of aerodynamic probes. On his return to Ottawa flame probes were assembled.

In 1968 a unique tunnel furnace was designed for systematic investigations of the time-temperature-space history of luminous and non-luminous combustion products. In these studies the IFRF probes were used to characterize thermo-physical parameters, turbulence, swirl, etc. Later the furnace was used to study 12 burners on behalf of the Oil-Heating Association of Canada for the improvement of domestic burners. A report on the tunnel furnace was given to the IFRF: "CCRL tunnel furnace design and application" by F.D. Friedrich, E.R. Mitchell, G.K. Lee and H. Whaley. Reprinted from IFRF, 2nd Members Conference, Ijmuiden Holland, Chapter XV pp 1 to 18, May 1971 (MBRS 104).



F.D. Friedrich and W.D. Shaw perform flame aerodynamic probing in tunnel furnace (Photo - George Hunter)

In 1970 largely on the initiative of Mitchell, Lee and Friedrich as active members of the Institute of Fuel Technology of Canada, organized in Ottawa a first conference under the sponsorship of the Canadian Institute, Institute of Fuel, London and the American Society of Mechanical Engineers, New York. It was named "North American Fuel Technology Conference" and dealt with four themes - "Utilization and conservation of fuel resources," "Trends in fuel science", "New applications of fuels technology" and "The effect of fuels on the environment".

In 1967 the Combustion Engineering Section was renamed Canadian Combustion Research Laboratory (CCRL) in the Fuels Research Centre, E.R. Mitchell being head with the following associates: G.K. Lee, F.D. Friedrich, R.G. Fouhse and Dr. H. Whaley. The professional staff numerically had an addition of one - L.B. Geller in 1960. In 1966 Dr. H. Whaley joined the group, Geller was transferred to the Mining Research Centre and D.G. Savignac, who started as a technician on the Linde Rock Piercing project, was appointed by the Civil Service Commission to a permanent position in 1963. B.C. Post was appointed in 1961, R.K. Jeffrey, W.D. Shaw and H. Raghunandan in 1966.

Mining

COAL

The mining research program arose largely from the survey of mining methods in Canadian coal mines mentioned in Chapter 5, which referred to the severity of geological conditions which interrupted production and inhibited underground mechanization in some of the coalfields.

At the second Dominion/Provincial Coal Research Conference held in February 1950, Ignatieff proposed two studies which were expressed in Resolutions 5 and 6 - "... inflammability and explosive properties of coal and industrial dusts ..." and "... new systematic and continuous work on rock pressures...". Dr. R.H. Howland representing Nova Scotia incorporated these resolutions as Exhibit 4 in his report of the Standing Committee on Coal which was adopted at the 7th Provincial Ministers of Mines Conference in Victoria, B.C. in September 1950.

The project on explosibility of coal and other dusts was assigned to the Solid Fuels Analytical Laboratory. Although some preliminary work was carried out earlier on the U.S. Bureau of Mines method, the laboratory work load prevented the project from getting under way until 1957. All the early research work on the rock pressure project was dedicated to the problem of violent relief of stress in coal mines, colloquially expressed in the two phenomena of bumps and outbursts. The bump, or rockburst, is a sudden relief of strain energy usually associated with deep mining of both coal and ore; the more usual occurrence takes place on the perimeter of relatively large extracted or stoped-out areas. The outburst is a sudden event almost entirely associated with coal mining, and its incidence is most frequent in virgin areas which are being opened up by driving tunnels or entries. By far the largest number of outbursts seem to take place in orogenic belts where the strata have been folded and faulted.

An interdisciplinary approach was used from the start in tackling this project by combining geological studies, mine observations and measurements, by developing appropriate instrumentation and by studying rock and coal properties. Besides the mining section, this project involved a number of other groups - the Geological Survey of Canada, the Physical Metallurgy Division for the development of instrumentation, and the Industrial Minerals Division providing initial laboratory facilities for testing rocks. When the work started in Nova Scotia, assistance was provided by the

General view of terrain in Crowsnest Pass area where strata pressure research was conducted. Frank slide stands out as pale scar (Photo - courtesy Dr. D. Norris, GSC, Calgary)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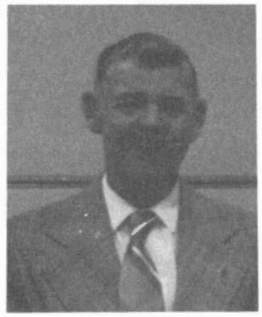
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Founding members of the Mines Branch mining group, along with the author were: 1 - F.L. Casey and 2 - A. Brown, followed by 3 - C.A. Vary, 4 - T.S. Cochrane, 5 - H. Zorychta, 6 - F. Grant and 7 - L.C. Richards

Nova Scotia Research Foundation through the project committee on "pressures in strata" under Howland, which in turn involved the Nova Scotia Technical College for laboratory facilities and the Nova Scotia Department of Mines for diamond drilling of boreholes.

The original Mines Branch mining group was composed of F.L. Casey (1941 - 1975), A. Brown (1949 - 1962) and A. Ignatieff (1947 - 1972). It was augmented by C.A. Vary (1948 -) in office studies in 1950, and by two mining engineers in the field: T.S. Cochrane (1951 -) and H. Zorychta (1951 -). When Ignatieff was appointed chief of the Fuels Division in 1954, Brown became head of the Mining Section. The first mine personnel added to the field staff were: F. Grant (1952 -) and L.C. Richards (1953 -). Both came from mines in the Crowsnest area of B.C. and Alberta. Following a brief period by J.E. Wilson from the Mineral Dressing and Process Metallurgy Division, R.H. Hardy, Jr. (1953 - 1966) was the first physicist to be appointed to evaluate the physical properties of coal and rocks.

With the concurrence of the mining companies and the provincial departments of mines, four mines in Western Canada were selected for research studies in 1951. These were the Elk River No. 3 mine near Fernie, B.C., with Herb Zorychta being the field engineer in charge; International and the adjoining McGillivray mines at Coleman, Alberta, with Tom Cochrane, field engineer in charge; and somewhat later, No. 8 Galt mine in Lethbridge, monitored by Cochrane and Grant. The first three mines were located in the geologically highly disturbed orogenic belt of the general Crowsnest Pass area. The inclined coal seams were about ten feet thick with depths of cover to 2400 ft. The mining method was room and pillar, with recovery of pillars in the deeper workings. At Lethbridge the mine was outside the orogenic belt on the eastern edge of the Alberta Syncline. Here room mining was practised without extracting narrow pillars left in a 5-ft flat seam at a depth of about 500 ft overlain by weak beds. The cooperation of the mining companies, provincial departments of mines and the local inspectorate was excellent. The sole disappointment experienced with the field studies was the progressively deteriorating market which prevented the regular working of the mines and resulted in the closure of some of the districts where measuring stations were installed.

In 1952 the Nova Scotia Department of Mines together with the Nova Scotia Research Foundation requested that the Mines Branch commence an investigation at the Springhill mines, No. 2 mine being one of the deepest coal mines in the world where bumps were occurring at a depth of over 4000 ft. Considerable assistance in launching this project was given by the Nova Scotia agencies mentioned previously. In 1953, Zorychta was transferred to Springhill from Fernie as the field officer in charge. The Springhill mines were located on the southern limb of a large depositional basin. Though the stratigraphic column contained a larger proportion of stronger rocks than those in the Sydney field, the geological conditions were not as severe as in the Crowsnest area, and it is interesting to note that despite the occurrence of bumps there was no history of outbursts.

As noted earlier, the program provided for geological investigations. The Geological Survey cooperated in finding a geologist in the person of Don K. Norris, who was completing his postgraduate studies at the California Institute of Technology. Dr. Norris proved to be a competent and enthusiastic geologist who spent many hours underground interpreting structural features, often in locations of potential hazard. In this connection, all of the Mines Branch staff members also were often exposed to hazardous conditions but never shirked their responsibilities. Norris continued his connection with the program into the 60's. He studied the Nova Scotia coalfield which differs in structure from the Western fields. His studies in all cases included stratigraphy and general as well as detailed mine structures. He analyzed the influence of geological factors on mining and the occurrence of violent relief of stress: "Structural conditions in Canadian coal mines" by D.K. Norris, Bull 44, GSC, 1958.

Dr. P.A. Hacquebard, also of the Geological Survey, made a number of petrographic studies of coal from outburst and non-outburst areas which indicated there was no discernible difference between the two types.

The Dominion Observatory at Victoria, B.C., cooperated in setting up seismic stations using Wilmore seismographs to determine whether regional seismicity contributed to occurrence of bumps, but the results generally indicated that the incidents were mining-induced: "A seismic investigation of mine 'bumps' in the Crowsnest Pass coal field" by W.G. Milne and W.R.H. White (Trans CIM, vol 61, pp 356-363 1958).

During the period that mining observations were being made, the surface over the extraction areas at McGillivray and Lethbridge was monitored for subsidence. At the former, the superincumbent beds were composed of rocks of variable strength with a layer of particularly strong conglomerate; on the other hand, at Lethbridge the overlying rocks were weak. This difference showed up on the surface. In the case of McGillivray, subsidence was in the form of subsidence cracks which followed the direction of the main entries or levels driven on strike for mining out successive blocks of coal, whereas in Lethbridge the classical subsidence declivity was developed over the extraction area.

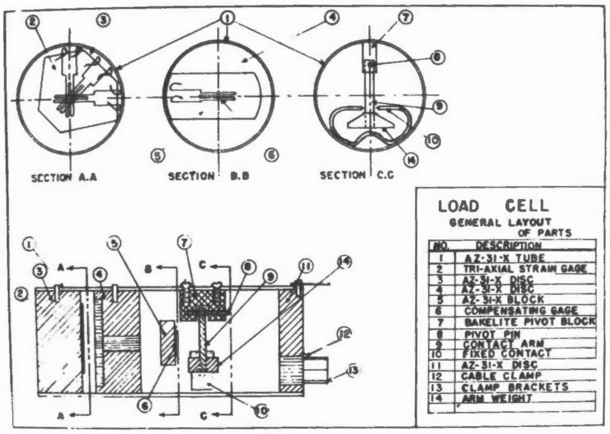
Underground, the measurements and observations were made in open workings, e.g., in entries and rooms largely for rates of ground movement and in situ or in pillars for changes in stress. In workings, the monitoring was for rate of closure, behaviour of roof and floor, separation and migration of roof beds by various

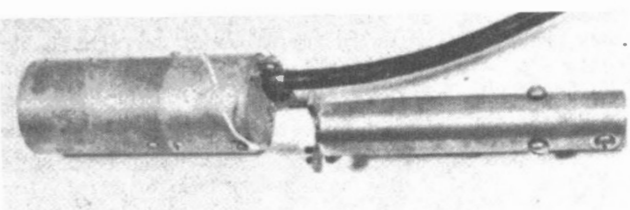
D.K. Norris

types of convergence-measuring devices and included roof level surveys and dynamometric props recording change of load. This instrumentation enabled the identification of high stress areas or abutment zones; this was particularly important close to or within the extraction area. The behaviour of solid structures like pillars required borehole instruments exclusively. The first crude devices were made of lead followed by hydraulic rubber and steel cylinders. These indicated the order of increased stress in an abutement zone; a doubling of stress was noted when the pillar extraction line was within 100 ft of one of these devices.

Meanwhile, the Engineering Physics Section of the Physical Metallurgy Division under R.C.A. Thurston, was encouraged by Convey when he was still chief of the division to assist the project by developing appropriate instrumentation based on metallurgical experience. Two of Thurston's associates were J.G. Buchanan (1950 - 1957) and F.W. Marsh (1950 -) the latter having had structural experience with Ontario Hydro. They designed three instruments: one for measuring electrical resistivity for outburst-prone areas, another a strain gauge load cell for measuring the magnitude and direction of principal stresses, and later a sonic instrument for evaluating the fissuring of rock in metal mines. To ensure safety in using electrically activated instruments in a coal mine atmosphere, Brown and Buchanan in 1952 carried out methane-air explosion tests which were successful. At that time the certification laboratory had not been established.

The resistivity 4-electrode apparatus was tried out in the Elk River mines, B.C., but most of the experimentation on outbursts was conducted at Canmore Mines, Alberta. For stress measurement the first model strain gauge load cell of cylindrical shape for embedding in a borehole enclosed a load responsive steel disc on which was mounted three strain gauges forming a 45-degree rosette bonded to the disc: "A method for measurement of stress changes during mining operations" by J.G. Buchanan, F.W. Marsh, and R.C.A. Thurston (Can Min Journal, pp 49-55 vol 76, 1955). These load cells were used in materials of highly contrasting properties - from weak deformable coals to strong, brittle rocks. Though a correlation of the stress in the metal disc with that in the host rock was not achieved and the load cell was found to be insufficiently strong in certain cases, the general results indicated that the direction of stresses was not related to a predominant stress derived from the weight of overlying rocks, amounting to approximately one pound per square inch for every foot of additional depth. All subsequent measurements of field stress in various rocks and ores in orogenic belts of different geologic periods indicated the presence of residual or remanent stresses. Some of these field stresses were many times greater than the weight of superincumbent rocks or gravitational stresses; the direction of the principal stress was not necessarily vertical. This evidence was possibly the most important contribution from experimental rock mechanics research. The results also confirmed the existence of some very high stresses in the abutment zones, indicated by the rate of convergence measurements mentioned earlier. It should be noted that these in situ measurements of stress provided data only on stress changes but not the existing or field stress which could be determined by separating a large enough core of rock or mineral around the original borehole and load cell by trepanning or overcoring techniques. This was not used in coal though some development tests were carried out in a rock tunnel at Canmore.





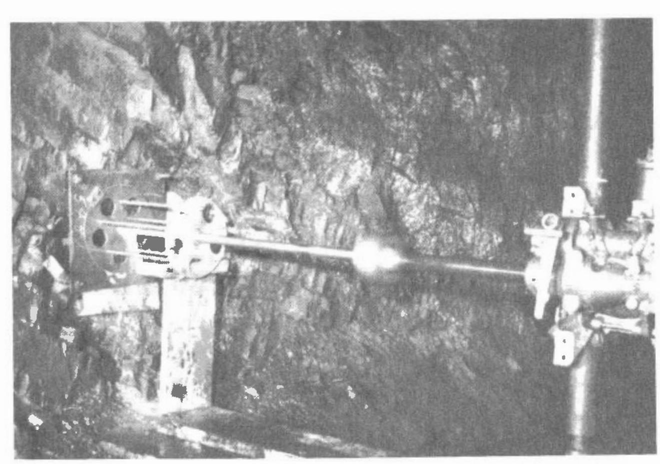
Construction of magnesium alloy load cell and view of the cell with inserter (Photo - CMJ, Dec. 1955)

The strain gauge load cells were first tried in No. 3 mine, Elk River; installations were also made at McGillivray mine, Coleman and Galt mine, Lethbridge, and at a later date in Springhill mine, Nova Scotia.

Rock and coal samples were tested for some physical properties in uniaxial compression - such as Young's modulus, ultimate compressive strength and strain energy at fracture. The difference between rock or coal substance and mass was recognized from the start but it was decided to carry out laboratory tests on specimens for comparing the strength and failure characteristics. This preliminary work indicated substantial variability in strengths of sandstone, sandy shales and shales. Most of the Western coal was highly sheared and weak but there were instances of coal blocks retaining primary bedding and cleavage which apparently were preserved in spite of the interstratal slippage of beds. In such cases, the strength of these Lower Cretaceous coals compared favourably with those of the Carboniferous period. This phase of the work was undertaken by Hardy and was carried out initially in the Industrial Minerals Construction Materials Laboratory and the Physical Metallurgy Division. Hardy published the results in 1957 (FRL Report 242) and they were reproduced in the new (1959) Mines Branch Series of Technical Bulletins: "Standardized procedures for the determination of the physical properties of mine rock under short-period uniaxial compression" by H.R. Hardy, Jr. (MB TB 8 1959). As it was evident that under mining conditions, rocks and coal were subject to time-strain effects, Hardy undertook the design and construction of special apparatus, the first model being completed in 1956: "The design and testing of apparatus for the experimental determination of the time-strain characteristics of mine rock" by H.R. Hardy (FRL Report 234). This became a major project during the period Hardy was with the Mines Branch. The initial research in the mine and laboratory indicated the difficulties which could be expected with variable rock materials in a complex stress environment.

In the light of the post-war revival of interest in ground mechanics in the coal mining countries of Europe and the continuing interest in the occurrence of rockbursts in the deep gold mines of South Africa, a small international symposium on ground stress with particular reference to bumps and outbursts was organized for an exchange of views by the Mines Branch through the Coal Division, CIM, at the Annual General Meeting in Montreal in April 1954. The chairman of this eight-paper symposium was W.A. Wilson, general manager of Canmore Mines Limited and chairman of the Coal Division: "Symposium on problems relating to ground stresses", (Trans CIM, vol 57, pp 246-282 and 506-520, 1954).

There were papers by Professor R.G.K. Morrison, head of the Department of Mining at McGill University, with whom close relations were established from the start of the mining program at the Mines Branch, and recognized as the leading authority in Canada on rockbursts; Professor Charles T. Holland, an authority on coal mining in the United States; Professor B. Schwartz, France, specializing in long-wall mining measurements; Oscar Weiss, consulting geophysicist from South Africa; J.J. McIntyre, former general manager of the adjoining International and McGillivray coal mines at Coleman on his long experience with ground control at these mines; W.A. Wilson on outburst experience in No. 4 and Upper Marsh seams at Canmore mines (paper also presented at November 1954 Western Annual Meeting) and Professor E.L. Cameron of the Nova Scotia Technical College on physical properties of Canadian mine rocks which included both hard rock and coal mines. Both McIntyre and Wilson indicated in their papers that the influence of tectonics should not be discounted in relation to the bumps at McGillivray and outbursts at Canmore respectively. The last paper summarizing the above described program of the department was also presented at the symposium: "Current investigations of stress relief in Canadian coal mines" by A. Ignatieff, A. Brown, R.C.A. Thurston and D.K. Norris.



First experimental stress relief trepanning at Canmore No. 3 mine

A second international symposium on ground stress was organized in 1956 through Mines Branch initiative by the Coal Division, CIM, in partnership with the Metal Mining Division, CIM, at the Annual General meeting of the Institute in Quebec City. The feature of this symposium was that the six papers were pre-published and a whole session was devoted to discussion: "Discussion on ground stress" (Trans CIM vol 59, pp 423-432, 1956). Dr. Convey was chairman and Professor H.R. Rice of the University of Toronto the moderator of the session. There were three papers from Canada (Professors R.G.K. Morrison and D.F. Coates from McGill University, Professor A.V. Corlett from Queen's University and W.L. Gibson of Ontario Hydro), one from United States (Professor S. Boshkov of Columbia University) and two from South Africa (A.J.A. Roux, H.G. Denkhaus and E.R. Leeman of the South African Council for Scientific and Industrial Research, and C.J. Irvine). Participants in the discussion were from Canada including the Mines Branch staff, Tanganyika, U.K. and U.S.A. These symposia helped to establish contact and promote dialogue within the small international constituency of specialists in the complex area of ground or rock mechanics as applied to mining. They were the forerunners of the Rock Mechanics Symposia which were institutionalized by creation of the Canadian Advisory Committee on Rock Mechanics in 1963.

In April 1958, a progress report on ground stress research in Western Canada was given in a 2-paper symposium at the Annual Western Meeting in Vancouver titled "Research in relation to ground stress". One paper was by Milne and White on seismic investigation, previously mentioned, and the second paper was "Ground stress studies in coal mines of western Canada - a progress report" in 2 parts by A. Brown, T.S. Cochrane and T.H. Patching (Trans CIM, vol 61, pp 364-375, 1958).

The narrative continues with studies on ground stress and will return later to specific outbursts which received considerable attention at Canmore between 1954 and 1962. All of the coal output from Canmore was derived from underground mines because of the attitude of the seams in relation to the mountain terrain, though some small-scale open pit mining was tried. On the other hand, output in the Crowsnest area from suitable open pit mine sites was increasing as markets were reduced.

Following Zorychta's transfer to Springhill in 1953, systematic measurements and observations were made in No. 2 and 6 mines at Springhill, N.S. at approximate depths of 4200 and 2500 ft respectively, employing longwall retreating and advancing methods respectively. Convergence readings were recorded on the 11,700 level in No. 2 mine and on the 5700 east face in No. 6 mine, and in both mines dynamometers monitored the loads on hardwood chocks or packs used as the principal face supports. Roof holes were drilled to several horizons for observing separation and migration of beds. Some migration was observed but little or no separation. Most of the convergence or closure came from the floor.

Redesigned steel load cells were used in the blocks of coal in advance of the two retreating faces in No. 2 mine. Due to the highly stressed conditions of these blocks in the abutment zone, drilling in the coal was difficult. One of the cells installed in the coal had its five-conductor cable, which was protected by a pipe, break due to the tensile stress in the coal rib. It was estimated that the tensile stress involved was well over 10,000 psi. Additional cells were installed in the roof and the floor and small bumps were recorded. The general results indicated that stresses of high magnitudes were occurring.

By arrangement with the Nova Scotia Research Foundation, a seismograph was installed over the active area of No. 2 mine. Rock specimens from both mines were obtained for testing properties at the Fuels Division and at the Nova Scotia Technical College under Professor E.L. Cameron's supervision and with assistance provided by the Nova Scotia Research Foundation. Diamond drilling was done by the Nova Scotia Department of Mines. Laboratory tests indicated that the Springhill rocks were on the average stronger than the Western rocks with the exception of the conglomerate bed in the McGillivray mine. The rocks compared favourably in strength with those from deep ore mines in Ontario and even with quartzites of the South African gold mines. A paper (companion to the one on Western Studies, previously mentioned) was presented at the 1956 Annual Meeting of the Nova Scotia Mining Society: "Rock pressure studies in the mines of Springhill, Nova Scotia - a progress report" by A. Brown, H. Zorychta, J.G. Buchanan, E.L. Cameron and H.R. Hardy (Trans CIM, vol 59, pp 242-251, 1956).

In October 1958, a disastrous bump occurred on the faces in No. 2 mine with heavy loss of life. Zorychta participated in the rescue operations and in securing and interpreting data which included samples of rock from the disaster site. A Royal Commission of Inquiry under the chairmanship of H. Wilton-Clark, general manager of Coleman Collieries, was set up. Briefs and evidence were presented to the Commission by Brown and Zorychta. The conclusions were not definitive, but the general view was that the economic mining limit at the depth of over 4000 ft with strong overlying rock in No. 2 mine had been reached. In any event, market conditions militated continuing operations in Springhill. The difficult economic conditions also had an effect in the West. The Galt mine at Lethbridge closed down in 1957, followed by the Elk River mines in 1958, and the McGillivray mine in 1960, with the International mine closing some years earlier. Grant left the Crowsnest Pass area in 1957 taking up residence in Calgary with an office in the Public Building, where Pickford was installed as administrative officer. Richards was transferred to Ottawa and after closing the office in Blairmore in 1959 Cochrane transferred to Ottawa, making visits to Western Canada as required.

Because of the deformable nature of coal the best but indirect indicators of changes in ground stress in coal mines were the rate of convergence, changes in support loads, behaviour of roof and floor beds measured and observed from accessible workings.

In 1959, Zorychta transferred to Glace Bay, Nova Scotia, at the suggestion of Harold Gordon, the general manager of Dosco's mining operations, who showed considerable interest in and support for the rock pressure studies. The corporation was introducing in its Cape Breton mines retreat longwall mining using friction props in place of hardwood packs on the faces and was experimenting with continuous miners other than the Dosco Miner, which the company had designed and built. The studies were conducted in the Harbour seam about six feet thick, in the Dominion No. 20 mine under about 1000 ft of cover, and in Dominion No. 12 submarine mine with 2500 ft of cover. The Nova Scotia Research Foundation, under the project committee on strata pressures, continued close cooperation and assistance to the project. Dr. J.E. Blanchard, geophysicist, and later head of the Foundation, was associated with the project from the Springhill days and provided Zorychta with an assistant - Floyd Smith. In none of these mines were there occurrences of bumps and outbursts of the severity experienced at Springhill or in the West.

The advancing longwall method was then general practice, giving rise to high maintenance cost of access roadways through extracted areas which remained in a state of squeeze for long periods. This was the reason for experimenting with retreat mining, notably in the Dominion No. 12 mine where convergence measurements were undertaken by Zorychta. A paper was prepared jointly with L. Frost, chief mining engineer of the Dominion Coal Company: "Rapid development of longwall retreating in the submarine area of the Sydney Coalfield of Nova Scotia" by L. Frost and H. Zorychta (Proceedings of International Conference on Rapid Excavation in Coal Mines, INICHAR, Liège, Belgium, 1963 and MB RS 72 English text, and RS 73, French text).

In 1957, the first longwall face in the Sydney coalfield at the Princess Colliery was equipped with steel friction props replacing hardwood packs and by 1964 there were 16 faces so equipped out of a total of 27 faces in the coalfield. It was decided to make a comparative study of the two support systems at a depth of about 1000 ft.

In this study, measurements and observations were conducted on a 400-ft retreating longwall face at No. 20 colliery with one stone "midwall" and a 900-foot advancing longwall face at the Princess colliery under a heavier cover of 1700 ft; in the latter case, stone midwalls were located at 100-foot intervals along the face. The results obtained were compared with hardwood packs which had been used on the 5700 face in No. 6 mine at Springhill under a cover of 2500 ft. These studies indicated that the steel friction props were more efficient than the hardwood packs. A joint paper with G.S. Merrill, field engineer of Dominion Coal Company, was presented at the 1964 Annual Meeting of the Mining Society of Nova Scotia and earned the authors the Leonard Medal of the Engineering Institute of Canada: "Loads on friction props on a longwall face" by H. Zorychta and G.S. Merrill (Trans CIM, vol 68, pp 48-54, 1965).

Monitoring of ground behaviour related to advance and retreat longwalls continued for several years: "Strata control measurements in the Sydney Coalfield" by H. Zorychta, D.W. MacFadgen of Dominion Coal Company and Floyd Smith of Nova Scotia Research Foundation (Trans CIM, vol 70, pp 38-48, 1967). On the dissolution of the Dominion Coal Company in 1969, Zorychta was transferred to the Elliot Lake Laboratory for three years, when he joined the Crown corporation of DEVCO in a senior position.

Roof Bolting

This was a subsidiary project of the mining or ground stress program. It was almost wholly devoted to bolting problems in the coal mines of Western Canada. Falls of roof are prime causes of coal mine accidents and hence the project had an important safety aspect. Bolting in Canadian coal mines arose partly in connection with the introduction of mechanization, more particularly of continuous mining machines which required more space for their manoeuvering to and from work faces in room and pillar mining, and partly to reduce the rising cost of timbering especially in the thick seams of Western Canada.

Roof bolting in Canadian coal mines started in the Sydney coalfield where the seams are thinner and the immediate roof strata more uniform than those of Western Canada. This allowed the use of split-rod and wedge-type bolting as already practised in metalliferous mines. The current mining development committee of the Coal Division, CIM, in one of its first projects requested L.M. Dwarkin, chief engineer of the Crow's Nest Pass Coal Company Limited, to review the Canadian practice: "Roof bolting" by L.M. Dwarkin, including addenda on roof bolting in Dominion No. 20 colliery by F. Doxey, and in Four Star colliery by J.C. Johnstone (Trans CIM, vol 54, pp 485-493, 1951). A second report for the committee was prepared by A. Brown: "Roof bolting in Canadian coal mines" (Trans CIM, vol 56, pp 400-412, 1953). This paper described tests including roof sag measurements which were carried out in Galt No. 8 mine, Lethbridge, and at Nacmine, Drumheller, by the Mines Branch field group. Some slot wedge-type bolting experiments were made in the International mine at Coleman before it was closed down, and in "A" and No. 3 seams at Michel colliery. At the latter, a 32-ft

1 - Former support method at Canmore coal mine using wooden props and lagging and 2 - roof bolting in same mine allows use of modern mechanized equipment; stone-dusting on walls shows as lighter shade

wide entry was bolted, which was the widest entry bolted in Canada at that date.

With the introduction of continuous miners in the Michel mine, a more systematic program was started by the Crow's Nest Pass Coal Company in "A-" North West and No. 1 mines with anchor shells of various types under Dwarkin's supervision and with consulting advice from D.F. Coates before he joined the Mines Branch. Norris carried out some detailed geological work which was helpful to the project: "Microtectonics of the Kootenay formation near Fernie, British Columbia" by D.K. Norris (Bull of Can Petroleum Geology, vol 12, Special Issue, "Flathead Valley", pp 383-398, Aug. 1964), and "Structural analysis of part of A-North coal mine, Michel, B.C. by D.K. Norris (Paper 64-24, GSC, 1965). The Mining Section had developed an hydraulic jack technique for pull tests of installed bolts, and this technique was used by the company in the Michel mine. In addition to this tool, two types of dynamometers were designed for measuring loads on the bolts using the strain gauge or the vibrating wire types as in the case of borehole load cells to be described later.

A roof bolting forum was organized in 1963 at the Annual CIM Meeting in Edmonton. The chairman of the meeting was W.J. Riva, chairman of the Coal Division, and the moderator D.F. Coates. There were three papers, one dealing with the bolting practice in Dominion Coal Company's mines in the Sydney coalfield by D. MacFadgen, which indicated that between 1950 and 1962, 1164 miles of roads and rooms were bolted; a second with roof bolt anchorage at Michel colliery by L.M. Dwarkin, and a third with pull tests as a measure of roof bolting efficiency and roof bolt design by T.S. Cochrane and F. Grant: "Forum on roof bolting", (CIM Bull, pp 877-887, Dec. 1963). An analysis of the roof bolt effectiveness at Michel was made by Coates and Dwarkin, and this was published in 1967 (Trans CIM, vol 70, pp 32-37, 1967). The latter paper together with the forum papers was reprinted (MB-RS 38, 1967).

Roof bolting tests in mines were continued at intervals on request. This included considerable work by Cochrane and A.V. St. Louis at Canmore mines. A review of roof bolting in Western mountain coal mines was prepared later by F. Grant who participated in this project from the early days: "Strata control by roof bolting in Western Canadian mountain coal mines" by F. Grant (CIM Bull, pp 79-86, Nov. 1973). Design specifications for rock bolting based on research and development conducted by the Mines Branch over the years were summarized in a report "Development of design specifications for rock bolting from research in Canadian mines" by D.F. Coates and T.S. Cochrane (MB RR 224, 1970).

A.V. St. Louis

Hard Rock Bolting

Metal mines did not have the problems with rock bolting that coal mines did, and the Mining Section thus did not carry out as many experimental studies in those underground mines.

An interesting cable and bolt installation was at an underground mill in a salt mine where cable bolts 30 ft long were grouted into inclined holes and prestressed to approximately 60 tons to ensure long-term stability. The loose rock in the immediate roof next to the opening was held in place by 5-ft bolts and wire mesh.

As little was known of stress distribution around mine anchors an analysis was made using the finite element technique: "Rock anchor design mechanics" by D.F. Coates and Y.S. Yu (MB RR 233, 1971). The technological aspects useful to industry of rock anchorage in underground and surface mines were reviewed in a publication: "Rock anchors in mining - a guide for their utilization and installation" by D.F. Coates and R. Sage (MB TB 181, 1974).

A bibliography on rock bolting was prepared by Professor A.V. Corlett's daughter (Mary Ruth Corlett Paterson) when she was attending university, and this covered the period to 1957. A second part was prepared by A.E. Gardner of the Explosives Laboratory for the period from 1958 to 1967 (MB IC 207 and MB IC 241 respectively).

Coal and Gas Outbursts

As mentioned earlier, the outburst is a phenomenon related to the association of methane and other gases with coal in a ground stress environment. There have also been outbursts reported in potash mines in Europe. A report of the Mining Developments Committee, Coal Division, CIM, on outbursts in connection with the topic of degasification of coal strata was published in 1954: "Outbursts in coal seams" by A. Ignatieff (Trans CIM, vol 57, pp 75-81, 1954).

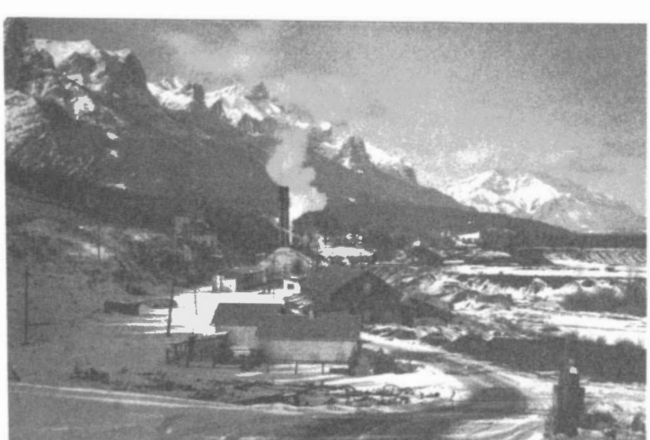
An extensive field and laboratory research project was launched in an endeavour to provide a better understanding of this phenomenon. It appeared in the Canadian context to be less influenced by excessive mining stresses during excavation than by pre-mining stresses of orogenic tectonic nature. A strong motivation for this work was provided by the geological evidence given by Dr. B.R. McKay to the 1946 Royal Commission on Coal on the mineable reserves of just two basins - Fernie, the deepest, and the Upper Elk River - both in southeast British Columbia. These he estimated to contain about three billion and three-quarter billion tons respectively of mostly coking coals to a depth of cover limited to 2500 ft because of bumps and outbursts, compared with the limit of 4000 ft for Nova Scotia's mineable reserves. In other words, there was preoccupation not only with the immediate problem but also with making deeper resources accessible to exploitation.

Most of the mine observations were made in the Upper Marsh seam, No. 3 mine, Canmore, which was suffering from a high frequency of outbursts. Borehole electric resistivity measurements by Buchanan mentioned earlier, though initially indicating some relation between high resistivity and occurrence of outbursts, proved to be inconclusive with up to six orders of magnitude difference between closely spaced intervals in the borehole. Independently of the mining program, Dr. Lewis King in 1957-58, working with Dr. Montgomery of the Bituminous Substances Research Section carried out a study on the resistivity of several Canadian coals of various ranks from anthracite to sub-bituminous. Through a tedious process, the coal samples were equilibrated at various moisture levels. There were large fluctuations in resistivity measurements similar to ones in the field tests, thought to be caused by the penetration of fractures by water; "Electrical resistivity measurements on Western Canadian coals", by Lewis H. King (MB RR 117, 1963).

As the coal was highly deformable and as difficulties were encountered in drilling holes into stressed coal pillars no strain gauge or other load cells were used. Hence, the ground stress component of the coal-gas system could not be determined. Indirect observation such as change in the rate of convergence was observed.

On the other hand, the physical properties of the coal-gas association were closely investigated, and in this regard J.C. Botham with Dr. G.T. Shaw of the Carbonization Gasification Section, as well as Professor T.H. Patching, head of the Mining Department, University of Alberta, played an important role.

Botham undertook these extra duties in addition to those he was responsible for in carbonization research. Starting in 1953, Botham carried out tests on the Canmore (Upper Marsh seam), Elk River No. 3 seam (No. 3 mine) and the Springhill No. 2 mine to simulate the outburst phenomenon. Whereas the first two mines had a cover not more than 1000 ft, the Springhill mine, as mentioned earlier, had more than 4000 ft. The results were successful and parallelled the mine experience. For example, with the coal from Springhill mine which had no outburst history, there was no ejection of fine coal from the apparatus; in the case of Elk River, there was partial ejection, whereas with



Canmore Mines Limited circa 1956

L. King

Canmore coal there was ejection of coal in a size consist similar to the natural outburst, namely 90% minus 100 mesh in both the mine and laboratory and 40% minus 325 mesh in a mine outburst and 34% minus 325 mesh in the laboratory outburst.

Some data indicative of property differences between these coals are given in the following abridged table from Botham's report: "Laboratory outburst tests on solid coal specimens" by J.C. Botham (Fuels Division, TM 75/57).

Property	Canmore	Elk River	Springhill
0 x 1/8" fraction of mine run coal as indicator of fragility (%)	44	29	22
% porosity	8	7	2
Methane sorption capacity at 3000 psi (ft^3/t)	600	500	300
Internal surface of micropores (m^2/g)*	32	25	18

* Determined by Dr. N. Berkowitz, Research Council of Alberta

This research was followed by:

(a) Measurement of total sorptive capacity in pores and cracks of various Canadian coals and for comparison with foreign coals, with various gases at different levels of pressure;
(b) Measurement of density and porosity of coals. The research was conducted by Shaw before he joined the catalysis group. He determined the true and apparent densities (TM 104/58) and overall pore volume: "Relationship of the density and porosity to the coal outburst phenomenon" by G.T. Shaw (Fuels Division TM 169/58);
(c) Determination of diffusion or emission of total or occluded gas in the laboratory and in the mine with specially designed portable apparatus developed by Botham as well as by Professor Hargraves of Sydney University, who was then conducting research on outbursts in Australia. Professor Patching became a close associate in this work from 1957 to the 60's. The problem with the in situ gas study was inability to separate the adsorbed fraction from the free gas fraction contained in pores and fissures of the coal.

Furthermore, the effect of ground stress on the gas was not clearly understood. However, observations in Canada and elsewhere suggested a major part of the energy was supplied by the outflowing gas. The phenomenon was generally less destructive than a bump or a methane-air explosion. Moreover, it was noted in the laboratory simulation of an outburst that mechanical stress incorporated into the apparatus was not needed;

(d) Studying gas flow characteristics in coal, or its permeability. This was a laboratory study which showed that unfissured coal discs were impermeable to methane, carbon dioxide or nitrogen at two atmospheres difference in pressure between the two sides of the disc: "Permeability tests" by J.C. Botham (TM 62/58). Independent research later by Professor Patching confirmed this result;

(e) Determination of impact strength indices (ISI) as developed by C.D. Pomeroy of the National Coal Board (U.K.). A number of samples from coal seams and different layers in the same seam either subject or not subject to outburst, showed no difference in the index. In another approach to simulated deformation and crushing of coal by tectonic action, a study was made of a range of sizes crushed to minus 1/4 in. and the percentage passing 28 mesh was considered as an index of size distribution. Again there was no difference between outbursting or non-outbursting coals. Both these indices correlated with the Hargraves grindability index. Triaxial compression tests were made on an outbursting and non-outbursting coal and showed little difference in strength between the two, though one of the coals was soft and the other hard. All these tests were carried out entirely by Professor Patching. He presented a paper on the foregoing at the First Canadian Rock Mechanics Symposium held at McGill University in 1962: "Investigations related to sudden outbursts of coal and gas" by T.H. Patching (Proceedings of the Rock Mechanics Symposium, pp 69-91, published by Mines Branch, Department of Mines and Technical Surveys, 1963).

Attempts at drainage of gas in the Upper Marsh seam and of water infusion to ascertain fracturing were not successful. Drilling into the solid coal was difficult due to the rapid deformation of the holes and at times by small outbursts in the hole, requiring barrier protection of the staff. Only rotary drilling was tried as percussive machines were liable to trigger outbursts. The project on outbursts terminated in 1962 and a joint paper by Patching and Botham was presented at the International Congress on Problems of Sudden Outbursts of Gas and Rock, Leipzig in 1966 (MB RS 28, 1966 English text, MB RS 29, 1966 French text).

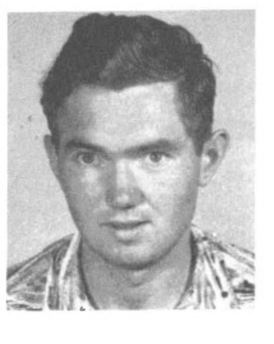
To overcome the hazard to mine personnel involved in machine cutting of coal followed by blasting as required by the Alberta Coal Mines Act, the mining group - Brown, Cochrane and Grant - discussed with mine management and the Alberta Department of Mines the possibility of simultaneous or shock blasting of solid coal at Canmore in the Upper Marsh seam. In this connection, Ignatieff in 1954 visited the Cevennes and Charleroi coal areas of France and Belgium respectively with their long experience of shock blasting to insure that methane-air explosions did not take place with this technique of "blasting coal off the solid". Armed with the official documents which were translated (FRL 209, 1955), trials of shock blasting were tried with Mines Branch participation and the Alberta Department of Mines eventually authorized its off-shift use. The management indicated that besides enhanced safety there were economic advantages in not having to cut the coal, but the main disadvantage was that when a large outburst occurred, a considerable area of unsupported roof was exposed causing a "squeeze" in the extraction area. However, this technique continues to provide safety to personnel in countries where outbursts take place.

Physics

The appointment in 1956 of Dr. W.M. Gray as consultant in physics and mathematics arose from the direction in which mining research in the Branch was developing. There had been recognition from the start that rocks and minerals in substance or in the mass were extremely heterogeneous structural materials and that a scientific and analytical approach would provide the necessary guidance to achieve a balance between empirical, experimental and mathematical research in this difficult area of applied physics. The formation of the Physics Section in 1959, sometimes known as the Rock Physics Section, was similar to the formation of the chemistry-oriented Bituminous Substances Research Section. The understanding with the director was that Dr. Gray would also act as a consultant to him in the same way as Dr. Walsh in metallurgy, and H.A. Graves, and later M.A. Twidale in mining. Thus Dr. Gray acted for the director on subjects such as the introduction of computers in the department, recruitment of scientists, review of scientific papers and reports, etc.

Reg Hardy was transferred to Gray's section together with N.A. Toews, who joined Gray in 1958 as an applied mathematician. He first studied the rigidity of the hydraulic borehole stress meter which was initially used by the Mining Section. Toews collaborated with K. Barron (1960 -) in a study on creep in mine shafts crossing salt beds above potash beds at International Minerals and Chemical Corporation, the first company to produce potash in Canada from deep mines. This research was reported at the Second Rock Mechanics Symposium at Queen's University in 1963: "Deformation around a mine shaft in salt" by K. Barron and N.A. Toews (Proceedings of the Rock Mechanics Symposium, Queen's University, 1963, pp 115-136, published by Mines Branch, 1964). Toews proved to be a capable mathematician; his service to scientists of the Mining Section were invaluable in undertaking the more complex mathematical analyses thereby being deprived from pub- lishing his own papers.

As regards Hardy, through his own diligent work, the departmental policy for sabbatical leaves and

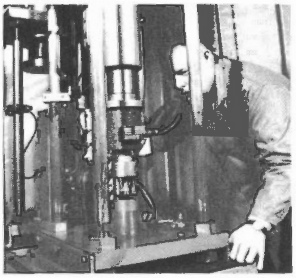


N.A. Toews

Gray's wise counsel, he earned a doctoral degree in 1965 at the West Viriginia Polytechnic. On his return, his research was directed to a time-dependent deformation of rocks which resulted eventually in the development of an advanced and rigorously controlled test facility (MB RR 165, 1965). The facility was erected at 552 Booth Street when the Physics Section was transferred earlier from 562 Booth Street. Two internal reports were written on the initial studies made with this facility: "Inelastic behaviour of geologic materials" by H.R. Hardy, "Part 1: Experimental and analytical techniques and initial studies with Wonbyan marble" (IR FMP 65/155); "Part II": (IR FMP 66/51). Hardy recorded all work in his studies on the static properties of rocks in the Internal Report series - FRL, TM and IR FMP. He resigned in 1966 to take up a position in the academic world.

Dr. P. LeComte joined the physics group in 1960 and was assigned the study of the dynamic properties of rocks. He came at a time when research was conducted in thermal piercing of rock, optimization of rock breakage by explosives and novel breakage methods. His first project was related to a continuous comminution process based on the propagation of shock waves generated in a liquid by an electric spark. In 1961, this project was discontinued as the outlook for industrial application was not promising.

A second project was more fundamental and long-term, dealing with the measurement of rock properties by dynamic methods in contrast to Hardy's static



John Sullivan, principal technician, assisted Reg Hardy in constructing the rock test facility

methods. The two approaches studied were based on first, the theory of vibrations (resonance) and second, the theory of wave propagation (ultrasonic pulse). LeComte developed an electrostatic apparatus capable of both longitudinal and tortional vibration. He discussed these methods in a paper presented at the Second Rock Mechanics Symposium in 1963: "Methods for measuring the dynamic properties of rock" by Paul LeComte (Proceedings of Rock Mechanics Symposium, Queen's University, pp 15-26, published by Mines Branch, Mines and Technical Surveys, 1964). Preliminary measurements of the coefficient of internal friction and Young's modulus for several types of rock were reported (IR FMP 66/44 French text). A high-pressure apparatus with capacity up to 30,000 psi and temperatures up to 2000°C was developed for ultrasonic pulse measurements, but this project terminated when LeComte left in 1966 for Hydro Québec.

Gray showed considerable versatility and breadth of knowledge. He had served six years in the R.C.N. during the war and then taken up an academic career in the U.K. before joining the Mines Branch in 1953. When he became head of the Physics Section he was not averse to visiting mines and finding out the conditions for himself; he suggested a biaxial compression test for measuring strata movement, etc. He gained the reputation of being a modest and very knowledgeable scientist: authors of papers consulted him on the soundness of their theories and conclusions. He was consulted on the jet piercing project carried out in the Combustion Engineering Section. He presented an elucidation of the spalling phenomenon: "Some remarks on the temperature distribution and thermal stresses in the semi-infinite solid during surface spalling" by W.M.

R. Hardy observing behaviour of a rock specimen under prolonged stress in apparatus of his design and built at Mines Branch in late 50's (Photo - George Hunter)

W.M. Gray

Gray (FMP 61/160). He presented a paper on this subject at the Third Rock Mechanics Symposium: "Surface spalling by thermal stresses in rocks" by W.M. Gray (Proceedings of the Rock Mechanics Symposium, University of Toronto, 1965, pp 85-106, published by Mines Branch, 1965).

With increased staff and facilities for measuring rock properties, notably the Elliot Lake Laboratory, this section was dissolved in 1966 and Gray was appointed senior scientific advisor, Mining Research Laboratories, and from 1967, Mining Research Centre.

Foreign Practice

Coal mining practice abroad was studied even before the formal inception of mining research at the Mines Branch. Contacts were established with the U.S. Bureau of Mines and the National Coal Board. The 1959 Royal Commission on Coal was made cognizant with the differences and similarities of Canadian mining conditions with those abroad. The Commission recommended that a survey be undertaken in Europe by representatives of industry and the department. Accordingly Brown as head of the Mining Section accompanied the group: "Report on the inspection of coal mining operations and incidental activities in Great Britain, France and West Germany as recommended by the Royal Commission on Coal (1959)" by A. Brown (IR FMP 60/184).

Concluding the narrative of this initial period of mining research dedicated to coal in the Mines Branch, it is appropriate to reflect on the perception prevalent in the group, from the study (Chapter 5) of Canadian coal mines made before the Mining Research Section was formed, that just as the quality of a large range of Canadian coals suffered from certain disadvantages, so did the mining conditions in many cases. Bearing in mind that the potential coal resources of Canada were large, particularly those of the valuable coking coals in the West, the project was not only worthwhile for any short-term benefits but probably more so for the long term as a large proportion of these resources would have to be mined at depth if they were eventually to be recovered.

The public image of the coal mining industry was that it was not as progressive as that of the United States. On the other hand, the public did not seem to appreciate that the majority of Canadian underground mines had to operate in conditions which were closer to those of continental Europe rather than to those of Great Britain or U.S.A. with which Canadian performance was usually compared. Two indicators from the survey mentioned told the story - thickness and attitude of seams. The per cent of national output derived from seams greater than 6 ft thick in Canada, U.S.A. and U.K., were 60, 30 and 8% respectively. The per cent of output according to attitudes showed that in Canada 69% came from seams inclined at over 5°, in the U.S.A. 90% came from flat seams, and in the U.K. about 80% from flat seams. The underground recoveries suffered severely as thickness increased, and so did the efficiency of mechanization in inclined seams.

In the light of these facts, studies were made and contacts maintained with developments in foreign practice where mining conditions approximated those of Alberta and British Columbia which possessed the bulk of Canadian coal resources, particularly with France through the Centre d'Etudes et Recherches des Charbonnages de France (CERCHAR). In addition, studies were made of the foreign literature, particularly Soviet. The French material was translated by Vary, and the Russian initially by the Bureau of Translation, but with the coming of Dr. Frisch in 1960 a scanning system in conjunction with Leo Casey and Charlie Vary was introduced. The accessibility of Soviet technical information was much improved. This led to the discovery that hydraulic mining or hydromechanization was being tried in the U.S.S.R. and in China. Brown evaluated these developments, presenting a paper to the 13th Dominion-Provincial Coal Reseach Conference in Toronto, 1961 (Proceedings of this Conference, pp 117-156, or IR FMP 62/68). The hydraulic method was eventually pioneered in Canada at the Michel mine, B.C. by Kaiser Resources Company Limited.

As indicated earlier, by the end of the sixties and early seventies, underground production was obtained only from the Sydney coalfield in the East, an hydraulic mine in B.C. and two mines in Alberta - the McIntyre mine in the Smoky River field and one mine in the Drumheller field. All other operations, particularly in Alberta and southeast British Columbia, were large open pit operations, the high-rank coal being dedicated for export and the low-rank for electric power generation. All indications at this writing are that large tonnages can be produced from this "outcrop" coal. However, these operations in mountain terrain have to contend with a complex geology which implies changes in attitude of seams making them unsuitable for open pit mining. Research related to underground coal mining at the Mines Branch was retrenching about the time of Brown's resignation in 1962. It could be said that this ended the pioneering stage of mining R & D in the branch. However, the branch's tradition of maintaining a long view of the Canadian mineral resources was not abandoned, as will be noted in the next chapter.

INDUSTRIAL MINERALS

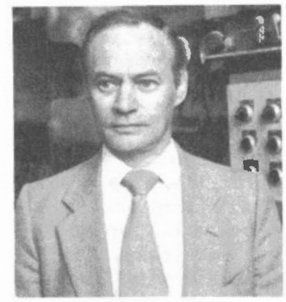
Chronologically the first metalliferous mine to be studied - Wabana in Newfoundland - preceded studies on the industrial minerals which included the evaporites, salt and potash, and asbestos. These were investigated for ground stress problems between 1957 and 1963 including a special study of the stability of a rock escarpment in Quebec City. It is pertinent that these follow coal, as both classes of rock and minerals were of sedimentary bed origin.

The Quebec City investigation arose from a concern by the Dept of Northern Affairs and National Resources (Nat Parks Branch) for stability of Dufferin Terrace cliffs which showed signs of progressive erosion through fissuring. The investigation was started in 1957 and comprised monitoring for about three years for any movement of the rock face behind the retaining wall using wire assemblies anchored in the wall. The fissuring was examined by boreholes drilled up to 100 ft long into the cliff side. Movement was found to be sporadic. For this purpose, a borescope and a crack detector were designed by Richards. Dr. Norris of the Geological Survey provided geological and petrological advice. The rock was largely calcareous mudstone. Some roof bolting done at the southern end of the Dufferin Terrace included dynamometric bolts for monitoring any change in load: "Investigation into the stability of Dufferin Terrace, Quebec City" by A. Brown and F.L. Casey (MB IR 60/112).

In 1960, at the request of the Sifto Salt Company of Goderich, Ontario, mining a salt deposit at a depth of nearly 2000 ft, a joint study on the stability of rooms and pillars was undertaken. The rooms were 60 ft wide and the pillars 200 ft square. Fracture of the roof and yield of the pillars were studied as well as the creep properties of salt, both in the mine and in the laboratory. Some in situ stress measurements were also made: "Rock mechanics investigations in a Canadian salt mine" by W.G. Muir and T.S. Cochrane (Proceedings of the 1st International Rock Mechanics Congress, vol 2, Lisbon, 1966). In 1961, a further project was set up for long-term measurement of deformation of salt pillars at the Ojibway mine near Windsor.

Dr. D.F.G. Hedley, who came as an NRC postdoctoral fellow in 1966 with a background of experience with salt and potash deformation and failure characteristics, analyzed the convergence measurements at the Sifto and Ojibway mines as well as the data from two mines in U.S.A. and one in U.K. He found that the convergence rates at these five mines to be in reasonable agreement. He derived an equation for the relationship and calculated pillar stress "An appraisal of convergence measurements in salt mines" by D.F.G. Hedley (Proc of 4th Rock Mechanics Symposium, Ottawa, pp 117-135, published by Mines Branch, 1967).

In 1962, at the suggestion of the Saskatchewan Department of Mines and a number of the potash companies, a program of ground control research was drawn up by Brown with a view to implementation under the auspices of a proposed research association. Meanwhile, the International Minerals and Chemical Corporation through their consultant, Dr. D.S. Serata, as mentioned earlier, suggested measuring the deformation of an unlined salt section of the shaft above the potash beds. Two types of extensometers were designed and constructed for measuring changes in the surface of the shaft walls and at varying depths to 10 ft in boreholes drilled into the sides of the shaft: "The portable tape dial extensometer and the borehole extensometer" by K. Barron and S.R. Cook (1960 -), (IR FMP 62/80). This instrumentation was used to monitor the deformation of entries, rooms and pillars with boreholes up to 20 ft in length drilled into the roof, floor and sides of an opening. From the data, the rate of closure and strain were determined: "Rock mechanics at International Minerals and Chemical Corporation (Canada), Limited" by George Zahary (1966-) (Proc of 3rd Rock Mechanics Symposium, University of Toronto, pp 1-17, published by Mines Branch, 1965).



D.F.G. Hedley

In 1961 the first open pit study was commenced in a cooperative project with D.F. Coates and the Asbestos Corporation related to stability of the pit perimeter and groundwater. A water level sensing unit was developed for the study by G.E. Larocque (1959 -) and F. Kapeller (1960 -). In the seventies, the com-

F. Kapeller installs control box for extensometer used in monitoring stability of large B.C. open pit mine coal prehensive program on open pits included stability studies of large open pit coal mines in Western Canada.

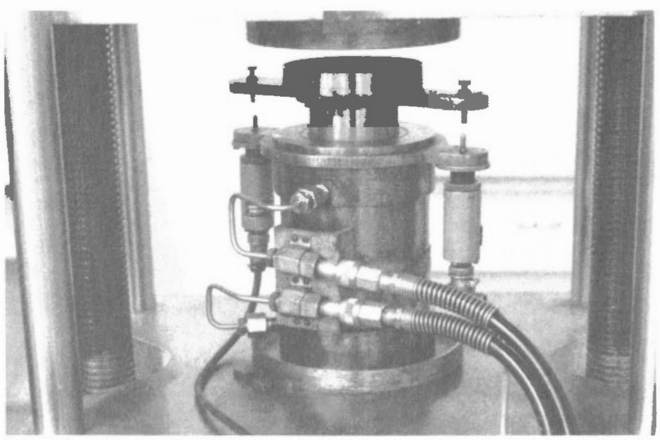
Limitations in the size of the staff at this time did not permit assigning resident engineers as was the case in the initial coal mining investigations. The practice instead was to draw up a project program, supply instrumentation, drawings or samples from which the requirements could be fabricated in the mine workshops, assist in the installation of observation stations and then rely on mine company staff to make the necessary measurements or to monitor the recording apparatus. In this regard, branch engineers received full cooperation from the mine staff. Samples of rock were tested for their properties in uniaxial compression for brittle rock and also in triaxial compression for plastic and viscous rocks. Triaxial apparatus was designed by Larocque, the officer in charge of rock testing in addition to performing other duties: "The triaxial apparatus" (IR FMP 62/5).

An overview of the rock mechanics studies as they related to bedded deposits was given at the Annual General Meeting of the CIM in Vancouver in 1968: "A review of rock mechanics applications in Canadian bedded deposits" by A. Ignatieff (Trans, CIM, vol 71, pp 290-294, 1968).

Probably the most interesting manifestation of residual or tectonic forces in a lode mine was a study extending over several years at the Director fluorite mine in Newfoundland. In 1962, at the request of the Deputy Minister of Mines of Newfoundland and following a preliminary visit and discussion with management at the property at St. Lawrence, Newfoundland by Cochrane and Barron, a cooperative research project program was drawn up by Cochrane and Coates (IR FMP 63/196).

The principal problem was rockbursting in development and extraction workings which occurred after mining had progressed to a cover of only about 250 ft. The shaft was less than 1000 ft deep. The fluorite occurred as a relatively weak vein material in a strong granite environment of high strain energy.

Some preliminary advice was given on stress relief blasting and optimizing stope geometry. The project started early in 1964 and included a detailed mine geology study of the severe structural conditions



Triaxial apparatus designed by G. Larocque

G. Larocque

by the company's geologist, monitoring the changes in closure and measuring sonic velocity through rock and ore with instruments supplied by the Mines Branch, and uniaxial compression tests on the ore and granite carried out by R.C. Parsons (DR FMP 65/55). The closure measurements were erratic but the sonic velocity tests indicated that the velocity in the granite was nearly twice greater than in the ore. Stress relief blasting discussed in the early meetings provided some relief to the problem. A report titled "Preliminary investigations into rockburst conditions at Director mine, Newfoundland Flurospar Limited" by T.S. Cochrane, completed the first phase of this research (DR FMP 65/69).

The next phase was in situ tests with the U.S. borehole deformation meter and the Leeman strain cell, to be mentioned later; the former instrument requiring trepanning or overcoring to obtain an absolute value of ground stress. In addition, sonic velocity measurements were made before and after blasting. The tests were conducted over a three-week period early in 1966 by W. Zawadski (1965 -) and J. St. Onge (1965 - 1969) from Elliot Lake Laboratory. The drilling was done by contract (DR FMP 66/188). Tests were conducted at four sites - three along the 950 foot bottom level and one at the shaft. At this depth the burden or gravitational stress was about 1000 psi, whereas the measured stresses, both major and minor, were many times higher, particularly in the active development area, one measurement being over twenty times the gravitational stress. The results convincingly indicated the presence of residual stresses even at this shallow depth. The sound velocity probing proved to be a useful technique for determining the effectiveness of stress relief blasting: "Results of rockburst investigations at Director mine, St. Lawrence, Newfoundland" by T.S. Cochrane (DR FMP 67/7).

Organization, 1950-1967

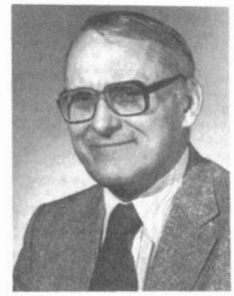
It is appropriate at this juncture to review the changes which took place in the Mining Section from the late fifties, with increased staff and scope, and culminated in the separation of Mining from Fuels in 1967.

In 1957 the first physicist recruited especially for the ground stress project was A.N. May (1957 - 1961) following the resignation in the same year of J.G. Buchanan of the Physical Metallurgy Division. In 1959, G.E. Larocque joined the Mines Branch, followed by K. Barron in 1960. Both were physicists. Larocque from 1960 was leader of the rock properties group, and K. Barron from 1961, leader of the ground mechanics and stress analysis group. A civil engineer, M. Gyenge, who was associated with Dr. Coates in the Steep Rock project to be mentioned later, joined the Mines Branch in 1962. Grant was transferred in 1962 from Calgary to Ottawa and the Public Building Office was closed.

Considerable demands were made on this section in the period between the middle fifties and the late sixties for the skills required in the design, construction and adaptation of instrumentation in the laboratory and in the field. Staff was recruited with this in mind. J.D. Sullivan (1950 - 1972) first assisted Hardy and then joined the Mining Section. In 1958 Harold Cross joined the branch. He had been severely wounded in World War II but courageously worked on in the laboratory and in the field. He had to resign in 1964. In 1960, F. Kapeller, S.R. Cook and A.V. St. Louis were recruited and were excellent assistants to the professional scientists and engineers. The next group of professionals, some of whom had taken formal courses in rock mechanics established by the universities after the war, was composed of G. Knight (1965 -), Y.S. Yu (1965 -), G. Zahary (1966 -), R. Tervo (1966 -). Dr. D.G.F. Hedley (1967 -), Dr. H. Bielenstein (1967 -), Dr. G. Herget (1968 -) and Dr. R.A. Washington (1968 -). Staff with less than ten years service with the Mines Branch are not listed except in the text. At the end of 1964 the Elliot Lake Laboratory was opened and some of the Ottawa staff were transferred there, for various periods: Cochrane as manager from 1964 to 1969, J.G.H. Carrière, administration officer (1947 -), assisted by Mrs. E.M. Labrosse (1964 - 1971 locally recruited), Casey, Grant, R.C. Parsons (1964 - 1967), Richards and St. Louis. Technicians who were recruited for the Elliot Lake group were: W. Zawadski (1965 -), J. St. Onge (1965 - 1969, deceased), H.B. Montone (1966 -), A.R. Lafrenière (1966 -), W. Stefanich (1966 -), H.L. Poliquin (1966 -) and W. Tirrul (1966 -). These men required and possessed not only mining skills but also mechanical skills. Generally speaking, the Elliot Lake Laboratory was fortunate in finding good men.

Respirable dust studies were started in 1961 by L.C. Richards under Cochrane's direction. Later, Knight became leader of the group at Elliot Lake. Retracing the narrative to the late fifties, serious consideration was given at that time to establishing an underground mining research laboratory at Bells Corners to provide a facility for "proof" testing instrumentation destined for underground use, as at the time virtually all measuring devices had to be designed, constructed, calibrated and tested for safety in mine gases and for ruggedness. The latter quality was particularly important as many instruments which

M. Gyenge



G. Zahary

proved satisfactory in laboratory tests malfunctioned underground. A further requirement was underground testing of explosives by the Explosives Laboratory which was to be transferred from Uplands to the Bells Corners complex. Geological and seismic studies were made by Dr. E.B. Owen and Dr. G.D. Hobson of the Geological Survey (Topical Report No. 57 by E.B. Owen, "Proposed site for an experimental mine", GSC, 1962). A formal proposal for the underground facilities was prepared by M.A. Twidale (IR FMP 63/1). The project was deferred and in 1964 the department accepted an offer from Rio Algom Company of a lease on the cafeteria and bunkhouses adjoining the Nordic mine near Elliot Lake, Ontario. The laboratory was set up in that year, with Cochrane being appointed as manager and his quiet leadership overcame the difficulties arising from the settling of transferred staff.

Twidale succeeded H.A. Graves (1947-1958) as mining advisor to the director. The arrangement was that the advisors would be attached to Fuels, as the division was responsible for the mining program. These appointments expressed the director's view of the importance of mining and may be regarded as the forerunners of the formal establishment in 1966 of a Mining Information Section at branch headquarters. Previously, Graves had been concerned as field engineer representing the Bureau of Mines on the bituminous sands drilling contract in the Mildred-Ruth Lakes area of northern Alberta, and he was appointed to the Mineral Resources Division before joining Fuels early in 1957. He was a keen-minded mining engineer and had prepared a proposal for mining bituminous sands (Fuels Rep TM 44/57) and a study on the problems of mining in the sub-Arctic areas of Canada (Fuels Rep TM 20). He had a fatal heart attack during a field trip to the Vermont quarries where "bumping" had been reported.

Alec Brown joined the Dominion Coal Board in 1962 as its mining engineer and Cochrane was acting head of the Mining Research Section until Coates' appointment as head in May 1963. Brown and his associates pioneered the difficult stage of many unknowns when dealing with the range of mostly inelastic rock materials. Historical reports were published on the activities of the Mining Research and the Physics Sections during the period as follows:

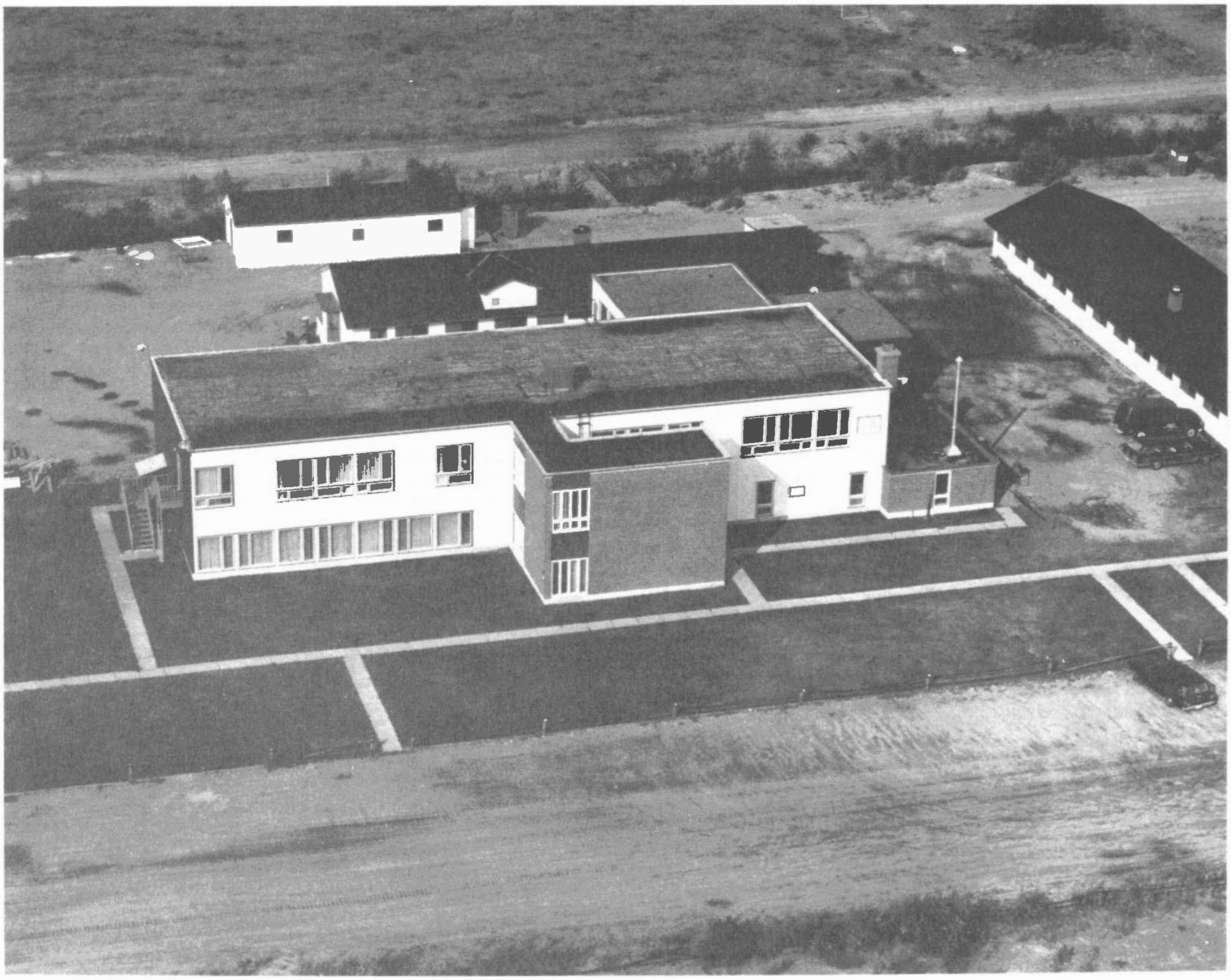
- "Development and progress of strata stress investigations conducted in the Division of Fuels, Mines Branch, Mines and Technical Surveys" by A. Brown, TM 67/57, and Supplement No. 1.
- "Development and progress of the Mining Research Section during the period 1958-62" by T.S. Cochrane, IR FMP 63/113.

- "Tabulation of reports by the Mining Research Laboratories, 1950-64 inclusive" by C.A. Vary, DR FMP 65/24.
- "Development and progress of the Physics Section, December 1959 to December 1962" by W.M. Gray, IR FMP 63/171.

Under Dr. Coates' leadership the Ottawa laboratory was responsible for theoretical analysis, physical and mathematical models, computer programs, instrument development, some rock property testing, and rock breakage with explosives. In regard to the latter, there were joint rock mechanics projects with the explosives laboratory to be mentioned later during the period 1963 to 1967 when the laboratory joined the Mining Research Centre.

The Elliot Lake laboratory was the centre for most field studies both in geology and in rock mechanics at local and other mines and later for rock property testing, and non-explosive rock breakage. Environmental research, notably on respirable dusts and radon emanation and later on suppression of noise were also responsibilities of the laboratory.

The Elliot Lake laboratory became the focus for students, academic staff and post doctorate fellows. Board and lodging at modest rates were provided to those who preferred to stay at the laboratory which was about 5 miles from town.



Elliot Lake Laboratory (Photo - George Hunter)

METALS

Underground Mining

The enlargement of the original "rock or strata pressures" coal mining program in the Mines Branch to include "hard rock" or metalliferous mines owes its origin to the interest shown in 1955 by the Newfoundland Deputy Minister of Mines, F. Gover, and by the Dominion Iron Ore Company at Wabana, an affiliate of Dosco, to increase the recovery of ore which was only approximately 50%, from the submarine mines at Bell Island, Newfoundland. Other projects followed because a number of ore producing companies identified some of their ground stress problems with those in coal mines which were being investigated by the Mines Branch.

It is pertinent to mention the important role played by the mining departments of Canadian universities at this time, and more particularly by the leadership shown by Professor R.G.K. Morrison at McGill University where he became MacDonald Professor of Mining in 1949 after considerable experience with deep mining problems in Ontario and India. Courses in graduate work in rock mechanics were established by him and these were followed by Professor A.V. Corlett at Queen's, Professor H.R. Rice at Toronto, all three in Central Canada, Professor Lee Cameron at Nova Scotia Technical College in the Maritimes, Professor T.H. Patching at the University of Alberta and Professor M.S. King at the University of Saskatchewan. The sixties were indeed a flourishing time for rock mechanics - quite a constituency of specialists developed in the mining and civil engineering professions largely as the result of university training and increased opportunities in government and industry.

The Mines Branch played a role as an informal coordinator of rock mechanics research at universities through a grants-in-aid scheme to be mentioned later and in industry. This function was personified by D.F. Coates, who as a civil engineer chose rock mechanics for graduate studies, industrial consulting and teaching, earning a doctoral degree at McGill in 1964; he became head of the Mining Research Laboratories in 1963. In the same year, the Canadian Advisory Committee on Rock Mechanics (CACRM) was formed. Coates later organized a rock mechanics group of geologists, physicists, and civil and mining engineers interested in this applied science. This group became affiliated with the International Society for Rock Mechanics in 1967. In 1974 the Canadian committee became one of the specialist committees of the Canadian Institute of Mining and Metallurgy and is now known as the Canadian National Committee on Rock Mechanics.

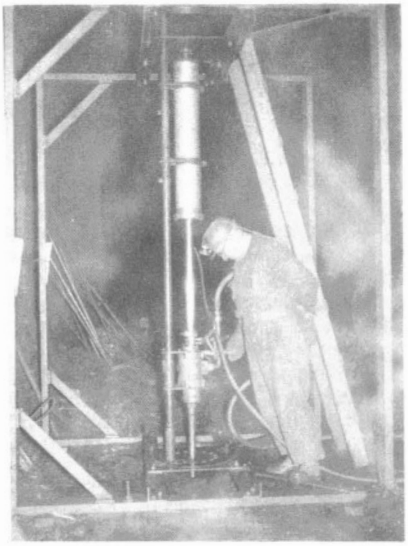
Dr. Coates vigorously pursued personal research while supervising the collective effort of the Mining Research Section, renamed Mining Research Laboratories (MRL) which in 1964 was divided into a headquarters laboratory and a field laboratory at Elliot Lake. Coates found time to write a classic tome entitled "Rock mechanics principles" published in 1965 (145). It has been translated into French, Spanish and Chinese and has become a course book in many universities in the world. At this writing it has undergone three editions in English text. A companion monograph which deals with extrapolating from the "known to the new", entitled "Incremental design in rock mechanics", by D.F. Coates and M. Gyenge was published in 1973 (146).

Despite the rapid increase of large-scale open pit mining which started with iron ore mining in northern Quebec and Labrador followed by base metal mines in British Columbia, accounting by the seventies for some 70% of Canadian mineral production, the rock mechanics emphasis was not surprisingly related to underground mining where most of the difficult ground control problems were present. In this connection, it is noteworthy that the largest number of diverse underground mines in the world is found in Canada. In 1973 Canada was credited with having 107 underground mines producing more than 150,000 tons per annum compared with 68 for South Africa and 61 for the U.S.A. in a world total of 560 underground mines (The Mining Magazine, London p 210, Sept. 1973).

The Wabana project was conducted in the same way as the coal mining study, starting with a geological investigation by D.K. Norris: "Structural conditions at the Wabana Iron Mines, Newfoundland, with reference to increased ore recovery" (Topical Report of the GSC No. 5, 1956, and CIM Bull, pp 539-549, Sept. 1957). There was some testing of pillar fissuring conducted by Buchanan before he left the Mines Branch in 1957, using the sonic method adapted for use in mines by Marsh. A.N. May, who joined the Mines Branch in 1957, redesigned the strain gauge load cell and during 1959-60 with Harold Cross conducted a program of measuring stress changes in room and pillar extraction areas.

Largely because of the borehole installations interfering with mining schedules, May suggested a model study: "The use of scale models in ground control studies" by A.N. May (IR FMP 60/168). This project was started by May before he left the Mines Branch in 1961 and was completed by Barron and Larocque. May reported fully on the underground measurements that were made in his time: "A report on the ground control study conducted at the Wabana Iron Ore Mine, January 1958 - January 1961 and an outline of the proposed future program of study" (IR FMP 61/41). The structural model study was based on the principles of similitude. The geometry of the working, the stress environment and the properties of rock were scaled, in the latter case by using appropriate plaster of Paris mixes of cured strength equivalent to the physical properties of the prototype. This required that the measurement of existing or field stress use the trepanning or overcoring technique. Six trepanning operations were carried out in 1963. The loading frame was designed for a 6 ft x 6 ft x 1-ft model representing a geometrical scale-down of 70 to 1. The compression load was supplied by a 50-ton hydraulic jack.

Ten internal reports by May, Cross, Barron, Larocque, Hunt, Cook and Kapeller were written during the period of 1961 to 1963 (see tabulation of reports of MRL IR FMP 65/24). At the first Rock Mechanics Symposium held in 1962 at McGill, the development of this model was described. At that stage the field stress in the Wabana mine had not been measured: "Development of a model for a mine structure" by K.

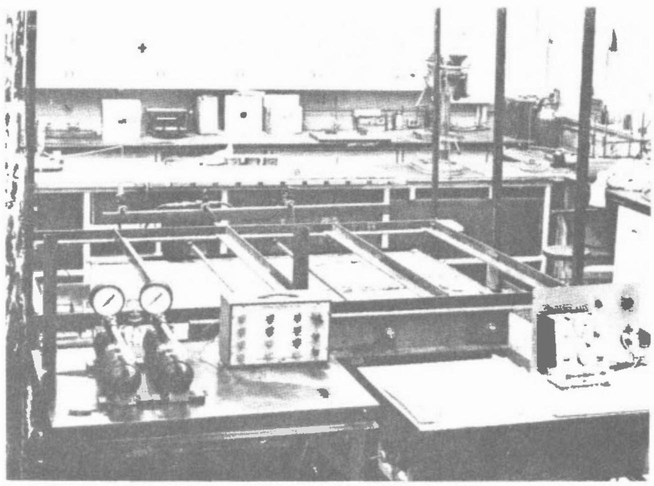


Vertical trepanning by diamond drilling at Dominion Wabana Iron Mines Limited, Bell Island, Newfoundland

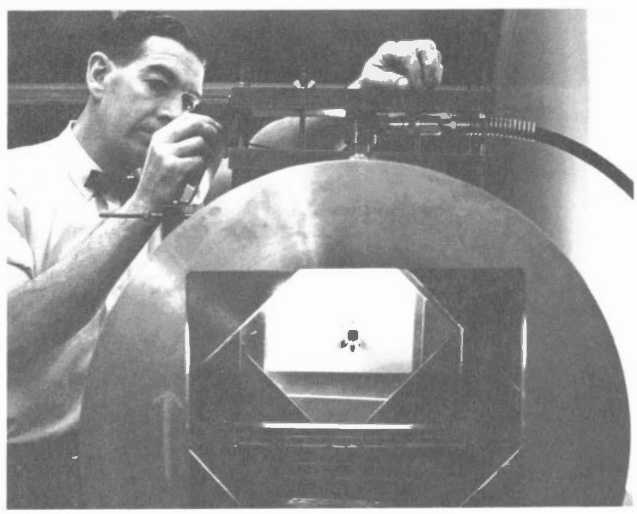
Barron and G.E. Larocque (Proc of Rock Mechanics Symposium at McGill University, pp 145-162, published by Mines Branch, 1963). Although the cost of the model study was considered to be lower than for comparable underground experimentation, the results and the effort were not considered to justify further research. Equivalent materials research was superseded by photoelastic models supplemented by observations in the mine. The studies at Wabana indicated in a preliminary way that somewhat higher recovery of ore could be expected without increasing the hazard. However, the mine closed in 1966 because ore quality did not compare with the better grade available from Quebec and Labrador.

In 1960, McIntyre Porcupine Mines Ltd. of Schumacher, Ontario, suggested a cooperative investigation of rockbursts in crown pillars in the steeply dipping gold orebody at depths below 5000 ft in a strong porphyry rock environment. Observation sites were established for deformation and stress change measurement. Boreholes were drilled into the ore and rock, and Mines Branch stressmeters were employed for monitoring the stress changes. The deformation was measured by extensometers. Sound velocity was measured to determine the degree of fissuring around the sites of stressmeters. The stoping method was cut-and-fill and the magnitude of loading in the fill was determined by dynamometers. A photoelastic model of stress around the cut-and-fill stopes based on stope geometry was prepared by Barron and Cross. The results provided tentative conclusions on the identification of mining-induced stresses or abutment zones, as was the case in the coal mining studies, and their relationship to the geometry and effectiveness of support in the stopes. Pending further studies in this connection, off shift stress relief blasting ensured the protection of personnel from accidents. Cochrane and Grant were mostly involved with the field work at this mine: "Studies of ground behaviour in a metal mine" by T.S. Cochrane, O.F. Carter (McIntyre Porcupine) and K. Barron (Proc Fourth International Conference on Strata Control and Rock Mechanics, pp 123-139, Special Volume, Columbia University in New York City, 1964).

In contrast to the last case, the Errington underground mine of Steep Rock Iron Mines Ltd. in northern Ontario had difficult conditions at a depth of less than 1000 ft. At the time of the preliminary discussions with the company in the late fifties, block caving was practised in a thick steeply-dipping iron ore deposit in geologically disturbed ground, with the immediate wallrocks and the ore being largely incompetent and with a high moisture content. Research work at the mine was conducted by J.R. Helliwell under the general direction of K.L. McRorie, general superintendent of underground mining. Some instrumentation in the form of dynamometers and hydraulic load cells was supplied by the Mines Branch as well as data on the physical properties of the rocks and ore. In the light of increasing demands for a higher grade of iron ore, a more selective mining method was chosen to avoid dilution of the ore with waste rock.



Strain-gauged model ready for loading (Wabana mine)



H. Cross carries out photoelastic stress analysis

A top-slicing longwall method was decided upon using a 3-row coal mining type friction prop system at the face. The slice was ten feet thick and mining progressed under a steel mat. In this research phase which started in 1960, Coates was retained as a consultant. He used Terzaghi's theory for deep bins containing loose material which he modified to allow for arching of cohesive ground. An equation was evolved for the undirectional pressure acting on the working face. The experimental results were in general agreement with Coates' postulation. M. Gyenge assisted him in this work, and the Mines Branch continued to supply and advise on instrumentation, some of which was fabricated at Steep Rock. Photo-stress unidirectional gauges were used for the first time for measuring prop loads and the results compared favourably with those of the electric strain gauge method. Field stress measurements were made by trepanning technique producing a 12-in. core. Crushing strength tests were conducted using an hydraulic prop to apply the load on a circular plate pressed on the rock or ore, and this method was compared with laboratory tests on rock and ore specimens. The results indicated that this in situ method was suitable for yielding rocks and ores but was not altogether satisfactory for brittle rocks: "Plate-load testing on rock for deformation and strength properties" by D.F. Coates and M. Gyenge (American Society for Testing Materials, Special Technical Publication 402, 1966, and MB RS 67, 1968). A study was also conducted at this time on the use of water in assisting the drawing of ore: "Hydraulic mine model studies" by D.F. Coates and M. Gyenge (IR FMP 63/28).

A paper was given by McRorie and Helliwell at the first Rock Mechanics Symposium at McGill University in 1962: "Mining research at Steep Rock Iron Mines Limited" by J.R. Helliwell and K.L. McRorie (Proceedings of Rock Mechanics Symposium at McGill University, pp 93-119, published by Mines Branch 1963). Although research on top-slicing was reported in this paper, it was not completed until mid-1962, and a paper giving full particulars of this later research was given in 1964: "The mechanics of support and caving in longwall top-slicing" by D.F. Coates and M. Gyenge (Proceedings of Fourth International Conference on Strata Control and Rock Mechanics, Columbia University, New York, pp 70-84, 1964).

In 1963, a cooperative research project was established with Algoma Steel Corporation to conduct rock mechanics studies at the MacLeod mine, Wawa, Ontario. This was a comprehensive study directed to the stability of pillars with the aim of assisting in solving problems of mining at depths greater than the existing 1000 ft in an orebody inclined steeply at about 65°. Various measurement approaches were tried to establish deformation and the stress regime in pillars with auxiliary tests of sonic velocity and microseismic activity. The latter two approaches did not yield any substantive data due to considerable cracking of the pillars and difficulty in interpreting noise levels. The extensometer measurements were made with bolt and multi-wire type instruments and provided the most useful information on pillar behaviour. The United States Bureau of Mines deformation meter to be described later with overcoring was used to determine the existing stress. Both horizontal and vertical stresses were larger than the gravitational or burden stress, the horizontal being greater than the vertical.

The finite element mathematical model technique was used for comparison and prediction. On the whole,

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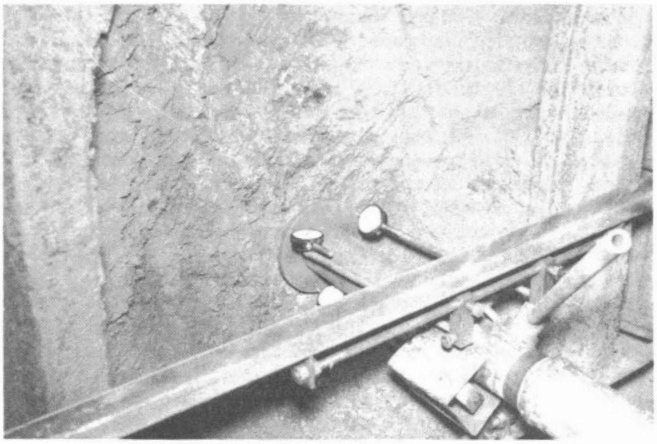

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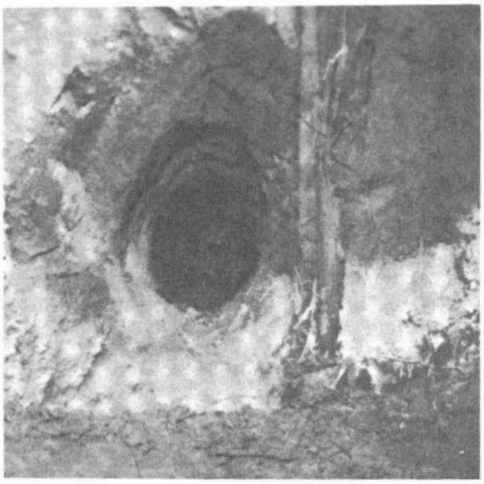


3

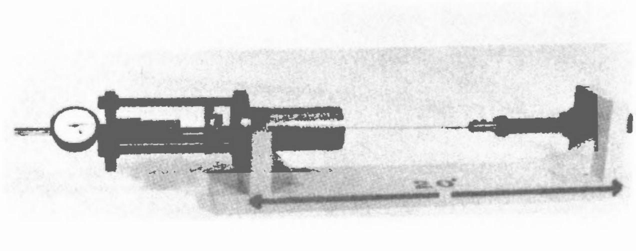
Stress phenomena and application of rock mechanics at Steep Rock Iron Mines Limited, Ontario.

1 - removing 12-in. core after trepanning at the Errington mine
2 - plate load testing
3 - horizontal residual stresses squeeze a drill hole in a small service drift

the model data yielded higher figures than those that were measured, probably due to the model being two-dimensional whereas the actual mining configuration was three-dimensional: "Underground measurements in a steeply dipping orebody" by D.G.F. Hedley, G. Zahary, H.W. Soderlund (chief engineer, Algoma Division, Algoma Steel Corporation, Wawa, Ont.) and D.F. Coates (Proc Fifth Canadian Rock Mechanics Symposium, University of Toronto, 1968, pp 105-125, published by Mines Branch, 1969). The structural geology and ground stress relationship in the Wawa area was studied by Dr. G. Herget (1968 -) in a similar way as in the Elliot Lake area by Bielenstein and Eisbacher: "Tectonic fabric and current stress field at an iron mine in the Lake Superior region" by G. Herget (Proc 24th International Geological Congress, Montreal, Section 13, pp 241-248, 1972).

There were numerous cases in the early period of assisting mining companies in their ground control research; two further examples may be quoted. In 1960 Cominco wanted to assess the stress changes in a pillar-extraction area around a large pillar containing about 200,000 tons of ore which it was planned to break in a single blast in the Sullivan mine. At the time only two BX (2 3/8-in. diameter) stressmeters were available and they were installed by the Cominco staff under guidance from Cross. AX (1 7/8-in. diameter) stressmeter drawings were left for any future fabrication in the company's workshops. The company showed considerable initiative in carrying out monitoring surveys using at first extensometers of Mines Branch design: "Ground control at Sullivan Mine" by staff (Rock Mechanics Symposium, McGill University, Mines Branch, 1963). Eventually a rock mechanics section was established by the company under M.J. Royea, McGill graduate in rock mechanics. He evolved a methodical and simplified procedure for field stress determination suited to the large variations occurring in the large pillars being mined: "Rock stress measurements at the Sullivan Mine" by M.J. Royea (Proc Fifth Canadian Rock Mechanics Symposium, University of Toronto, 1968, pp 59-74, published by Mines Branch, 1969).

In 1963 rock-bolt extensometer drawings were supplied to the Geco mine in northern Ontario in connection with that company's ground control program. It would appear that useful information was obtained from the measurements, particularly from the extensometers installed close to operating stopes. Later experiments were carried out with multi-wire borehole extensometers of Mines Branch design: "Control of ground movement at the Geco Mine" by R.C.E. Bray (Proc Fourth Canadian Rock Mechanics Symposium, Ottawa, pp 35-66, published by Mines Branch, 1967).



Extensometer developed by Mines Branch

Before going on to open pit mining, it is pertinent in this metals subsection to refer to a review paper on the extensive rock mechanics research at Elliot Lake mentioned in greater detail later, which illustrates the importance of joint geological-rock mechanics studies in all orogenic belts: "A rock mechanics case history of Elliot Lake" by D.F. Coates, H.U. Bielenstein and D.F.G. Hedley (Canadian Journal of Earth Sciences, vol 10, No. 7, pp 1023-58, July 1973).

Open Pit Mining

Before joining the Mines Branch, Coates recognized the growing importance of open pit mining in Canada and as a civil engineer conversant with soil mechanics appreciated the deficiency of knowledge on the stability of rock slopes. He and Brown published a paper wherein modes of failure were presented together with suggestions for research and investigation: "Stability of rock slopes at mines" by D.F. Coates and A. Brown (CIM Bull, pp 514-521, July 1961).

Coates' aim was to design rock slopes with the same degree of accuracy as in the case of soil slopes, as well as to design support systems if needed, with the same degree of effectiveness as in underground mines. On joining the Mines Branch he and Gyenge carried out a survey of case histories of rock slope failure through slides, making a particular study of slides of incompetent rocks at the Iron Ore Company of Canada at Knob Lake, Labrador. The original aim was to ascertain whether instability could be predicted from measuring the strength of incompetent wall rocks. Triaxial tests were carried out on rock recompacted in the laboratory to the same density as if measured in the field. The results indicated that the recompacted samples had strength values similar to those deduced from previous slides. The coefficient of variation was about 45%, which was not excessive. An attempt to procure undisturbed core samples was not successful due to hard particles enclosed in a soft matrix. In addition, deformation, groundwater and microseismic observations were carried out. "Slope stability studies at Knob Lake" by D.F. Coates, M. Gyenge and J.B. Stubbins (chief engineer, Knob Lake Operations, Iron Ore Company of Canada) (Proc Third Canadian Rock Mechanics Symposium, University of Toronto, pp 35- 46, published by Mines Branch, 1965).

In contrast to the previous case, competent rock in open pit slopes offered the opportunity of increased profitability by increasing the angle of the slope without loss of stability by using deep cable anchors and mesh support. A comprehensive engineering feasibility study was made over a lengthy period: "Artificial support of rock slopes" by K. Barron, D.F. Coates, M. Gyenge (MB RR 228, 1970, revised 1971). In 1968 an experimental project was carried out with the assistance of Hilton Mines, Quebec on a prototype face 50 ft long and 68 ft high. The trial indicated that the slope angle could be safely increased from 37 1/2° without support to an optimum of 53° with support with an increased margin of profit of about a thousand dollars per linear foot of pit wall: "Support for pit slopes" by the same authors (Trans CIM, vol 74, pp 77-84, 1971).

One of the principal problems in dealing with stability of rock slopes is inability to assess the distribution of stresses within a rock slope. Ordinary mathematical treatment based on the theory of elasticity did not yield acceptable results. The first alternative was to use photoelastic models. A gelatin deformable under its own weight was found insufficiently stable with change of time, temperature and humidity. Gyenge developed a more stable mixture which he named "Mirelite". This material in conjunction with reverse loading with mercury provided a technique for producing photoelastic fringes of stress distributions. A computer program was suggested to deal with the calculations involved: "A computer program for calculating principal stresses in photoelasticity" by M. Gyenge (MB TB 88, 1967).

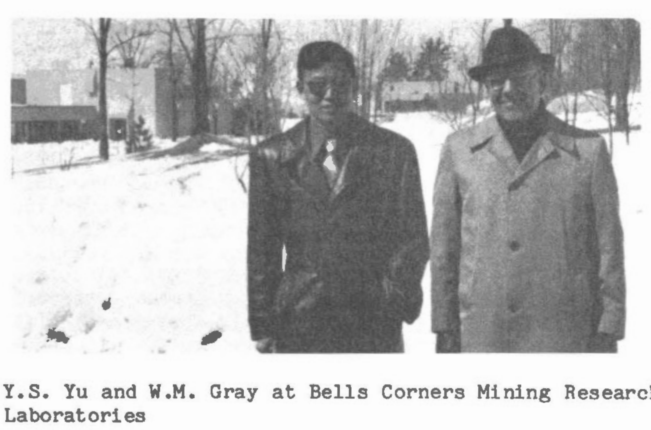
An iterative or repetitive process using finite elements employed in solving problems in concrete dams suggested the use of this technique in the determination of stress in slopes: "Analysis of rock slopes using the finite element method" by Y.S. Yu and D.F. Coates (MB RR 229, 1970).

An earlier bilingual research report had been prepared describing the development of computer programs, related to open pit mine stresses and providing detailed information and instruction on their use: "Development and use of computer programs for finite element analysis - La mise au point et l'utilisation de programmes sur ordinateur en vue de l'analyse de la méthode des éléments finis" by Y.S. Yu and D.F. Coates (MB RR 198, 1969).

In establishing a computer group in 1966, Coates used the comparison of rock mechanics research and systems with the mathematics of systems such as mine ventilation, heat flow and mine cost structure which take into account the interaction of variables. An ambitious project on the various factors governing the stability of open pits and the optimization of operation known as the "Pit Slope Project" was inaugurated in 1971.

Stress Measurement (Instrumentation)

From the inception of rock mechanics studies it was evident that ground or field stress within the solid mass of rock or mineral, would not be due just to the weight of overlying rocks at any given depth. As there were no commercially available borehole ground stress measuring devices until the 1960's considerable effort in designing instruments rugged enough for stress measurements in mines was made by the Mines Branch and other research groups, and this effort is worthy of some detailed description.

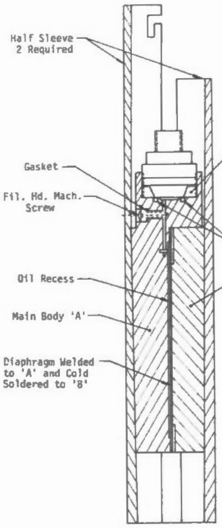


Y.S. Yu and W.M. Gray at Bells Corners Mining Research Laboratories

The early strain-gauge load cells designed by the Physical Metallurgy Division with the gauges mounted on a disc within a magnesium cylinder and later changed to steel, designed for a 2 1/4-in. borehole to measure ground stress changes were found to be insufficiently strong mechanically, and the correlation of stresses between the disc and host rocks was difficult. Earlier research on concrete suggested that the modulus of elasticity of a rigid "inclusion" or stressmeter should be about four times greater than that of concrete to ensure that the strain in the inclusion was dependent on the stress and not on the strain in the concrete; in that case, accurate knowledge of the modulus of elasticity of the host rock was not required and the "inclusion" could be truly described as a stressmeter: "Theory of an experimental method of determining stresses not requiring an accurate knowledge of the modulus of elasticity" by A. Coutinho (International Association for Bridge and Structural Engineering, Publication 7, pp 83-103, 1949). The designs to be described were based on an attempt to make use of Coutinho's concepts. This aim was not entirely achieved because the large proportion of rocks with high modulus of elasticity encountered in Canadian mines would considerably increase the cost of stressmeters to fulfil Coutinho's principles.

May redesigned the early strain gauge load cell into a stronger hydraulic type with a modulus of elasticity of 13.5 x 10^6 psi made from a split steel rod, wherein a narrow recess along the axis of the rod provided an oil bath; when squeeze was applied to the load cell due to the pressure of the rock the oil was displaced deflecting a diaphragm with strain gauges mounted in the head end of the load cell. The load cell was prestressed to improve sensitivity of the stressmeter to changes in stress as well as to give intimate contact with the rock and reduce the amount of grout used between the stressmeter and the rock. For this purpose the outside diameter of the stressmeter was tapered and sleeves with a matching taper were used in loading it into a 2 3/8-in. diam (BX) borehole. This uniaxial stressmeter was used with some success, but when an overcoring or trepanning operation was introduced to measure the existing or absolute ground stress it was recognized that a smaller instrument would be required to avoid the effect of prior prestressing on the rock around the original 2 3/8-in. borehole. Even for a 1 7/8-in. diameter (AX) hole, the trepanned core had to be 12 inches in diameter.

Barron redesigned the BX stressmeter to an AX size, taking into account some of the weaknesses noted in field experience with the BX type. Because of the difficulty in machining an accurate taper on the inside of the sleeve, the meter was fabricated from rectangular rod. However, the same principle of diaphragm strain measurement through the medium of oil pressure was retained, though beryllium-copper was substituted for the steel diaphragm used in the BX model. The strength of the modulus of the stressmeter was much lower at 0.92 x 10^6 psi, than that of the BX type. Hence, for most Canadian mine rocks, Coutinho's relationship between the inclusion and the host medium would not apply, thus the modulus for most host rocks had to be known. All stressmeters were calibrated in the laboratory with material of known properties, aluminum being selected for its good machineability to close limits. In addition to the two "active" strain



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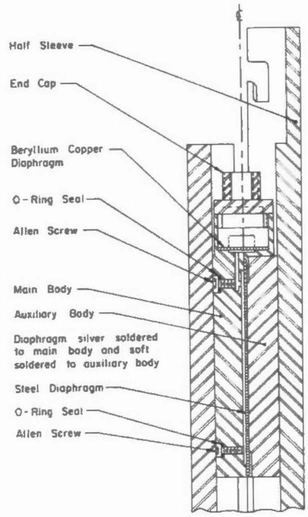

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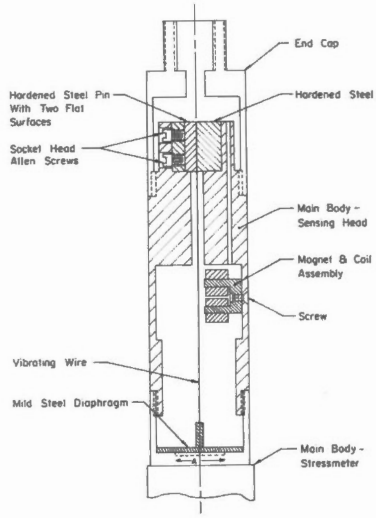

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1 - Cross section through BX (2 3/8-in.) stressmeter and sleeves

2 - Cross section through AX (1 7/8-in.) stressmeter and sleeves

3 - Cross section through general assembly of vibrating wire sensing head (drawings by Don Dugmore, MRL)

gauges on the deformable diaphragm, a dummy disc carried two unstrained gauges. The gauges were wired for a Wheatstone bridge circuit and the output was measured by a portable explosion-proof strain-gauge indicator.

The same stress measurement principles described in the foregoing for uniaxial stressmeters were used in the design of a biaxial unit for a BX borehole. The aim was to extend the resolution of the stress field to two planes, one normal to the axis of the borehole as used by the uniaxial stressmeter and the other perpendicular to the axis of the borehole: "The design and development of a biaxial stressmeter" by H.E. Cross (IR FMP 61/84). Preliminary tests showed some promise in a salt mine but the project was discontinued as the ground stress program was changing from measurement of stress changes to the measurement of instantaneous stress using smaller diameter borehole instruments.

The strain gauge stressmeter was found to be stable for periods up to three months; with time, a slow drift of the gauge zero developed, which was attributed to the effects of moisture and humidity on the gauges and their cements. Coating techniques were used but the problem was not entirely eliminated.

Because a principal function of the various models of Mines Branch strain gauge load cells or stressmeters was the measurement of stress change, stability of a borehole instrument was an important requirement. To overcome the electrical problems of strain gauges, an acoustic vibrating wire sensing head which screwed into the hydraulic oil stressmeter was designed by Barron, who had done some research in this area related to concrete at the National Coal Board before joining the Mines Branch. In principle, plated high-strength steel wire, 0.010 inches in diameter, was soldered to a steel diaphragm at one end of the sensing head, and the wire passed less than one sixteenth of an inch from an exciter unit comprising a U-shaped magnet and coils at the other end of the head. The exciter unit provided the means of inducing a DC pulse that plucked the wire causing it to vibrate at its natural frequency. The magnetic field produced an EMF of the same frequency in the coils. The alternating voltage was amplified and its frequency determined with the use of a comparator which contained a standard wire in continuous vibration. A commercial unit made by Maihak was first used but it was redesigned by Larocque as a battery-operated transistorized unit intrinsically safe for coal mines. This unit was based on the work at the National Coal Board: "Construction of a vibrating wire comparator" by G.E. Larocque (IR FMP 60/191).

These devices for measuring changes in stress proved useful during early studies of stress change for outlining abutment zones induced by mining, and provided a better insight into high stresses as a cause of sudden failure of rock or mineral.

In 1965, Barron completed a report on the various stressmeter models with a section devoted to guiding potential users who would undertake the fabrication of strain gauge and vibrating-type stressmeters as well as a section on trepanning to determine the instantaneous value of the existing ground stress. He gave credit to May's and Cross's early work by joint authorship of the report in which he mentions the valuable assistance from Richards, Cook and St. Louis: "The Mines Branch stressmeter" by K. Barron, A.N. May and H.E. Cross (DR FMP 65/172).

By the early sixties the research and development work in rock mechanics at universities and government establishments was yielding not only useful analytical concepts of the stress and strain phenomena as applied to rocks but also an array of measuring devices. The Mines Branch kept in touch with these developments partly to reduce the costly effort of developing

K. Barron

instrumentation which involved a large proportion of manpower by the Mining Research Laboratories in design, fabrication and prooftesting despite the excellent assistance rendered by the Technical Services workshops. It was also recognized that comparatively lengthy underground programs of stress change measurement were costly. Thus the measurement of instantaneous ground stress was an attractive method, particularly in dealing with hard rock mines without rockburst history.

The University of Sheffield (England) suggested the assessment by the Mines Branch of a glass or photoelastic stressmeter which was being developed by them and Kyoto University in Japan. This was a device designed to observe the stress changes in rock and in this regard was similar to the Mines Branch stressmeter. It had the advantage of being a simple biaxial device which was cheaply constructed. Barron found in his investigations that the meter sensitivity, to be independent of the host rock strength, had to be used in rock with a much lower modulus of elasticity than previously assumed and that the sensitivity decreased as the ratio of biaxial stresses approached unity. Laboratory calibration of the stressmeter was in good agreement with theory, and the photoelastic fringe patterns gave excellent indications of the applied stress directions: "Glass insert stressmeters" by K. Barron (Journal of the Society of Mining Engineers, pp 287-299, and MB RS 15, 1965).

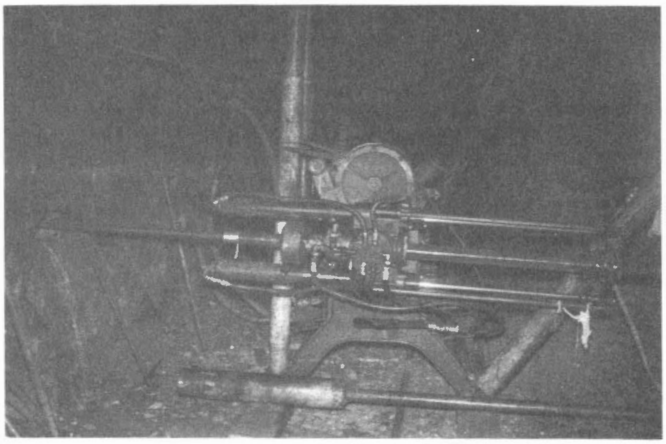
Two instruments for field stress measurement with particular application in "hard rock" mines were developed by the U.S. Bureau of Mines (USBM) and the National Mechanical Engineering and Research Institute of the South African Council of Scientific and Industrial Research (CSIR) respectively in the early 1960's. The first of these instruments to be tried out by the Mining Research Laboratories at the Nordic mine near Elliot Lake in 1965 shortly after the laboratory was established was the USBM borehole deformation meter for EX boreholes (1.5-in. diameter): "Borehole deformation gage for determining stresses in mine rock" by L. Obert, R.H. Merrill and T.A. Morgan (USBM Report of Investigation 5978, 1962). The sensing element in this device was a beryllium-copper cantilever on which four strain gauges were mounted to form a Wheatstone bridge. The cantilever produced sufficient force to keep a piston and spacing studs in contact with the sidewalls of the borehole. The Bureau made available fabrication drawings and units were made by the Technical Services Division. The value of the existing stress was obtained by overcoring with a 6-inch diameter bit.

The Nordic uranium mine was on the southern limb of a structural basin of Precambrian rocks with compressive strengths of 31,000 to 38,000 pounds per square inch. Two locations were selected for study: a stoped-out area at a depth of 850 to 1010 ft and in drifts remote from the stope pillars at depths of 840 to 1360 ft below surface. The ground stresses were calculated from the expansion of the diameter of the EX hole following the overcoring stress relief operation and showed that the pillar area stresses were up to 15,600 pounds per square inch, with possibly even higher stresses reached in cases where the stress relief operation had to be abandoned due to "discing" of the core. The ground stress in the drift sites remote from the stopes was on the average, for the vertical component twice and for the horizontal component three times the burden or gravitational stress. The cores were shipped to the Ottawa laboratory for determination of uniaxial compressive strength, modulus of deformation, specific gravity and mineralogical examination. This study was carried out by Coates and Grant with assistance from Cochrane, I. Bayne, St. Louis, Zawadski and St. Onge at Elliot Lake, and from Parsons, Cook and M.A. Ellis in Ottawa: "Stress measurements at Elliot Lake" by D.F. Coates and F. Grant (Trans CIM, vol 69, pp 182-192, 1966, and MB RS 68, 1968).

A second test in the same area as the Nordic mine was carried out somewhat later using the "doorstopper" strain cell developed by the South African CSIR: "The measurement of stress in rock, Part 2: Borehole rock stress measuring instruments" by E.R. Leeman (Journal of SA Inst of Mining and Metallurgy, vol 65, pp 82-114, Sept. 1964). For immediate comparison, the USBM deformation gauge was also used in this study.

The strain cell was installed in a smoothed-out and clean bottom of a BX (2 3/8 in. diameter) hole by means of a special installing tool, a modification of which was made in Ottawa: "A new strain cell installing tool" by W.L. van Heerden, C. Szombathy and A.V. St. Louis (DR FMP 66-37). The measuring element was a strain-gauge rosette for vertical, 45° and horizontal directions similar to the early Mines Branch stressmeter. The leads from the gauges were connected to four pins and an insulated connector plug. Both gauges were incapsulated in a silicon rubber compound. In operation the strain cell was cleaned and plugged into the installing tool, smeared with glue and pushed to

R. Miller (left) prepares "doorstopper" strain cell for installation in a borehole, Nordic mine, Elliot Lake, Ontario



Drill set-up during coring of installed "doorstopper"

the end of the borehole where it was oriented and made to adhere to the rock face of the borehole. When strain readings became constant the tool was removed and the drill using a BX coring bit was used to core out the rock to which the strain cell was attached for a final strain reading.

The results of both methods were generally in good agreement, allowing for errors in instruments and rock modulus measurements, and compared favourably with the direction and order of magnitude of stresses measured by Coates and Grant. Perhaps it should be noted that the direct attachment of strain gauges to rock was considered by the Buchanan-Marsh-Thurston group in their first proposal for measuring stresses in coal mining, but this method was not tried because of the softness of some of the coal strata and the fragility of the coal.

W.L. van Heerden, a research officer of the National Mechanical Research Institute, Pretoria, South Africa, carried out the study with Grant while on an exchange with Barron when they spent 18 months during 1965-66 in their respective exchange countries. In the study mentioned above, the following assisted at Elliot Lake: St. Onge, Zawadski, St. Louis, H. Montone, E. Timms and P. Pike: "A comparison of two methods for measuring stress in rocks" by W.L. van Heerden and F. Grant (International Journal of Rock Mechanics and Mining Sciences, vol 4, pp 376-382, 1967, and MB RS 68, 1968). This research was also reported in the Proc Fourth Canadian Rock Mechanics Symposium under the auspices of the CIM and the Canadian Advisory Committee on Rock Mechanics, held in Ottawa in 1967.

J. St. Onge carries out laboratory measurements following field stress investigations; Leeman doorstopper stress gauges shown

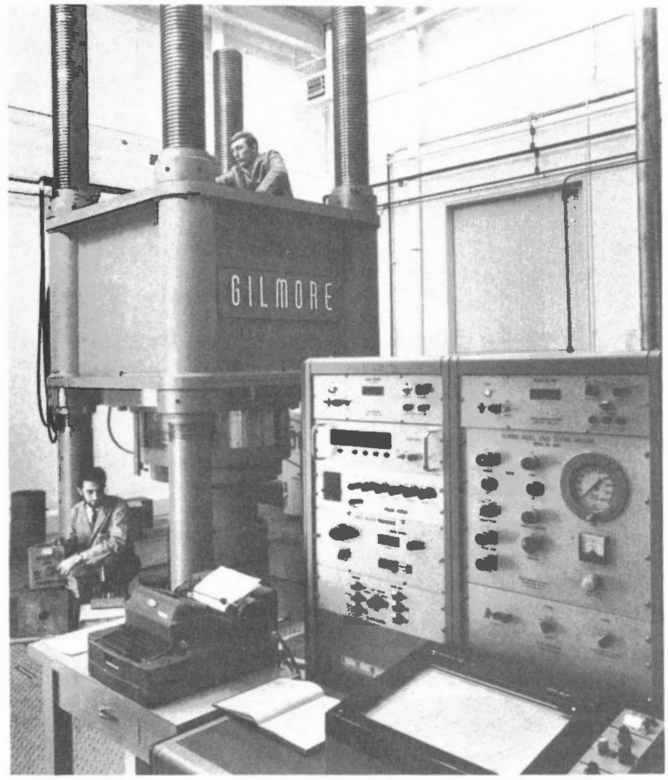
The research at Elliot Lake outlined above added more conclusively to the evidence noted in prior work of the existence and influence of residual or orogenic stresses of variable and complex character in many mining fields. The geological viewpoint was expressed in comprehensive studies undertaken by Dr. H.U. Bielenstein (1967 -) and by G.H. Eisbacher of the Geological Survey of Canada. These studies included large- and small-scale structural geological analyses related to the dominant feature of the Quirke syncline, and strain recovery tests with the CSIR strain cell. The principal conclusion was that the high horizontal stresses observed earlier by Coates, van Heerden and Grant contained a significant proportion of "remanent" stresses from an orogeny earlier than the broad regional arching that followed: "In-situ stress determinations and tectonic fabric at Elliot Lake, Ontario" by H.U. Bielenstein and G.H. Eisbacher (Proc Sixth Canadian Rock Mechanics Symposium, University of Montreal, 1970, pp 91-101, published by Mines Branch, 1971).

The soniscope was a complementary instrument to the stressmeter, useful in scouting and delineating fracture zones in rock and mineral masses and in measuring dynamic properties of unfractured rock. The original sonic instrument redesigned by Marsh from a unit used for testing the soundness of concrete over short distances used piezoelectric Rochelle salt crystals as a source of elastic wave energy. In 1963, Larocque and Kapeller designed a new instrument by which a stronger source was produced by a barium titanate transducer. There was an improved coupling of receiver and transmitter with the host rock. The instrument was more portable and reliable as a control unit and did not require an AC outlet or a large converter power supply: "A sonic unit for the determination of "in-situ" dynamic properties and for the outlining of fracture zones" by G.E. Larocque (Proc Sixth Symposium on Rock Mechanics at the University of Missouri at Rolla, October 1964, pp 358-380, and MB TB 75, 1965).

Reference has been made previously to various instruments such as extensometers for measuring deformation of mine workings and pillars, and to laboratory apparatus mostly related to measuring properties of rock substance samples. Space does not allow of detailed descriptions of this instrumentation.

Pillar Mechanics

The pillar is the principal structural unit in a mine, fulfilling this function as long as its imposed load is less than its strength. It acts as a separate entity from the rock or mineral mass, providing the major natural support of various kinds and amounts of artifical supports depending on the size of the excavation. As pillars formed in the initial period of mine development represent a high proportion of potential mineral production, a large percentage of pillars must be recovered. A gradual enlarging of the excavation results in continuous transfer of stress to adjoining pillars and the solid ground on the perimeter of the excavation, and this results in the formation of abutments - zones of higher stresses. The essence of ground control is in the control of the cavity created by the excavation and is achieved by a methodical mining sequence which includes pillar extraction, the use of appropriate artificial support and finally in the systematic filling of the cavity of large excavations by fill or by caving relatively weak rocks such as occur in coal mines. The mining process proceeds laterally from the shaft or the main entry to the limits of an inclined orebody, and in the case of flat deposits to the limits of the property or to a geological dislocation such as a major fault. The process continues from level or lift downward to the next level as the mine deepens.



R. Miller adjusts the Gilmore press

The role of pillar mechanics is to optimize mineral recovery without endangering the stability of the mine; as a first approximation the ratio of the average pillar strength to the average pillar stress provides an approximate safety factor. Because of the multitude of variables encountered in the natural rock and ore environment, structural analysis of a kind determined for man-made materials and structures cannot be easily applied to rock. In the past, largely empirical hypotheses were made which, in the post-war era, allowed Coates and others to postulate hypotheses which attempted to analyze some of the identifiable variables for inclusion in the theoretically sounder interpretation of the function of a mine pillar as a structural unit. Coates completed a doctoral thesis in pillar mechanics and continued this research in the Mines Branch. In addition to the important parameter of the extraction ratio accepted by all research workers, he identified as significant: the ratio of compressibility of the pillar rock to the rocks in the hanging and footwalls (roof and floor), the height of a pillar, and the widths of the pillars if the width were unequal. A four-part publication "Pillar loading" was issued in 1965 to 1967 (147).

F. Kapeller adjusts instrument to measure sonic velocity in rock

The estimation of pillar strength had presented a difficulty in extrapolating the strength of rock substance specimens to the rock mass in a pillar. In 1969, a Gilmore 4 million-lb machine with automatic control and output was installed at Elliot Lake for test specimens which were large enough for the failure pattern to resemble that of a pillar. A technique was established for sampling rock using random number selection and analyzing the compressive strength and dispersion of the results. From these data the pillar strengths could be predicted by extrapolation, which in the case of uranium quartzitic ore indicated a compressive strength of pillars of about 19,000 psi: "Strength distribution in hard rock" by B. Kostak (NRC Postdoctorate Fellow) and H.U. Bielenstein (International Journal of Rock Mechanics and Mining Science, vol 8, No. 5, pp 501-521, 1971).

In 1972, a paper was published reviewing the geological and mining conditions in twelve mines at Elliot Lake and the data bank of stress and strength measurements carried out in the mines and in the laboratory respectively over a period of five or six years. Calculated estimates were made based on theory and on

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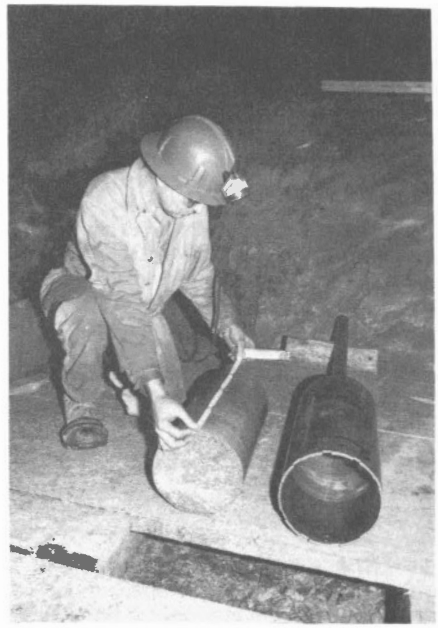

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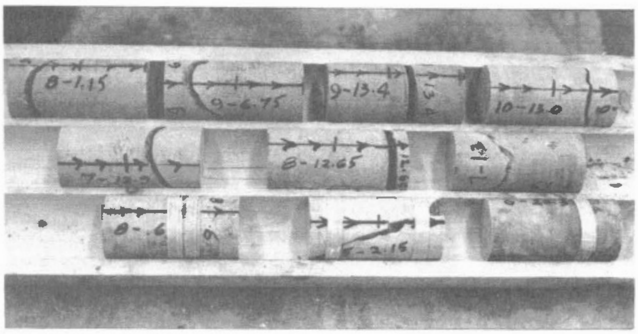

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Prediction of pillar strength by measurement of 10-in. diameter rock core; 1 - 10-in. crown diamond core barrel designed by Mines Branch; 2 - extracted core held by driller's assistant; 3 - A.V. St. Louis measures 24-in. long core for strength testing; 4 - core specimens showing open natural fractures

experimental data to predict stability of pillars as mining progresses deeper: "Stope-and-pillar design for the Elliot Lake uranium mines" by D.G.F. Hedley and F. Grant (Trans CIM, vol 75, pp 121-128, 1972).

Complementary to pillar stability studies, research on backfill as a mass support system in ore-extracted areas was undertaken. The state of the art in Canadian mines was reviewed by Twidale: "Backfill methods in Canadian mines" by M.A. Twidale (MB IC 141, 1962), and the same was done by A.S. Romaniuk (1966 -) for foreign practice: "Backfill techniques used outside Canada" (DR FMP 67/2).

A specification for a percolation test was developed in consultation with several mining companies. "Tentative specifications: test for percolation rate, or coefficient of permeability, of fill" by the Ground Control Research Group (MB TB 101, 1968). An analysis was made of grading effects on hydraulic and consolidated fill by Coates and Yu (Trans CIM, vol 72, pp 36-41, 1969).

To test a computer program developed to solve multi-variable problems with nonlinear functions for optimizing mining operations, the optimization of a simplified transportation mine fill system was analyzed selecting four parameters in the study: the diameters of the vertical borehole and horizontal steel pipe, the duration and hours per day of the filling operation, and solids concentration in the slurry. The analyses indicated that the size of the borehole and pipe were close to those currently used in practice in actual fill systems: "Mine fill system design based on optimization" by M. Gyenge and D.F. Coates (Proc 9th International Symposium on Techniques for Decision-Making in the Mineral Industry, Montreal, June 1970, CIM Special Volume 12, pp 384-391, 1971).

Rock Classification

Coates considered it important for a growing rock mechanics community in particular and for general communication, to establish a rock classification similar to existing soil specifications, and based on the mechanical properties of the rock substance, the geologic name and description of the rock mass. He involved the newly organized Canadian Advisory Committee on Rock Mechanics (CACRM) in the subject, and a report was prepared by Professor B. Ladanyi of University of Montreal on "uniaxial tests of rocks for classification purposes". Coates published a paper in 1964 for the dissemination of and research on a proposed classification: "Classification of rocks for rock mechanics" (International Journal of Rock Mechanics and Mining Sciences, vol 1, pp 421-9, 1964). Coates' classification system was composed of two parts: for the rock substance requiring the following tests - rock density, uniaxial compressive strength, modulus of deformation, strain rate and ratio of irrecoverable to total strain, and for the rock mass - description in geologic terms, gross homogeneity (massed or layered) and continuity of the rock substance in the rock formation (solid, blocky or broken).

Terms and groupings of rock substance properties were simplified in a second proposal in 1966 into two simple categories - strong and weak - with compressive strength above and below 10,000 psi respectively; and elastic or yielding - the latter indicating a relative permanent strain greater than 25% or a creep rate greater than 2 micro inches per inch per hour: "Experimental criteria for classification of rock substances" by D.F. Coates and R.C. Parsons (International Journal of Rock Mechanics and Mining Sciences, vol 3, No. 3, pp 181-9, 1966). The experimental data for these conclusions were derived from research projects conducted primarily for evaluating stress phenomena in rock masses in mines. Some supplementary testing was done for the classification project: "Analysis of the viscous properties of rocks for classification" by R.C. Parsons and D.G.F. Hedley (International Journal Rock Mechanics and Mining Sciences, vol 3, No. 3, pp 325-335, 1966, and MB RS 36, 1967).

The CACRM continued its interest in a rock classification system, publishing a paper in 1968. Essentially the 1966 classification was accepted with revisions of rock compressive strength ranges and groupings. Five groups instead of two with compressive strengths ranging from less than 4,000 psi to more than 32,000 psi were recommended: "A recommended rock classification for rock mechanics purposes" by T.H. Patching and D.F. Coates (CIM Bull, pp 1195-1197, Oct. 1968).

During the period 1967 to 1968, studies were undertaken by Barron to predict the strength of rock masses as distinct from rock substances by simulating the effects of structural discontinuities (joints and bedding planes) on both solid specimens and on specimens with indeterminate planes of failure. An hypothesis based on the Griffiths theory of fracture indicated a means of predicting fracture initiation and ultimate failure of isotropic and anisotropic rocks. He designed a fracture initiation instrument which he used in his studies: "Detection of fracture initiation in rock specimens by the use of a simple ultrasonic listening device" by K. Barron (International Journal of Rock Mechanics and Mining Sciences, vol 8, No. 1, pp 55-59, 1971). A three-part paper was published on the project titled "Brittle fracture initiation in and ultimate failure of rocks - Part I: Isotropic Rock; Part II: Anisotropic Rocks - Theory; Part III: Anisotropic rocks - Experimental results" by K. Barron (International Journal of Rock Mechanics and Mining Sciences, vol 8, No. 6, pp 541-551, pp 553-563, pp 565-575, 1971). Barron was a dedicated research scientist, and through his determination and perseverance he was granted an external Ph.D degree at the University of London for his thesis: "Fracture of brittle rocks around mining excavations".

A postdoctorate fellow in geophysics, D.M. Cruden, during his tenure at the Mines Branch in 1969-70 contributed to the analysis of strain phenomena under uniaxial compression. Two papers were published by him "A theory of brittle creep in rock under uniaxial compression" by D.M. Cruden (Journal Geophysical Research, vol 75, No. 17, pp 3431-3442, June 1970); and "A theory of the static fatigue of rock under uniaxial compression" (paper presented to 51st Annual Meeting of American Geophysics Union, April 1970, see Transactions, vol 51, No. 4, p 424, 1970 for abstract).

Mine Environment

Respirable Dusts

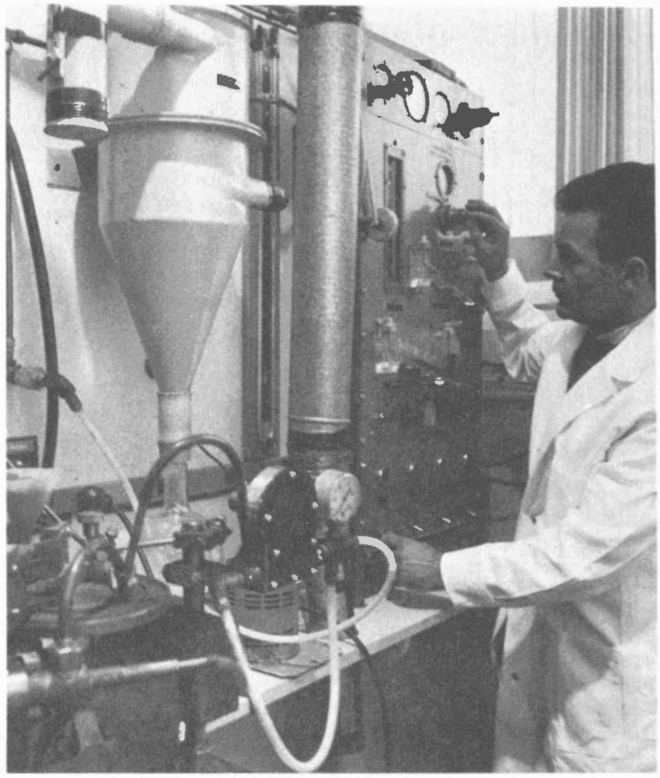
The Mines Branch mining research program was inspired by the aim of contributing to the improvement of safety and health of mine personnel. The "rock pressure" project started in 1950 had the essential overtone of preventing injury or death from the effect of sudden relief of stress, though the economic factor was also important. This was followed by establishment of the Certification Laboratory for preventing explosions from electric sources in coal mines and hazardous locations in 1954, explosibility tests for coal and sulphide dusts in 1957, explosives research in 1959, and finally a dust project was initiated in 1958 following a discussion with the Department of National Health and Welfare which had responsibility for occupational health including pollution across Canada. Conscious of the provincial responsibility in safety and health, the scope of the project was limited to a scientific appraisal of the characteristics of various dusts encountered in Canadian mines and of sampling instrumentation. Greater emphasis was placed on hard rock mines than on coal mines, as mostly thick coal seams were mined underground in Canada and thinner seams were mined in Europe where more rock work was done. A dust aspirator was used for collecting airborne samples to determine the size distribution of rock dusts. This sampling campaign was used for collecting coal dusts for explosibility tests, the latter being examined in the Solid Fuels Analysis Laboratory as mentioned in the section on fuels.

The United States Bureau of Mines was very helpful in assisting the Mines Branch in this new field. Richards spent several months in 1961 at the Bureau's dust laboratory in Pittsburgh. The project became the responsibility of Cochrane, who in 1963 visited seven dust research centres in Europe. He found Germany most advanced in the use of an optical instrument, the Tyndallascope: "Dust research in West Germany" by T.S. Cochrane, (CIM Bull, pp 719-728, July 1964).

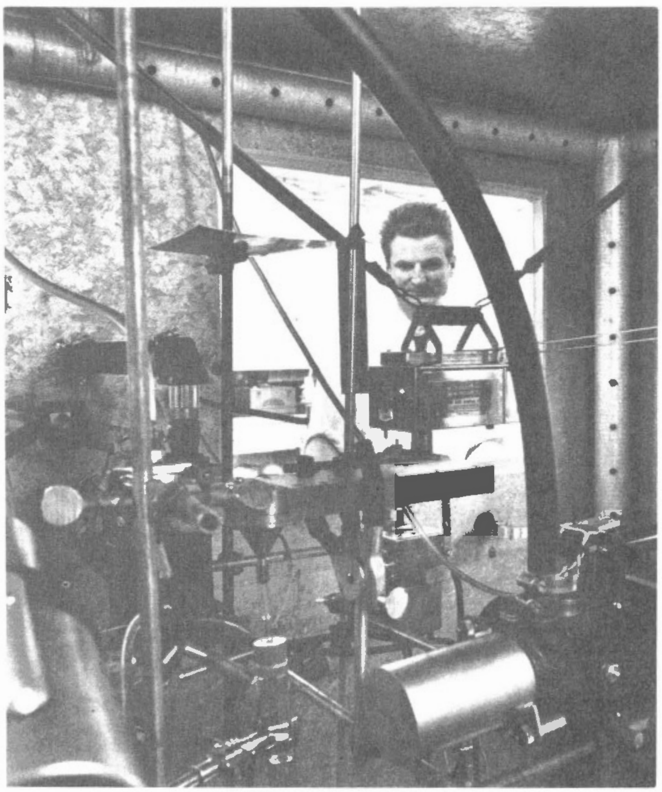
Bulk dust samples were prepared using the dust classifier and preliminary tests were made with a midget impinger. A dust chamber was completed in 1963 and several instruments were tested for their efficacy in evaluating mine dusts; these were - the midget impinger, the tyndallascope, the electrostatic precipitator, the konimeter in general use in Canada, and a specially mounted filter paper unit. Means for simultaneous sampling by various instruments were developed. In this connection, G. Grassmück with wide experience of mining in several countries, who was technical head of the Quebec Metal Mines Accident Prevention Association and later professor at the Ecole Polytechnique in Montreal, showed considerable interest in this instrument comparison research. Initial tests with the midget impinger and the Tyndallascope in the dust chamber were made from seven field samples from underground operations in Quebec.

The dust chamber was reinstalled in 1965 at the Elliot Lake Laboratory, and G. Knight (1965-) with previous experience in dust research with the National Coal Board in the U.K., was appointed officer-in-charge of the laboratory. The added facilities of the recommissioned dust chamber were described in four reports of the Mining Research Laboratories (DR FMP 67-41, DR FMP 67-44, IR MR 68-22 and IR MR 68-34). The research was directed to the evaluation of dust clouds in terms of specific parameters such as size distribution, particle density and shape, and composition using conventional and special instruments. Knight wrote 16 internal reports on this project entitled "Comparison of dust sampling instruments". Unfortunately, the correlation between the various types of instruments was unsatisfactory and this inhibited progress of research on physiological aspects of mine dusts. This phase of the work was summarized in a research report: "Comparison of dust sampling instruments" by T.S. Cochrane, G. Knight, G.C. Richards and W. Stefanich (1965 -) (MB RR 250, 1972). The "state of the art" related to dust measurements and standards in North America and overseas was reviewed by Cochrane, who had maintained the close contacts he established in the early sixties: "Routine dust measurements and standards" by T.S. Cochrane (CIM Bull, pp 46-50, Jan. 1972).

Long-term research in the United Kingdom, mostly at the Safety in Mines Research Establishment, indicated by the late sixties that the total amount of dust inhaled rather than the peak concentration during a shift was the more likely cause of pneumoconiosis, and this led to the development of the personal sampling unit known as SIMPED (Safety in Mines Personal Dust Sampler). Development work was undertaken at Elliot Lake to adapt this instrument for use in Canadian metal mines. For identification the instrument was named CAMPEDS for Canadian Mining Personal Dust Sampler. The sampling head was incorporated with the cap battery instead of with the cap lamp as in the United Kingdom; a smaller dust size selector and filter holder was used. The combustible portion of the sample was assessed after incineration, whereas the quartz component was assessed by an X-ray diffractometer. Gray and C.M. Mitchell of the Physical Metallurgy Division, as physicists, assisted the Elliot Lake group with the X-ray work as did also Dr. J. Leroux of the Department of National Health and Welfare, and an NRC Fellow, Dr. Machacek: "Gravimetric dust sampling with quartz analysis and its use in metal and mineral mines" by G. Knight and T.S. Cochrane (Proc International Mine Ventilation Congress, Johannesburg, S.A., pp 407-414, Sept. 1975), also Report DR MR 74-131 (same title) by G. Knight and T.S. Cochrane. A manual describing the operation and maintenance of the CAMPEDS Mark II unit was drafted by Knight (DR MR 75/31, 1975). At this writing this development has a high expectation for successful application in mine air dust measurement as applied to physiological needs.



W. Stefanich adjusts dust feed in chamber (Photo - George Hunter)



G. Knight checks dust sampling instruments fitted inside dust chamber during a run (Photo - George Hunter)

In 1971 the McIntyre Research Foundation in cooperation with the Accident Prevention Association of Ontario sponsored research on "testing of respirable dust sampling techniques for use in Ontario mines". R. Kowalchuk of the Foundation carried out the experimental work under Knight's guidance, assisted from time to time by students. R. Yourt, consulting engineer, represented the Association. Six internal reports were written on this project including two on personal samplers. Two papers were presented: "Full shift assessment of respirable dust exposure" by G. Knight, T.E. Newkirk and G.R. Yourt, (CIM Bull, pp 61-72, April 1974) and "Development of a dust sampling system for hard rock mines based on gravimetric and quartz (by X-ray diffraction) assessment" by G. Knight, R. Kowalchuck and R. Yourt (American Industrial Hygiene Association Journal, vol 35, No. 11, pp 671-680, Nov. 1974)

Emanation of Radon Gas

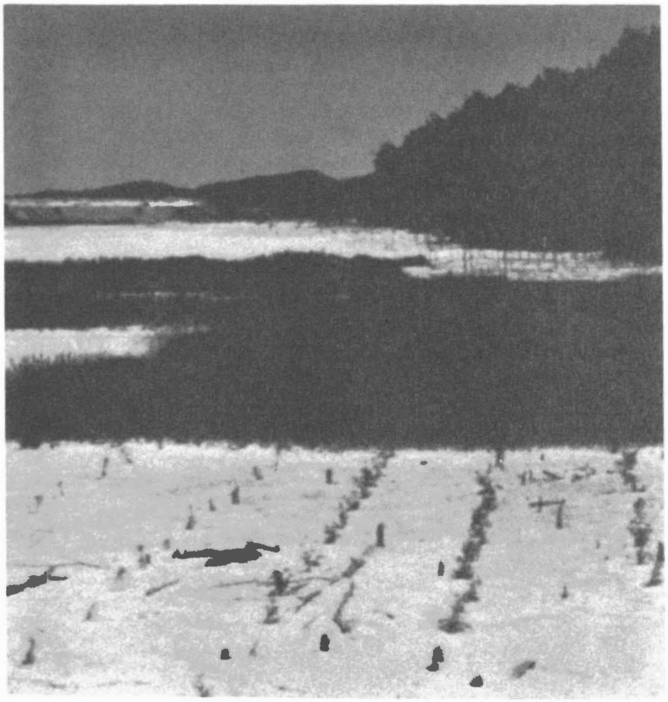
Another environmental hazard encountered in the uranium mines was the emanation of and adsorption on dust particles of radon gas. Dr. R.A. Washington (1968 -), who joined the Mined Branch in 1968 from the AECB, was engaged for several years in research started by Knight on methods to remove this undesirable impurity from the ventilation circuit in a mine by various filtration systems. One such proposed system involved the use of vermiculite at the Denison mine with flow rates up to 10,000 cubic ft per minute: "The use of vermiculite to control dust and radon daughters in underground mine air" by R.A. Washington, W. Chi (1970 - 1972) and R.T. Regan (1969 -). (CIM Bull, pp 152-160, March 1973) A résumé was made in 1974 by Washington of the hazards, measurement and control methods for radon and its daughters in Canadian uranium mines (MR IR 74-26).

Noise

One of the environmental factors of concern to the mining industry was noise levels. A project was started in 1973 by M. Savich (1972 -) who designed a chamber as "echo-less": "Development of an anechoic chamber" by M. Savich (Reprinted in English RS 130, 1974, from Mining and Metallurgy Bulletin, No. 1-2, pp 65-81, Ljubliana, Yugoslavia, 1973). Medium and light percussive rock drills were investigated and it was found that the noise was generated in the following manner - at frequencies below 125 Hz by the impact between the piston and drill steel; at between 125 and 2000 Hz by the exhaustion of air from exhaust ports, and above 2000 Hz by the impact between the piston and drill steel and between the drill steel and the rock: "Production, characteristics and abatement of noise from light and medium rock drills" by Miron U. Savich (CIM Bull, pp 66-79, Nov. 1974).

Mine Waste

The surface environment in regard to safety and ecology was not overlooked. The CACRM formed in 1968 a sub-committee to review the requirements for improved practices with respect to waste embankments. The Mines Branch commissioned three consultant groups which prepared a report which was reviewed by four engineers and then published: "Tentative design guide for mine waste embankments in Canada (MB TB 145, 1972). In 1972 D.R. Murray was appointed as an ecologist to undertake studies on vegetation of embankments, worked-out open pit sites, etc. He published an information circular for general information on the subject: "Vegetation of mine waste embankments in Canada" (MB IC 301, 1973).



Grass grown on base tailings with addition of lime and fertilizer, Elliot Lake, Ontario

Two geologists employed in the Mining Research Program: Above - H.U. Bielenstein; Below - G. Herget

Electrical Equipment Certification (Canadian Explosive Atmospheres Laboratory)

This project originated from a resolution adopted at the Third Ministers of Mines Conference in Winnipeg in 1946, stating in relation to testing of electrical equipment for coal mines: "The Ministers of Mines Conference has approved of the Canadian Standards Association under the National Research Council setting up the necessary method by which electrical equipment for use in coal mines and atmospheres containing inflammable matter shall be tested in Canada". This proposal was eventually transferred to the Bureau of Mines which was cognizant of the international certification practice, and the department agreed to proceed in setting up such a service. At the Second Dominion-Provincial Coal Research Conference in 1950, Resolution 10 stated: "To express great satisfaction that an electric mine equipment testing station is being set up by the federal government. This is considered as a vital step in the traditional service of the Federal Department of Mines to the Canadian coal industry. The delegates would urge the Provincial Ministers of Mines their utmost support to the continued development of this project". This resolution was included in Exhibit IV along with Resolutions 5 and 6 on mining research in Dr. Howland's report of the Standing Committee on Coal, which was adopted at the Seventh Ministers of Mines Conference at Victoria, B.C., in 1950.

There was a suggestion at first to recruit from abroad a person with the relevant experience in the new field for Canada. However, a wise decision was made by selecting G.K. Brown, who had joined the Maintenance Section of the Mines Branch in 1948 as electrical engineer after demobilization from the R.C.N. and completing his university studies. This appointment required the attributes not only of competence but of special responsibility to prevent the risk of explosions which might be lethal to a large number of humans. It is to the credit of Brown and his associates that no accident involving equipment certified by him occurred during 21 years of service as head of the laboratory.

In 1953, Brown made a thorough study of facilities and methods at the USBM in Pittsburgh, the Underwriters Laboratories in Chicago, the Safety in Mines Research Establishment in Buxton and Sheffield in England, CERCHAR at Creil near Paris, France, and the research centres at Dortmund, West Germany and the Dutch State Mines at Heerlen, Holland. Brown maintained close relationships with these establishments throughout his career. Close contact was also established with the Canadian Standards Association (CSA) administration and testing laboratory and with the provincial electrical inspectors who were responsible for permitting the use of electrical equipment in mines. Most of the industrial equipment destined for use in hazardous locations was tested for the CSA at the Mines Branch laboratory. The CSA continued to exercise authority for inspection of all electrical equipment related to their standards.

Electrical Certification Laboratory (554 Booth St.) 1954, on site of old machine shop; new machine shop (556 Booth St.) is at left rear; Butler building for carbonization studies is in middle rear

In 1954, the old timber one-story building which previously housed the workshops at 554 Booth Street became the site for the laboratory. Mel Ralph (1941 -), who saw service in the RCAF, was transferred from the Physical Metallurgy Division in that year to assist Brown as technician in the equipping and commissioning of the laboratory. He was diligent and loyal in his work in the laboratory as well as in the field. Meticulous inspection and checking of dimensions had to be carried out with electrical gear submitted for certification.

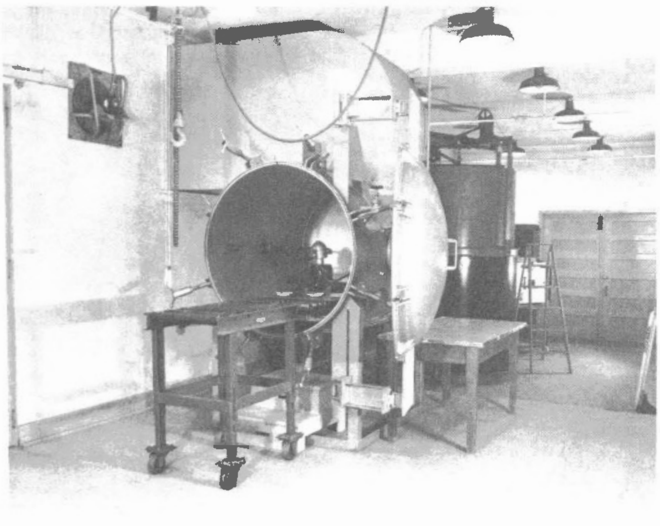
Brown was appointed Federal Certification Officer in August 1954, and was given sole authority for certification. Certified equipment carried a plate with

G.K. Brown

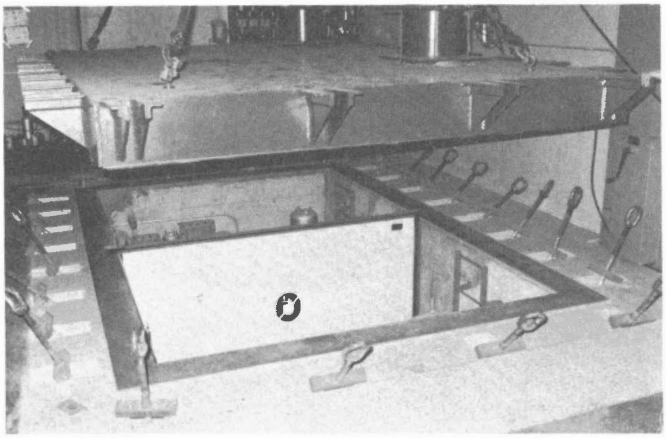
M. Ralph

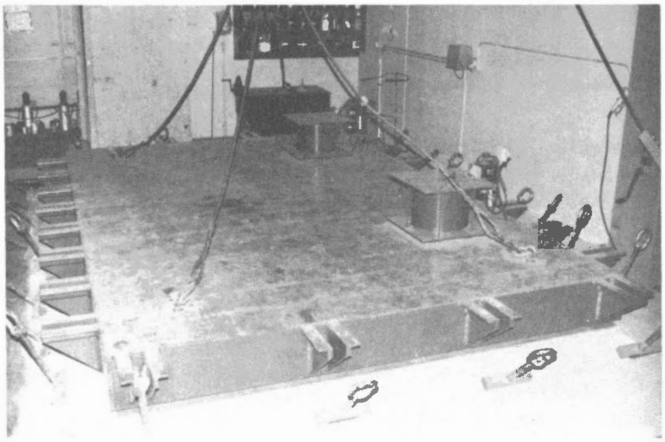
the number of the certificate and departmental identification. Two principal categories of electrical equipment were involved, the first being known as "flameproof" included electric appliances, switch gear, etc., capable of producing flashes which could ignite an air-gas mixture unless they were cladded or enclosed in a prescribed manner to prevent flame from an explosion of entrapped gas within the enclosure to issue into the surrounding atmosphere. Replicate explosion tests were carried out on a flameproof unit or on a complete assembly in the test chamber, and both were filled with an explosive gas-air mixture. Any ignition of the external air-gas mixture resulted in the disqualification of the equipment. Because of the proximity to other buildings and to the traffic on Booth Street itself, the largest chamber with a capacity of about 70 cubic ft of explosive gas was equipped with four spring-loaded metal covers and not a paper diaphragm which was international practice. This was to muffle the noise from an explosion of the main body of gas in the chamber. Later, to deal with larger equipment assemblies, a pit of larger capacity was excavated outside the laboratory. An even larger 2-chamber pit is currently used at Bells Corners in a separate building with blowout panels. The strength of enclosures was tested when necessary by a dynamic test with gun cotton - one such enclosure fabricated from light metal alloy failed, and though the laboratory was damaged, no one was injured because of the use of a wire mesh curtain. Brown and his associates were imbued with the same degree of safety consciousness as the staff of the whole division in all their potentially hazardous operations. Special equipment was used for the tests such as a gas holder, and gas pressure, analytical and photographic apparatus.

The second category of equipment was termed "intrinsically safe" and included telephones, signalling apparatus, and instrumentation such as used by the mining research section in coal mines, which not only the department but the provincial inspectors required to be certified by Brown prior to underground use. The safety of this class depends on characteristics of occurrence such as inductance, capacitance, voltage,



Explosion test chamber and gas holder, both 70 cu ft capacity at 554 Booth St.



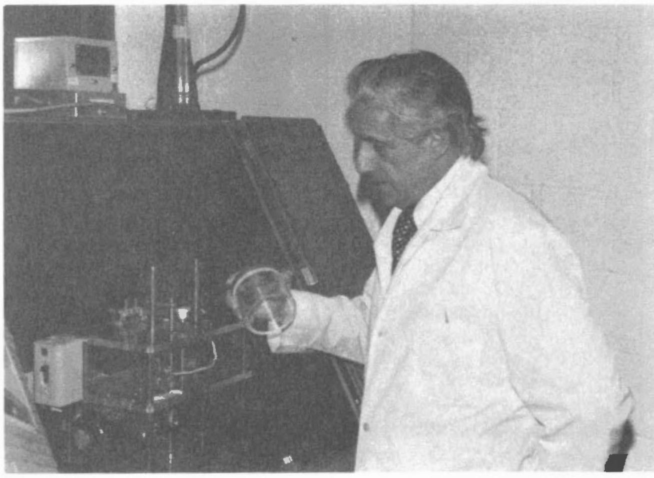


CEAL explosion test pit at Bells Corners for large electrical operations, open and with cover in position

amperage and resistance. A fast break-flash apparatus capable of producing 34 sparks per minute was constructed in accordance with U.K. specifications. The test was self-contained with its own small chamber and auxiliary apparatus.

Until 1956 Brown and Ralph were the only staff allotted to this laboratory though the versatile Richards was loaned for a period. Cooperation provided by the Maintenance Section enabled the laboratory to be functional in 1955. A memorandum was issued outlining the certification procedures which included not only testing but a meticulous examination of detailed shop drawings comparing the measurements with those of the item submitted for test. This was a laborious and highly responsible operation in the certification procedure. Where other national laboratories insisted on testing complete assemblies because of adaptations, particularly in electrics, the Canadian laboratory accepted components for tests in Ottawa with inspection and checking at the suppliers' factories or at the mines: "Certification of flameproof electrical apparatus for underground use in coal mines (Certification Memorandum No. 1)" by G.K. Brown (FRL Report 208, 1955).

The CSA testing laboratories moved to Toronto and was a principal client in requests for tests in an



S. Silver observing operation of device to assess intrinsical safety of electrical equipment

explosive gas atmosphere electrical apparatus of Class 1, Group D and Class 1, Group C. This was the period when the International Electrotechnical Commission (IEC), which was affiliated with the International Standards Organization, was formulating standards. It was decided to use the recommendations of IEC, and the specifications when necessary of the U.K. and U.S.A. in the certification work. Brown was invited to join the Canadian National Committee (CNC) of the IEC and the chairmanship of the CNC of the IEC TC 31 "Electrical Apparatus for Explosive Gas Atmospheres". Brown's attitude and judgement were respected by his foreign colleagues, who were eager to have an international meeting of the committee in Canada, and this took place in 1966. Brown was also a member of the CSA Committee on the Canadian Electric Code and Safety Code for Hospital Hazards.

To inform the coal mining industry of the facilities then available, Brown published a paper "Official certification of electric equipment lessens explosion hazard" by G.K. Brown (Can Min Journal, pp 64-66, Aug. 1956).

In 1956, S. Silver joined the section, followed by E.D. Dainty in 1960. Not until 1966 was another technician, A. D'Aoust, made available to the laboratory.

E.D. Dainty

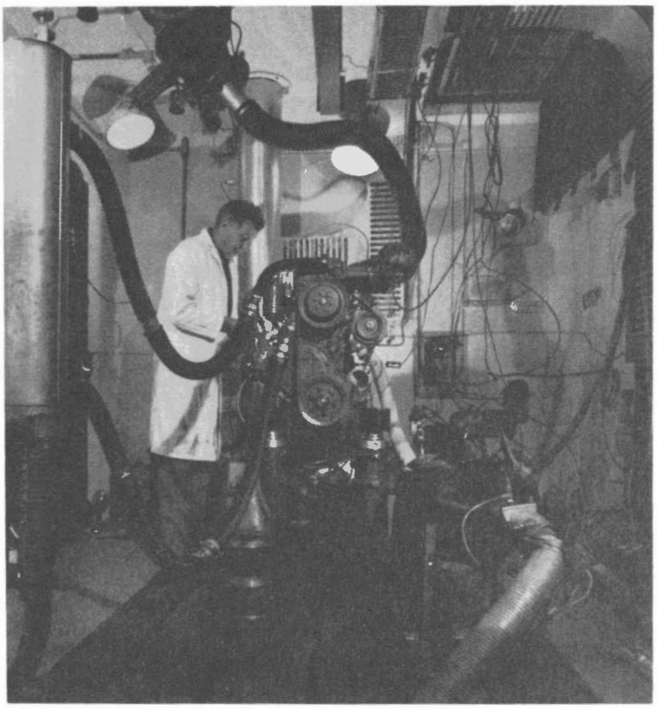
In 1957, as the result of fires usually arising from idling belt conveyors in mines, requests were made from industry to establish certification tests which consisted of a flame test and a drum friction test: "Certification of fire resistant conveyor belting for the mines (Certification Memorandum No. 2)" by G.K. Brown (FRL Report 269, 1957).

The scope of investigations arising from requests increased rapidly and equipment had to be designed and either acquired or constructed; these included the testing of electric cables, electric cap and flame lamps, methanometers and other instruments, and diesel engines in respect of electrics and exhausts. The latter had to be carried out at the manufacturers' works until a diesel facility was developed in the new laboratory at Bells Corners. A list of certified equipment was issued periodically; three successive editions were published in 1961, 1964 and 1968: "List of certified electrical apparatus, certified fire-resistant conveyor belting and certified diesel engines for coal mine use" by G.K Brown (MB IC 203, 1968 3rd edition, Certification List No. 3, 1968, superseding MB IC 131, 1961, and IC 163 1964).

In 1958 Brown assisted Dr. Montgomery who was requested by the Department of Justice to represent the Attorney General's office in a technical investigation of a natural gas explosion in the basement of an Ottawa downtown building which was destroyed.

Research had to be fitted into a busy schedule of the wide range of test work. The forum for reporting research was the periodic conferences by invitation of the directors of safety in mines research establishments in existence in most of the large underground coal producing countries. The Mines Branch was invited to these conferences and made contributions. Thus, a study was reported on the design of flame arrestors and on the transmission through short cylindrical channels: "An investigation of gas explosion transmission through short cylindrical channels of varying length and diameter" by E.D. Dainty and G.K. Brown (Proceedings of the 11th Restricted International Conference of Directors of Safety in Mines Research, Sheffield, England, 1965, and Reprint MB RS 2). As indicated earlier, the principle of flameproof protection is based on the acceptance of the concept of diffusion of gas into a flameproof enclosure, also on the prevention of any such gas exploding in the enclosure transmitting flame to the external gas atmosphere. Thus, a study was conducted on the rates of diffusion into flameproof enclosures: "Diffusion of external methane atmospheres through gaps of various sizes and widths into enclosures of different volumes, and the effect of greased joints" by E.D. Dainty and G.K. Brown (Proceedings of the 12th International Conference of Mine-Safety Research Establishments, Dortmund, West Germany, 1967, and MB RS 54, 1967). Considerable research was undertaken in the early period by Brown and Silver of the most ignitable ranges of various gases and vapours including those used in hospitals, and particularly of hydrogen in the light of its importance in the hydrocarbon research of the division: "Laboratory investigations of hydrogen explosion phenomena relating to electrical apparatus" by G.K. Brown, E.D. Dainty and S. Silver (MB RR 182, 1966).

Because of this laboratory's unique position in certification and research in the gas explosion field, it was named in 1966 the Canadian Explosive Atmospheres Laboratory (CEAL). Aside from certification and research, this laboratory had to deal with numerous inquiries requiring authoritative advice to manufacturers on design details and to government agencies on hazards related to the accumulation of explosive gas mixtures, e.g., in ships' holds. The performance of this laboratory which was staffed initially with two men, increasing in a period of over 10 years only to five, including Pierette Guibord, secretary, is worthy of special mention. An historical record of the laboratory from 1954 to 1958, with a supplement from 1958 to 1962, was prepared by Brown: "Electric Equipment Certification Section" TM 96/58 and Supplement No. 1, IR FMP 63/9.



E. Jones in diesel testing laboratory at Bells Corners (Photo - George Hunter)

The laboratory was transferred in 1969 to Building No. 9 in the Bells Corners complex, which was a part of the Fuels Research Centre formed in 1967. An important addition was made by the development of a comprehensive diesel testing laboratory known as the Combustion Engine Emissions Investigating Facility (CEEIF). Mogan was transferred in 1970 to the laboratory to assist Dainty, who became officer-in-charge of the diesel testing facility. Brown issued a Certification Memorandum on diesels in 1971: "Certification of diesel apparatus for use in mines", Certification Memorandum No. 3, (DR 71/8).

For coal mines, dual tests had to be carried out for safety in the presence of explosive gas and emissions which could be toxic to the mine environment; in non-coal mines the latter was the principal concern. Research determined that a high proportion of diesel smoke contained particulates of respirable size, this together with gaseous emissions of a toxic character became the subject of on-going research: "Some characteristics of particulate emissions in diesel exhaust" by D.B. Stewart (1974 -), P. Mogan and E.D. Dainty (CIM Bull, vol 68, pp 62-69, April 1975).

E.D. Dainty and P. Mogan in diesel bunker with engine under test

The International Electrotechnical Commission selected Canada in 1966 for the meetings of TC31 (Use in Explosive Gas Atmospheres) and SC31A (Explosion Proof Enclosures) held in Camsell Hall attesting to the international recognition of the laboratory attained in a short span of a few years since its inception. G.K. Brown second from left

A. Bossert, left at Building 9 succeeded G.K. Brown at right as Head of CEAL in 1975. Bossert was senior officer of CSA testing laboratories which had a long association with the laboratory

Explosives Research Section (Canadian Explosives Research Laboratory)

The historic association of the Mines Branch with the Canadian Explosives Act and with explosives testing described in Chapters 2, 3 and 5 was renewed by the transfer of the Explosives Laboratory to the jurisdiction of the Mines Branch (Fuels and Mining Practice Division) on April 1, 1959. The explosives industry, manufacturing about 20 million pounds in 1919, the year of promulgation of the Explosives Act, had increased the production of Canadian explosives to about 200 million pounds in 1959, and this figure was doubled to 400 million pounds by 1975.

The transfer largely arose from the desire by Dr. van Steenburgh to provide a "research atmosphere" for the laboratory which existed in isolation following the busy wartime period at the NRC under the auspices of the Associate Committee on Explosives.

In 1952, the Department of Public Works built for the Department of Mines and Technical Surveys the laboratory on Riverside Road near Uplands Airport, and this was occupied until the explosives group moved again in 1968 to a self-contained area in the Bells Corners complex: Buildings 11 to 16, with an additional mounded magazine, Building 17, added later.

It should be recalled that the Explosives Division was a component of the Bureau of Mines from the formation of the Department of Mines and Resources in 1936, becoming a headquarters unit in 1950 when the Department of Mines and Technical Surveys was formed. Staff changes took place at this time. In 1951, M.C. Fletcher, the chief chemist, retired and was replaced by D.A.B. Stevenson (1951 - 1967 deceased). N. Randall (1940 - 1950) also retired and was replaced by J.A. Darling (1951 -). C.B. Mohr retired in 1957, having served 34 years in the Fuels and Explosives Divisions. Ann Hardy, who joined the inspectorate of the Explosives Division in 1947, became secretary of the laboratory in 1949, retiring in 1969. No technicians were employed by the Explosives Laboratory until the appointment of P. Larsen (1958 -), a skilled gunsmith whose services were very useful because of the considerable mechanical work required. On the laboratory joining the Mines Branch in 1959, G.L. Morgan (1959 - 1965) was recruited. He was later replaced by W.D. Maddick (1967 -). The explosives area was a difficult one for recruitment because of the relatively limited nature of the industry.

The explosives inspectorate was provided with office space in the Mines Branch building at 555 Booth Street. W.P. Campbell, the chief inspector, retired in 1955 and was succeeded by H.P. Kimball, who retired in 1964. E.J. Fraser succeeded him and at this writing still occupies the position although the Explosives Division was elevated to branch status in 1975 and the offices were moved to the new departmental building at 580 Booth Street.

There was a definite undertaking that the administration of the Explosives Act was the first priority of the Explosives Research Laboratory as it had been in the previous period of association with the Mines Branch. Authorization tests for explosives, blasting caps, fireworks, etc., were of course the primary reason for the laboratory, but a large proportion of the staff's time was taken up in investigations of manufacturing, transportation, storage, and use problems related to blasting explosives and accessories. The annual number of samples submitted for authorization in "run of work" samples, ammunition, fireworks, etc., varied extensively, but on the average were in excess of 200 per annum. These investigations originated not only from the Inspectors of Explosives but from various government agencies such as the Departments of National Defence, Transport, and the Post Office, the police, and from manufacturers. The consulting role of the laboratory cannot be over-emphasized: opinions were based on the accumulated knowledge of explosives chemistry and continuing experimental investigations which space does not permit of reporting. The term "chemical advisors" used in the United Kingdom is appropriate in designating the role of the Canadian laboratory.

Explosion Research Laboratory, Uplands, 1953

D.A.B. Stevenson

Ann Hardy

P. Larsen determines the power rating of an explosive sample, 1968

H.P. Kimball, chief inspector of Explosives, 1956-64

The transfer of the Explosives Laboratory occurred at the time of the rapid introduction of ammonium nitrate (AN) explosives either in granular form sensitized with fuel oil (ANFO) or in slurry forms sensitized with chemical or metal additives. These were very popular as they were much cheaper than the nitroglycerine explosives. In 1957, AN explosives represented about 10% of the total high explosives used, whereas by 1964 the consumption increased to about 70%. Licences were issued by the chief inspector of Explosives for on-site manufacture of AN slurries in mobile units which pumped the material into the boreholes; this practice was particularly attractive to large open pit operations. In 1969 the AN blasting agents were designated as Class 2 explosives resulting in considerable reduction in transportation costs. Ammonium nitrate had of course been known as an important component of permissible or short flame explosives used in coal mines as mentioned in Chapter 3.

As these new explosives did not easily deflagrate and explode as did the nitroglycerine explosives, it was profitable to investigate the implied increase in their safety characteristics. Furthermore, as the Bichel gauge for evaluating the products of fumes from detonation could not be used it was decided to simulate the confined conditions of a borehole by using lead cylinders both for the fume test as well as for the velocity test. The fume results were reported by Darling: "Approximation of boreholes: fume classification" (IR FMP 61-85). The results were not conclusive and eventually the project was discontinued owing to the damage to the "thunder hut" in which these tests were carried out and these problems still remain to be definitively solved. A hazard associated with the pneumatic loading of ANFO into blastholes was investigated. It was found that humidity was required to prevent the generation of static electricity, and a Technical Bulletin was published for users' guidance: "Humidity and static electricity in pneumatic loading of blasting explosives" by J.A. Darling and D.A.B. Stevenson (MB TB 59, 1964).

A long-term investigation was undertaken related to the difficulty of correlating results between laboratories of impact sensitivity tests on explosives. The tests were carried out in the Rotter machine at the request of the Royal Canadian Navy: "Rotter machine impact test results (correlation of impact tests) by J.A. Darling and D.A.B. Stevenson (IR FMP 62/206). Samples of the same series were tested at the Canadian Arsenals at Valleyfield, the Naval Ordnance Laboratory at Washington and the Royal Armament R & D Establishment, Woolwich, U.K. In 1963, Darling attended the tripartite meeting in England when it was decided to continue the comparative tests. Two series of tests were carried out by Stevenson and Darling, the first using the Rotter machine and the second continuing impact and friction. This research was reported as the Canadian contribution in a publication by the Canadian Arsenals R & D Establishment on the sensitivity research (Canadian Section, Manual of Sensitiveness Tests, TTCP Panel, 0-2 (Explosives) Working Group on Sensitivity CARDE, 1967).

In addition to attending the tripartite meeting in 1963 referred to, Darling attended an OECD subcom-

J.A. Darling, E. Gardiner and W.D. Maddick evaluate a minature cannon for use during Centennial presentations in 1967 mittee meeting on "Unstable Substances" in Paris, where a cooperative research program was discussed and agreed upon. This was carried out by the laboratory and reported: "Examination of samples for the research group on unstable substances, OECD" by J.A. Darling and D.A.B. Stevenson (DR FMP 66/56). While in western Europe, Darling visited most of the central explosives laboratories and established contacts which exist at this writing. Darling issued a report for the guidance of government agencies: "Comparison of North American and European regulations for the transportation of dangerous goods", (DR FMP 64/14). In 1964, Stevenson attended an OECD meeting on the generation of static electricity; this was reported in DR FMP 64/149. Stevenson also visited the explosives research establishments; thus two of the senior officers of the laboratory became acquainted at first hand with test techniques and the philosophy of safety measures prevalent in Europe. Some of these could be applied to Canada in the general aim of optimizing explosives safety. An ammonium nitrate subcommittee of the International Group on Unstable Substances (IGUS) was formed in 1970 to study collectively the characteristics and limitations of these new classes of blasting agents. The definitions of and regulations on unstable or dangerous substances became the reponsibility of a UNESCO Committee on which Canada was represented by the chief inspector of Explosives, with J.A. Darling as his technical advisor.

During the summer of 1973, large-scale burning tests involving up to 10,000 lb were conducted by arrangement with the Defence Research Board Establishment, Suffield, Alberta, on an ANFO and two AN slurry explosives to determine whether larger loads of these blasting agents could be transported. The results were very encouraging, as no detonations occurred: "Burning trials of blasting agents" by J.A. Darling (CIM Bull vol 67, pp 101-104, July 1974). As a result of the trials, 40,000-lb loads of blasting agents were allowed in approved motor vehicles in Canada as of August 1973 by the chief inspector of Explosives.

"Critical limit" tests based on increased sensitivity engendered by using a larger diameter of cartridge and stronger detonator charges or boosters were carried out on ANFO prills at Cominco in British Columbia by R. Vandebeek with assistance from the company. The results were also successful: "Bulk tests of Canadian ammonium nitrate" by R.R. Vandebeek (MR IR 74/16).

The Canadian contribution in this area was appreciated by members of the AN subcommittee of IGUS who suggested a meeting in Ottawa which took place in February 1974. Later, Darling was elected to the chairmanship of the renamed Ammonium Nitrate and Ammonium Nitrate Mixed Subcommittee.

The Explosives Research Section, besides fulfilling its primary role under the Explosives Act, assisted in the explosives rock breakage project developed by Coates in 1964 and described briefly below. In 1967, Bruce Stevenson died suddenly and was succeeded by Darling as head of the section. Darling served in the RCAF during the war and also had experience with CIL

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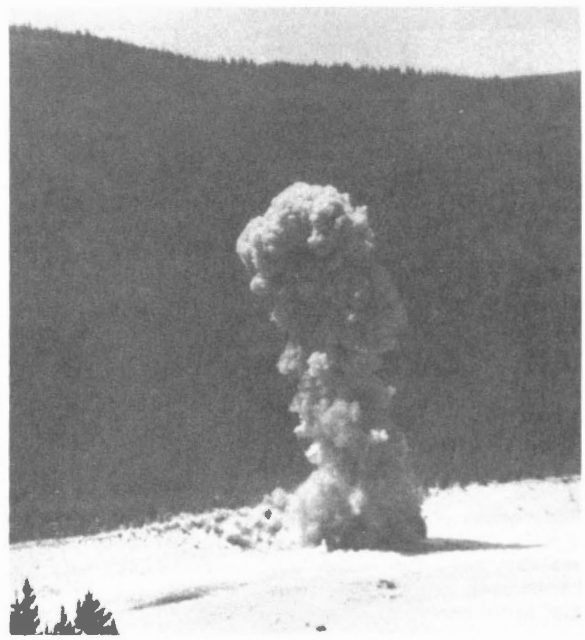

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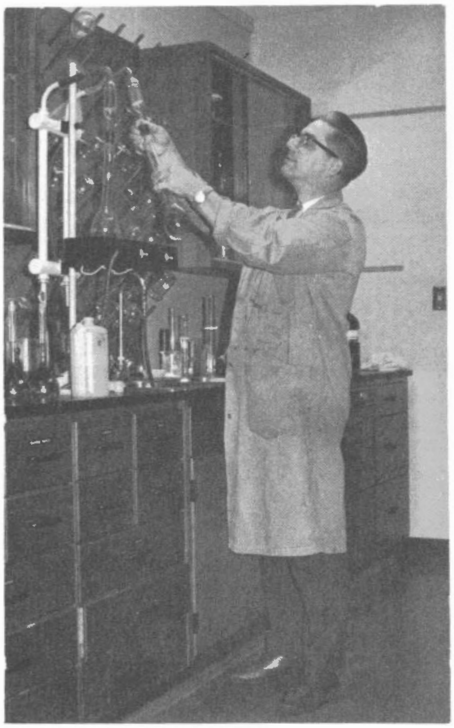
Mines Branch testing ammonium nitrate blasting agents: 1 - truck loaded with 10,000 lb ANFO for burning trial, Ralston, Alberta, 1973; 2 - truck after 17 minutes of fire (Photos - courtesy Defence Research Establishment, Suffield); 3 - shock sensitivity testing of 2,000 lb "Nitraprills" initiated by 10,000 grain P.E.T.N., Kimberly, B.C. (Photo - courtesy W. Russell, Cominco)

J.A. Darling



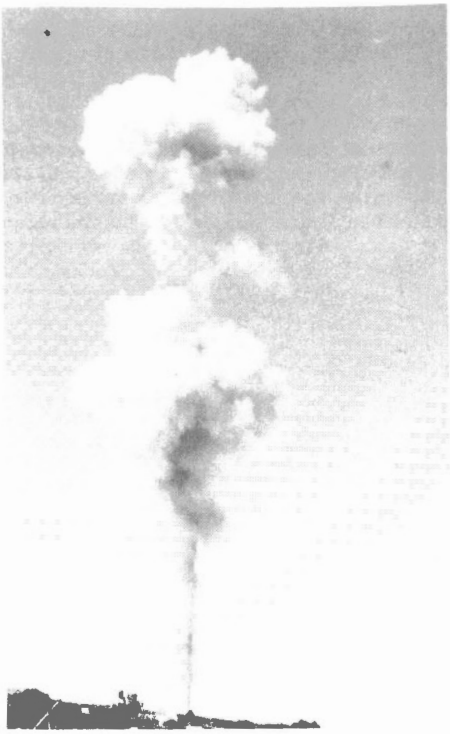
C.A. Vary makes chemical analysis of high explosives sample

before joining the department. Following Stevenson's death, A.E. Gardiner joined the section in 1967 from the Naval Branch of the Department of National Defence, retiring in 1971. C.A. Vary was transferred to the chemical laboratory in 1970 because of the increasing load. R.R. Vandebeek joined in 1970, Dr. K.K. Feng in 1971, and E. Contestabile in 1973. In 1966, the section was renamed Canadian Explosives Research Laboratory as the unique regulatory and research laboratory on blasting explosives in Canada and the following year joined the newly formed Mining Research Centre.

Rock Breakage Blasting Research

Before joining the Mines Branch in 1963, Coates had done a study for the Department of National Defence (DND) on the design of underground installations to resist nuclear blasts: "Rock mechanics applied to the design of underground installations to resist ground shock from nuclear blasts" by D.F. Coates (Proceedings of the 5th Symposium on Rock Mechanics, University of Minnesota, 1962, and MB RS 56, 1968). Almost immediately after joining, Coates proposed a blasting research project (DR FMP 64/37). The essential aim was to optimize explosive energy used in blasting and to develop an ability to predict stress distributions around a blast and the extent of fragmentation. He set up a group consisting of himself, Larocque, Dr. Sassa of Kyoto University (NRC Postdoctorate Fellow), Darling, Parsons and technical assistance from Kapeller, St. Louis and Larsen.

The initial research consisted of laboratory experiments using low and high velocity type gelatinous explosives in small-scale rock plate breakage tests. The properties of the rocks were measured, particularly the dynamic tensile strength which is important in delimiting the rock fragmentation area. Detonation pressures were computed and checked by experiment. Field studies were then conducted at the Iron Ore Company's Carol Lake mine with mine staff assistance. Two groups of experiments were carried out using accelerometers as well as a crater study. A computer program had been developed previously by Professor I. Ito and Dr. Sassa, both of Kyoto University, on "The stress distribution of an explosion of a confined spherical charge near a free face". This program was rewritten for Fortran II for use with the departmental computer. The field trials confirmed the computer simulation of the stress distributions and the boundaries of fragmentation: "The analysis of stress for prediction of crater boundaries" by K. Sassa, G.E. Larocque, D.F. Coates and J.A. Darling (MB RR 192, 1966).



Ground vibration studies at Carol Lake mine of Iron Ore Company of Canada

This method of stress analysis was extended to column charges and it was found in preliminary tests that 2-point simultaneous detonation was preferable to single-point bottom detonation if uniform peak stress along the length of a column charge was desired. This was reported in a paper which included much material of the research report previously mentioned that was given at the 4th Rock Mechanics Symposium in Ottawa in 1967: "Field blasting studies" by G.E. Larocque, K. Sassa, J.A. Darling and D.F. Coates (Proc 4th Canadian Rock Mechanics Symposium, Ottawa, 1967, pp 169-203, published by Mines Branch, 1967).

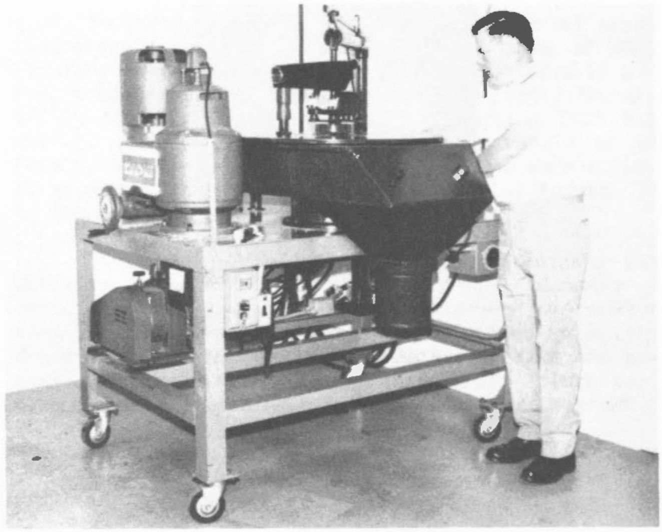
The CERL and Rock Mechanics Laboratories of the Mining Research Centre worked together for several years with the aim of developing improved blasting designs in open pit mining. A new computer code, Tonisok, was adapted from two U.S. previous codes for predicting stress distribution related to ultimate tensile-shear failure of rock from a detonating explosive charge. As previously, laboratory tests of properties and field trials were conducted. A model was developed which could predict rock mass behaviour resulting from detonating a column charge in a production blast. This led to the design of bench blasting patterns: "A proposed method of establishing bench blast patterns" by G.E. Larocque (IR MR 71/93).

Attention was paid to control blasting techniques such as pre-splitting and smooth wall blasting: "Comparative ground shock measurements for evaluating pre-splitting" by G.E. Larocque and D.F. Coates (The Western Miner, vol 45, pp 33-38, Dec. 1972). A paper was presented by Larocque reviewing the explosives research program at the Mines Branch: "Blasting research at the Mines Branch" by G.E. Larocque and R.F. Favreau (Consultant, CIL), (Proc 12th Symposium on Rock Mechanics, Univ. of Missouri, Rolla, pp 341-358, 1970).

Non-Explosive Rock Breakage

This project was started in 1966 as complementary to the explosive rock breakage project at the suggestion of the Mining Association of Canada. In light of the considerable success with continuous mining machines in coal mining and with mechanical moles, etc., in tunnelling sedimentary rocks, there was interest in the non-explosive rock breakage of the stronger ground encountered in hard rock mines with an eye to possible future bulk mining of low-grade ores at depth with continuous mining machines.

R. Tervo, a physicist, was appointed in 1966 at Elliot Lake Laboratory, and Geller was transferred in 1967 from the Combustion Laboratory to the Rock Mechanics Laboratory in Ottawa to undertake some fundamental work in this area. At Elliot Lake, research was conducted on two impact machines fabricated by the Technical Services Division on particles as small as 100 microns under partial vacuum and as large as 5 cm in diameter in air. One particle at a time of a closely sized fraction of rock particles was impacted by one or another of two steel plates mounted at opposite ends of a steel bar at the periphery of a steel disc (see illustration). The implication of this research was to establish the properties of rocks that govern the amount of energy required for breakage into specific size ranges in the hope that mathematical models could be developed using computer simulation to control and optimize performance. The research was done in the



R. Tervo with impact research apparatus for testing rock particle strength, 1967

M. Blais adjusts the rock impact apparatus constructed by the Technical Services Division (Photo - George Hunter)

context of the strengths of different rocks; a strength-size anomaly (strength increasing with particle size) was noticed: "Fracture characteristics of rock particles tested under impact" by K.D. Lyall (NRC PDF, 67-68) and R.O. Tervo (Proc 5th Canadian Rock Mechanics Symposium, University of Toronto, 1968, pp 171-183, published by Mines Branch, 1969). Some tests were later made to compare size distributions from ball milling with those from impact breakage, and they were found to be dissimilar.

In Ottawa, Geller reviewed the broad field of rock breakage from excavation to grinding, providing a reference list of 182 items, suggested that possibly the most fruitful route to explore for improved non-explosive breakage of rock would be to study superimposed fields of stress either mechanical hydraulic or mechanical/thermal: "Research in improved methods of rock breakage" by L.B. Geller (Transactions Section A, Institution of Mining and Metallurgy, London, vol 76, pp A-105/A-124, 1967). In the light of his earlier work on thermal treatment of rocks, Geller carried out a theoretical study of thermal shock (heating and quenching) which causes cracking of rock particles. He identified the parameters and presented the results in series of graphs, with all relationships expressed in dimensionless form. The spherical shape particle undergoes the severest thermal stress conditions of breakage and spheres are hardest to fracture by quenching. Thus the analysis for the spherical shape should embrace the breakage characteristics of other shapes: "Thermal stresses in spheres - a basis for studying the grinding of pre-heated rocks" by L.B. Geller (International Journal of Rock Mechanics and Mining Science, vol 9, pp 213-240, 1972).

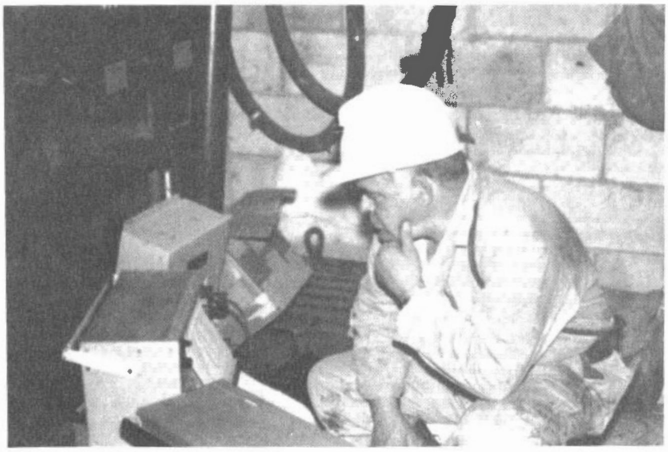
In 1968, Coates inaugurated a mine systems engineering program to examine individual operations such as drilling, blasting, transportation, etc., and analyzing their influence on mining economics with the aim of indicating possible optimization of the particular operation. As several projects under this program were concerned with non-explosive rock breakage, they are included in this section of the narrative. One such project examined long blasthole mining which accounted for about half the stoping costs and was in wide use in Canada involving the drilling of about six million feet of hole annually. Some office studies were made of data from operating companies but it was decided to carry out a field study at the Nordic mine using a ring drilling borehole layout on an arc of 180°, thus providing data from holes at different inclinations. Equations were derived for establishing drilling efficiency: "Studies of long hole drilling" by A. Dubnie and M. Gyenge (Can Min Journal, vol 93, Dec. 1972).

In 1970, the Mines Branch established a Tunnelling Office with an Advisory Panel under the chairmanship of Dr. W.R. Horn, Research Coordinator of the Mining Association of Canada. A project arose from the interest in the U.S.A. by the National Engineering Academy and National Research Council Rapid Excavation Committee, and in Europe through OECD, for pooling technology of rapid excavation in urban and other civil engineering as well as mining applications. Though advanced technology in classical excavation in drilling and blasting was not excluded in this project, the emphasis was on novel, mechanical and thermal methods of excavation. T.W. Verity, who had joined the Mines Branch in 1967, was officer in charge of this project. He attended a second symposium on rapid excavation in Sacramento, California, in 1969 (IR MR 69/94), and the OECD Advisory Conference on Tunnelling in Washington in 1970 (IR MR 70/69). Verity published a review on tunnel machines in Canada: "The operation of mechanical tunnel-boring machines in Canada" by T.W. Verity, (MB IC 256, 1971). Following Verity's return to the Mineral Resources Branch in 1971, Geller was placed in charge of the project and he issued several "awareness" reports under the Tunnelling Office auspices, providing information on developments in tunnelling in Canada and abroad.

Another project under the mine systems engineering program of non-explosive rock breakage was undertaken in 1971 on the automation of raise borers as representative of continuous mining machines of the mechanical mole type. The initial research was done on a laboratory drill press with remote controlled features and the recording of variables such as rate of rock penetration, speed of the drill, etc. The control hardware was designed jointly by the Mining Research Centre and the Ecole Polytechnique Electrical Engineering Department. With the cooperation of INCO, the research was scaled up to a raise borer in actual mine operation; a specially designed data logging unit was used preceding the development of automatic control equipment, some of which was developed before the project was discontinued in 1975.

Dr. M.D. Everell joined the Mines Branch in 1970 following his graduation at the doctoral level from Ecole Polytechnique that year. It is pertinent to mention that he joined Sirois of the Mineral Processing Division and Professor D.E. Gill of Ecole Polytechnique in presenting a paper to the 6th Rock Mechanics Symposium held at Ecole Polytechnique in 1970: "Relation of grinding selection functions to physicomechanical properties of rocks" by M.D. Everell, D.E. Gill and

L.B. Geller at extreme right seen with his wife and Dr. and Mrs. Gray at Dr. Gray's retirement in 1977



H. Poliquin monitors a raise borer

L.L. Sirois (Proc 6th Canadian Rock Mechanics Symposium, University of Montreal, 1970, pp 177-193, published by Mines Branch, 1971). Everell first worked at Elliot Lake, but in 1973 by arrangement with Laval University a "rock fracture" group with Everell in charge was located at the university. However, it was discontinued in 1975 because of loss of staff and relative costliness of developing mine equipment. In 1973, research on automating a laboratory diamond drill was undertaken at the Laval laboratory by applying an analog computer to the control strategy. "A preliminary control strategy for the automatic control of an instrumented diamond drill" by M.D. Everell, M. Dessureault, A. Cauchon and R. Tervo (6th Conference on Drilling and Rock Mechanics, Society of Petroleum Engineers of AIME, Special paper 4235, Austin, Texas, January 1973). Contracts in the amount of nearly $150,000 were awarded for external research, which included studies of hole deviation, sample recovery and the development of a prototype carrier for a lightweight drill.

Dr. Everell and A. Dubnie published jointly an Information Circular in 1974: "Mechanical boring of tunnels and raises" by M.D. Everell and A. Dubnie (MB IC 304, 1974).

Mineral Resources Division

As mentioned in Chapter 5, the reconstitution of the Industrial Minerals Division in 1950, caused the Mineral Resources Division, enlarged in 1946 to include industrial minerals, to return to its principal role of economics but with a reduced responsibility in resource evaluation. The new Industrial Minerals Division had its own specialists and could perform this function, mainly related to non-metallics. Because of Monture's wartime contribution to the Allied cause by advising on mineral resources, he was later in constant demand as an advisor to various agencies such as the Department of Defence Production, United Nations, International Bank of Reconstruction and Development, Colombo Plan, etc. During Monture's absences, which were as long as several months at a time, E.S. Martindale, the senior engineer of the division, acted as chief until his retirement in 1953; he had had service in both the Bureau of Mines and in the Mines Branch from 1936 plus many years prior service in the Department of the Interior. Until his untimely death in 1956, McClelland succeeded Martindale as senior officer of the division, acting for Monture during the latter's absences. It will be recalled that McClelland, with 33 years of service in the branch and bureau, was a devoted assistant to Traill in the early period of hydrometallurgical research including processing of radioactive ores.

The organization of the Mineral Resources Division in its last six years with the Mines Branch comprised six sections:

Economics: This section was staffed with specific mineral specialists who from the early days of the Mines Branch provided detailed knowledge on the occurrence, economic feasibility of production and utilization of a given resource. This group was also responsible for the interpretation of legislation on taxation and other matters related to the mineral industries. In this period in particular, the section assisted the director-general of Scientific Services in the administration of the Emergency Gold Mining Assistance Act (EGMA). In the period under review, the section was limited to metals and hydrocarbons, as the Industrial Minerals Division noted earlier, had its own specialists, and coal and peat remained the responsibility of the Fuels Division.

Mineral Resources Inventory: This record, started by the Geological Survey in 1886, represented the government's archival material on past mining ventures and resource information, and was of course of inestimable value.

Statistics: This section dealt with interpretive studies of mineral statistics. It will be recalled from Chapter 4 that mineral statistics in general became the responsibility of the Dominion Bureau of Statistics in 1921.

Library and Research: The library was administered by the division from 1936 and continued until separation of the Mineral Resources Division in 1956.

Records and Files: This represented the material on past and current mineral investigations and correspondence from which the most pertinent material was extracted for the Mineral Resources Inventory.

Clerical and Stenographic: Besides its own requirements, this section functioned as a pool for the typing of some of the branch reports; some editing was also done by the technical staff of the division.

In 1951 the Organization and Methods Branch of the Civil Service Commission reviewed the function of the Mineral Resources Division and recommended transfer of the first three sections to headquarters of the department, which was eventually done in 1956. Incidentally, an organizational survey of the Mines Branch in 1965 by the Civil Service Commission, mentioned that the technical reasons for this change became obscured but there were probably several reasons for the decision. During the war and immediate post-war period, Parsons' main preoccupations were with physical metallurgy and uranium processing fields which were more scientific than economic in implication. The mineral resource-oriented divisions, such as Economics, Fuels, and Industrial Minerals, and the processing side of Metallic Minerals, supplied specialists to the war agencies that were concerned mostly with the supply aspects of prosecuting the war at the lowest cost to the nation. Hence, the Bureau of Mines delivered on the two fronts so to speak - both science and technology and economics.

After the war the scientific content of branch activities increased. On the other hand, administration of departments also increased, with the creation of executive positions such as directors-general and later assistant deputy ministers, whereas the position of directors of scientific branches diminished; after all, economics were closer to politics in decision-making than were science and technology. In the past, in the then smaller departments, the economic significance of scientific work was reported directly to the deputy minister and from him to the minister - some like Camsell (Chapter 4) found time for personal technical and economic inquiry and study.

The 1965 Civil Service Commission survey referred to above suggested the employment of economists for selecting and costing of research projects. Generally speaking, the Mines Branch engineers, many drawn from industry, were capable of evaluating the costs and benefits of projects. This subject was more informally treated under institutional funding than in program funding introduced in the late sixties. The discontinuance of R & D projects and programs was usually because the researcher in charge or his division concluded that the particular research on the mineral commodity concerned would no longer be practical or justified.

The history of the Mines Branch bears witness to the value of a well-informed resource specialist who could supply data on the geological, compositional or mineralogical data, maintain contact with any processing procedure at the branch and with the particular industry concerned, and finally provide information on the uses of the product. Cole, Ells and Spence were examples of such specialists in earlier times and, in the period under review, McClelland, Buck and Toombs were other such examples.

As noted earlier in the narrative, the decade of the fifties was a "boom" period for Canada's minerals except coal. It was probably the busiest period in Canadian history for prospectors and new mining enterprises. This was reflected in the number of oral and written enquiries and requests for publications directed to the division. Thus, written enquiries for several years averaged over 3,000 annually. The Mineral Resource Inventory was frequently consulted by prospectors; the inventory itself, which earlier comprised some 4,000 cards recording mineral properties which at one time or another had been under development, increased substantially after World War II. Thus, in the fiscal year 1952-53, 424 new entries were made. The division was responsible for the distribution of Mines Branch publications to the public, amounting in fiscal year 1954-55 alone to over 71,000 copies.

The division participated in the stimulus given by the government to the mineral industry through its taxation policy, granting exemptions or relief to new metalliferous mines and industrial mines working non-bedded deposits. In cooperation with the Geological Survey, the division was involved with tax concessions to companies drilling deep test oil wells. Again the division was concerned in evaluating claims from pipeline companies for accelerated depreciation in cases where reserves were likely to be exhausted in 15 years, and, as mentioned previously, it was involved in the administration of EGMA, which entailed mine inspection and data preparation for the head office of the department.

The fourth and fifth issues of "Mining Laws of Canada" were prepared during this period: the first of these was the last publication by Buisson, who had been responsible for all the previous issues starting in 1924: "The Mining Laws of Canada" 4th edition, by A. Buisson (MB Rep 828, 1950) and "Digest of the Mining Laws of Canada" by H.A. Graves and G.R.L. Potter (MB Rep 854, 1957).

Despite the small staff, the division managed to publish several resource reports. In the period 1950-56 R.J. Jones (1945 - 1956) authored a report on cobalt in the Mines Branch report series (No. 847), and McClelland prepared reports on copper (MS 113), tin (MS 125) and nickel (MS 130) in the Memorandum Series. McClelland also prepared reports on lead and antimony: "Notes on lead occurrences in Canada" (MS 99, 1948) and "Notes on antimony deposits and occurrences in Canada" (MS 108, 1950, reprinted 1955).

An Information Circular Series (MR 1 to 26 excluding 6) was published for free distribution between 1954 and 1957 on minerals of topical interest. A high proportion of these was written by two energetic engineers - W. Keith Buck and Ralph Toombs, who joined the branch in 1951 and 1952 respectively to positions vacated by Goodwin and Trevor through retirement. Buck reported on the iron ore industry for 1953, 1954 and 1955 (MR 2, 13 and 17) a special study on the Canadian iron ore industry and its relationship to the St. Lawrence Seaway (MR 5), and on developments in the titanium industry (MR 1, 14 and 18). Buck participated in the dialogue between the branch, industry and government during the prosecution of the Mines Branch titanium program. The 1956 reports on the iron ore industry and developments of the titanium industry were written by Janes, who transferred from Industrial Minerals to the Mineral Resources Division in 1956. Toombs reported on the petroleum industry during the same period of 1953 to 1955: (MR 4, 15 and 19) and on natural gas (MR 3, 16 and 20), and for 1956, he was co-author with R.A. Simpson who had transferred from the Industrial Minerals Division (MR 23 and 24). Toombs became head of the Fuels Section in the Mineral Resources headquarters unit.

In this series the other contributors were:

- R.J. Jones on zirconium (MR 7) and columbium and tantalum (MR 8)
- W.J. Beard (1954-1956) on cerium (MR 9), beryllium (MR 10) and germanium (MR 12)
- R.E. Neelands (1945-1957) indium (MR 11)
- T.H. Janes on rare or less common minerals (MR 21)
- T.W. Verity, assigned directly to the headquarters unit of Mineral Resources - "Survey of the gold mining industry in Canada during 1956 (MR 25)

The series continued in the Headquarters Division from MR 27 with a change of name to Mineral Information Bulletins.

In 1955 and 1956 the division was called upon for considerable data related to minerals including energy minerals, by the Royal Commission on Canada's Economic prospects. In this respect, Toombs was one of the main contributors. With separation of the division from the branch, Monture resigned in 1956. A promotional competition awarded the position of chief to Buck, who had demonstrated his competence and organizational potential in the five-year period of service with the Mines Branch.

Though independent in character, Dr. Monture had many good friends. He served a total of 33 years in the department, of which 16 were in the editorial division of which he was acting chief and chief for 6 years, and 17 years with the Bureau of Mines and Mines Branch. He was a recipient of many honours: for his war service he was awarded in 1946 the Order of the British Empire by the King, and in 1948 an honorary doctorate by the University of Western Ontario. On his retirement from the Mines Branch he was one of the first recipients of the Mines Branch "Oscar", a statuette of a beaver symbolizing the hard working Canadian. This was cast from metals of Canadian origin. The Oscar was established by Dr. John Convey a year or two earlier as a reward for distinguished service. In 1957, Monture was honoured by the Indian Council with the "Fire" medal and somewhat later made honorary chief and named "Big Feather" of the Six Nations of Grand River, a fitting tribute for a distinguished descendant of Chief Joseph Brant. In 1966 he received the Vanier Gold Medal by the Institute of Public Administration of Canada. "Slim" Monture, as he was known from the university days, continued an active career as a consultant both in Canada and abroad to within a few years of his death in 1973.

G. Monture (Photo - NFB)

Technical Services

The new workshops building at 556 Booth Street of the then Maintenance Section was completed in 1952, ending a period of 42 years of frugal housing in one-storey timber huts for this important adjunct of an engineering oriented establishment. Equipment was modernized and added to, thus in the main machine shop by the early sixties there were over 50 high-grade machines of the tool room type. The staff was doubled from about 40 in 1946 to approximately 80 in 1952, and this included several classified positions and a large proportion of prevailing rate tradesmen. S.J. Hayes (1941 - 1969) succeeded A.W. Mantle (1910 - 1939) as mechanical superintendent. G.K. Brown (1948 - 1975) was the electrical engineer and when he transferred to the Fuels Division in 1953 the position was filled by E.K. Swimmings (1953 -). In 1959 the Maintenance Section was elevated to divisional status, being renamed Technical Services. The old name of mechanical superintendent was replaced by chief of division. In 1961 a position of mechanical engineer was created and filled by D.M. Norman.

The division was organized into six sections, as outlined in the following list which includes the names of the principal officers and the shops:

Administration and Engineering
Chief - S.J. Hayes
Administration - H.W. Armstrong (1936 - 1972)
Design and Shop Drawings
General foreman - C.J. Fresque (1912 - 1960)

Electrical Section
Engineer - E.K. Swimmings
Electrician foreman - P. Ferrigan (1943 - 1969) succeeded by R.J. Binette
Electrical and instrument workshops

Responsible for electrical installation and maintenance

Mechanical Section
Engineer - D.M. Norman (1961 -)
Machine shop foreman - H.J. Brindamour (1941 - 1972) succeeded by R. Chauret (1961 -)
Mechanical foreman - W.G. Robertson (1953 - 1972) succeeded by M. Blais (1945 -)
Main machine shop with Tool Room quality control and (welding, blacksmith, and sheet metal shops

Responsible for fabrication of components, maintenance and assistance in installation

Carpentry Section
Foreman - M. Gadbois (1947 - 1972) succeeded by R.B. Huot (1955 -)

Transport and Trades Support Section
Foreman - L. Fleury (1953 - 1971) succeeded by M.M. Plosenski (1959 - 1974) succeeded by P.E. Gagnon (1965 -)

Stores and Procurement Section
Officer i/c - W.A. Martineau (1946 - 1970) succeeded by C. Law (1947 -)

All divisions benefited from services provided by the Technical Services Division, with the Physical Metallurgy Division making the major demand because of the manufacture of metallurgical test specimens. In 1962 this reached a peak of 27,300 pieces, accounting with that division's other requirements for nearly 50% of the work orders of the Technical Services Division. The remainder of the work in this division was connected with fabrication of various instruments, pilot plant components and assemblies, presenting a challenge for the skills of the division in dealing with the variety and contrasting scale of products for the wide spectrum of disciplines in the Mines Branch divisions. In addition, the Mechanical Section was responsible for the preparation of foundations for large machines,

Retirement of E.A. Swimmings and B. Smith, 1955; left to right - Dr. Convey, B. Smith, E.A. Swimmings, S.J. Hays

installation, alignment, etc. A preventive maintenance program similar to the earlier procedure already in place by the Electrical Section was put into practice.

The latter section was responsible for the electrical system of the department on Booth Street and later in the Bells Corners complex. It was also responsible for all of the electrics of the apparatus and pilot plants in the Booth Street area. A preventive system of inspection and maintenance has been practised from the early days. The small number of outages during the 25 years of considerable change and growth in the Booth Street area bespeaks of the conscientious attitude adopted by the section. During the fifties, when so much R & D and processing, including electric smelting of ores and melting of metals, was done at pilot-plant scale, the demand for electrical power was at its peak, reported in 1962 to be approximately 30,000 kVA of transformer capacity. By 1970 this levelled off to about 14,000 kVA for both Booth Street and Bells Corners installations. The largest user of electric power in the department was the Mines

Main machine workshop in the new building, 1952

Queen Julianna of the Netherlands examines a saw in the new workshops. Left to right: Dr. G.S. Hume, director-general of Scientific Services, Department of Mines and Technical Surveys; R.J. Traill, acting director, Mines Branch; J.J. Hayes, mechanical superintendent 1952; the Queen; H.F. Feaver, chief of Protocol for Canada (Courtesy of IBM Canada Ltd)

Branch, at about two thirds of the total power required for the department, amounting to 24 million kWh in 1971. In that year a modernization program was carried out on Booth Street by replacing the old distribution transformers with the grounded-neutral type which improved the safety of the 575-volt system. Incidentally, the hydro system voltage was increased from 11.6 kV to 12.4 kV and later to 13.2 kV. All this was done under the general supervision of Swimmings.

In addition to active participation in the planning, designing and construction steps of R & D projects in the branch, the division assisted in special development projects. Notably amongst these for several years was Dr. Wlodek's project of spiral rolled mine drill rods and attachments that included considerable fatigue testing.

The division's own R & D projects were concerned with innovation to increase the yield of manufactured articles, for example, abrasion machining of test specimens. A principal project was the machinability of various metals. A 6,000 rpm, 12 x 30-in. lathe equipped with a strain gauge tool post dynamometer and a 2-channel recording oscilloscope was used. An alternative known as the compact machinability testing method was developed wherein a pendulum device of known foot pounds of energy, a tool bit of standard dimensions, and a controlled cutting edge were used to produce chips of specific thickness, cut in three directions from standard flat samples. A record of average cutting energy and forces was obtained by means of a dynamometer mounted with strain gauges and automatic recording devices. The results by this method were correlated with data from the high-speed instrumented lathe. A variety of standard steel alloys as well as alloys with additions of sulphur, lead and selenium were investigated. This work was of interest to the steel industry which cooperated in this research. The pendulum device was later redesigned to bring the centre of gravity of the larger pendulum mass closer to the cutting edge of the tool bit. Some machinability tests were carried out for commercial companies at their request.

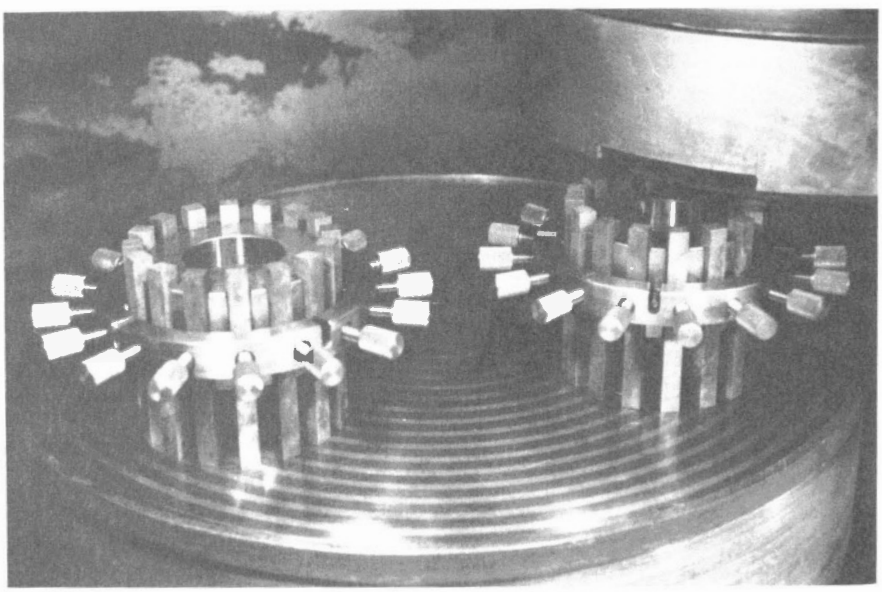
In the late sixties and early seventies the Mechanical Section facilities were expanded to include shearing, forming and rolling of ¼-in. mild steel

R. Beer, M. Séguin and S. Samson operating machinability research lathe with recording (x,y) instruments and tool post dynamometer

plate. The welding shop was also enlarged. Innovation was practised in the machine shop, for example in the use of the electrical discharge method (EDM), wherein a controlled electric arc erodes metal in the presence of a flowing dielectric liquid such as oil. The method was used for precision slotting and notching of metallurgical test specimens. The non-traditional methods such as electrochemical machining (ECM), laser beam machining and drilling, and ultrasonic machining were examined. In this connection, lectures and demonstrations to university students were provided.

Aside from providing electrical maintenance in the department, requests for special fabrications by other branches were handled by the division. The two recommendations in the 1962 report of the Royal (Glassco) Commission on Government Organization were concerned with central government purchasing and implementation of the make-or-buy policy. As Technical Services was probably assumed by the Treasury Board to be a self-contained supplier-client organization, the division was directed to establish an industrial costing system, which was undoubtedly beneficial from a cost accountancy viewpoint. However, integration of the division in the R & D projects of the branch at the development stage of apparatus and equipment was not fully appreciated. Many of the requirements from research scientists were explained orally or on a rough sketch, and this had to be translated into a design and a shop drawing.

A financial administrator, O. Hora (1966 - 1974) was appointed to develop the cost accounting system with the assistance of the senior officers of the division. The cost centres were based on the organization outlined earlier and were composed essentially of four producing centres representing direct costs of labour and material - mechanical (M-1 and M-2), electrical, and carpentry - and of three non-producing centres representing indirect labour and material costs - administration, central stores, and motor transport. About 75% of the division's personnel were employed in the producing centres and the investment in machines and equipment in these centres represented over 90% of the division's inventory of fixed assets. The Mechanical Section accounted for about half the personnel and three quarters of the division's inventory of assets. The cost control system indicated that over three quarters of the completed work required 24 man hours or less, which implied the high proportion of short-term jobs and "one-off" production. In the context of the Treasury Board desideratum for government departments to accept the planning-programming-budgeting (PPB) system in predicting fund requirements based on authentic cost data, it would seem that Technical Services was one of the first to achieve this aim. Swimmings provided a full report in Mines Memo, 1972 (report for 1971) covering divisional organization, the cost-accounting system, examples of R & D in the



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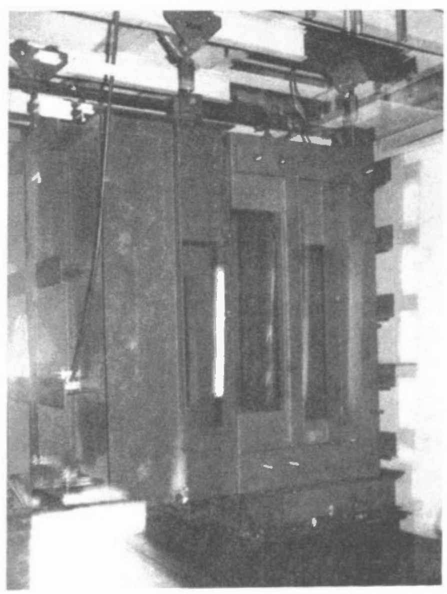

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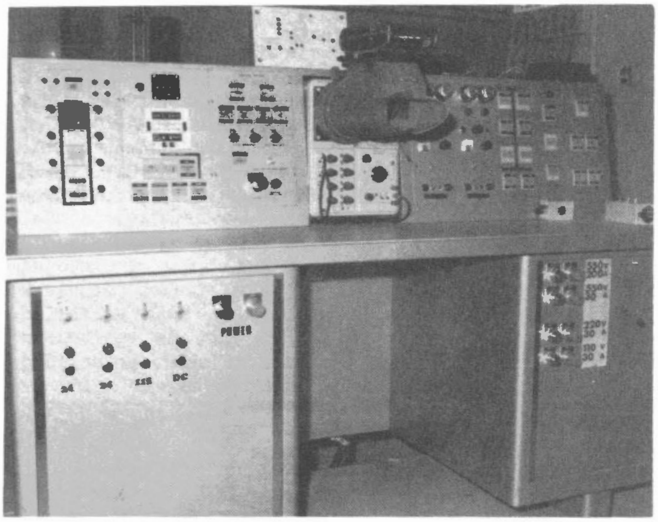

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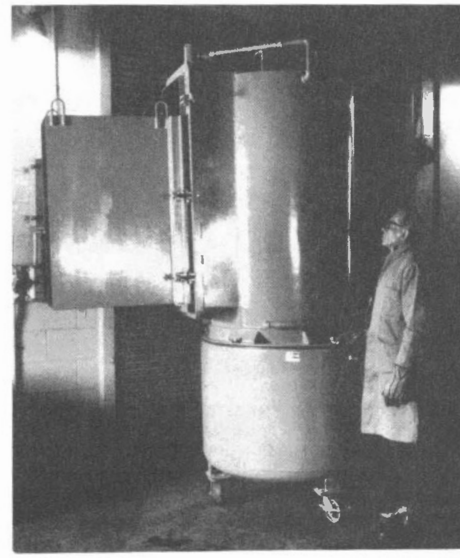

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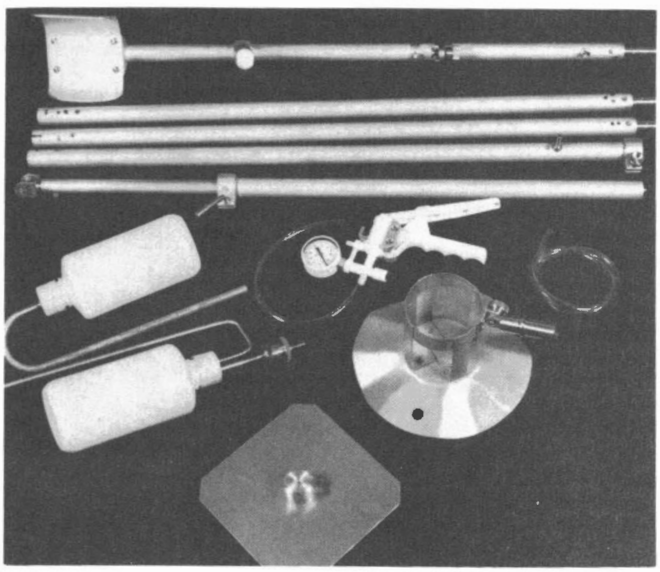

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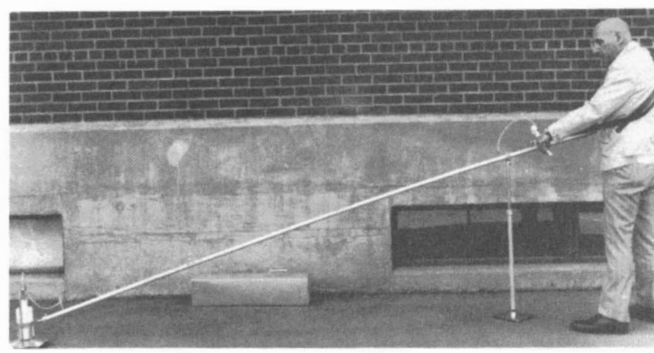

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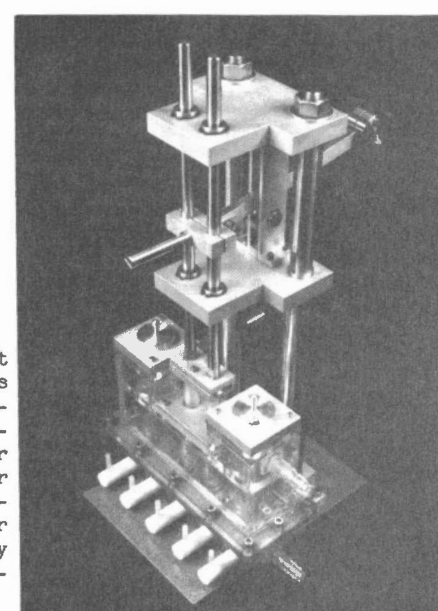

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The Technical Services Division designs and builds precision equipment and instruments for use by branch research scientists. Some examples are: 1 - jigs designed for PMRL by C.R. Jermy for Charpy test specimen production; 2 - 18-in. moveable-wall coke oven under construction, Bells Corners, 1971; 3 - explosion monitoring console built for Canadian Explosive Atmospheres Laboratory, 1970-71; 4 - Z.J. Tazbir and dry quench apparatus in carbonization pilot plant, 1972; 5 - components for tailing pond water samples; 6 - tailing pond water samples built in 1974 for Mineral Sciences Division - C.R. Jermy checking assembly; 7 - rapid mixing device built for Extraction Metallurgy Division, 1975 division, and the division's participation in R & D projects of the branch as a whole.

The turnover of staff at prevailing rates was somewhat higher than in other divisions of the branch. Standards for appointment for the skilled jobs were high, and this accounted for the smaller number of long-term employees, as many were hired on the basis of their previous experience. During the period under review, in addition to the staff already mentioned, the following retired with 25 years or more of service:

C. Fresque (1912 - 1960), S. Holman (1917 - 1954), G. Reaume (1926 - 1969), R. Rooney (1936 - 1961), H.V. McCann (1938 - 1964), H.J. Brindamour (1941 - 1972), W.R. Acres (1942 - 1973, deceased), E.J. Trudeau (1944 - 1971), A.S. Brownlee (1945 - 1975), J.G.R. Martel (1947 - 1973), J.D. Routliffe (1947 - 1973), A.V. Grant (1947 - 1974), and J.R.M. White (1949 - 1974).

Technical Services Division recipients of 25-years pins: Front row, left to right: W.R. (Ron) Acres, J.G.R. (Rolly) Martel, E.K. (Ed) Swimmings, J.D. (Jimmy) Routliffe, W.A. (Bill) Martineau

Back row - E.J. (Ed) Trudeau, A.S. (Albert) Brownlee, M. (Mike) Gadbois (1947-1972)

Information, Communication and Liaison

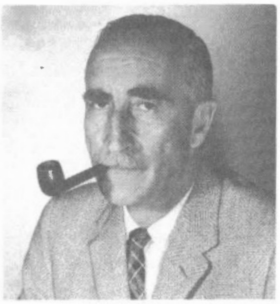
This area of the above-noted related functions in acquiring and disseminating knowledge was an important attribute in the history of the Mines Branch from its informal foundation in 1901 to the present time. Dr. Haanel recognized the two-way flow of knowledge by his early informal, and from 1911 formal, organization of laboratory and non-laboratory divisions in the Mines Branch in using the staff not primarily involved in laboratory work to gather and convey information. External consultants participated in collecting and collating data on the Canadian mineral resources and technology as well as on relevant foreign technology, publishing these data in the Report or Monograph series in which reasearch and investigations conducted within the branch or contracted were also published. Haanel attached considerable importance to maintaining liaison with industry, and this was achieved largely through resource specialists like Fréchette, Cole, Spence and Ells.

After World War I, the Mineral Resources Division became the principal Mines Branch group concerned with the evaluation of resources including the publication of the data, and this continued until its separation from the Mines Branch in 1956. Much of the resource data was contained in the Mineral Index Inventory and in the personal files of the resource specialists. Coal being under continuous investigation in the Fuels Division from 1910, all aspects including resource evaluation remained that division's responsibility. Again, during functioning of the Industrial Minerals as a separate division, much of the evaluation was done by the specialists of that division, many of whom crossed over from the Mineral Resources Division.

The foregoing remarks imply in essence that the Mines Branch from its inception collected and distributed considerable information on the mineral resources of this country.

After World War II, following launching of the mining research program in 1951, H.A. Graves was appointed in 1957 in an advisory and industry liaison capacity to the director, and he was followed by M.A. Twidale in 1958. Twidale, as a mature mining engineer with managerial experience, visited a large number of mines in operation and wrote reports on these in the FMP Internal Report series, but none of the companies' confidential data was divulged. A formal Mining Information Centre was developed when A.S. Romaniuk joined the Mines Branch in 1966, though the Extraction Metallurgy Division started earlier in an informal way, and both these will be described later.

H.A. Graves



M.A. Twidale

A.S. Romaniuk

Patricia L. Stevenson, after a short period in the Physical Metallurgy Laboratories during the war, was appointed information officer in the department with particular attention to the needs of the Mines Branch. In 1959 she transferred back to the Mines Branch where she was responsible for public relations, press releases and liaison with various agencies and industry. She was responsible for a photoprint library; displays of models, equipment and publications; organization of special technical meetings; and participated in arranging for press coverage of major meetings such as the Commonwealth Mining and Metallurgical Congresses, etc.

F.T. Rabbitts returned to the Mines Branch in 1961, replacing W.H. Norrish in 1962 as executive assistant to the director. Because he was a good writer and communicator, the director made him responsible for the preparation of the extensive annual report on the research and development in the branch entitled "Mines Memo". The first issue was in 1961 in respect of that year, and the last issue with this title in 1976 was in respect of 1975. A report was published by Convey and Rabbitts in 1964 as a study related to aims of the National Productivity Council and its successor, the Economic Council of Canada, to stimulate interest by Canadian industry in research and development in Canada: "Dissemination of technical information to Canadian industry" by John Convey and F.T. Rabbitts (MB IC 165, 1964). In 1967, Rabbitts was invited to join the Science Secretariat (later Science Council of Canada) study group on scientific and technical information in Canada, and he contributed to several chapters of a comprehensive report. He was also appointed chairman of the Departmental Committee on Scientific and Technical Information. It should be noted that since establishment of the Technical Information Service (TIS) by the National Research Council of Canada, the Mines Branch has cooperated freely with the service in its areas of specialization.

When the Extraction Metallurgy Division was formed in 1959, Downes, whose R & D policy was influenced by problems of the industry as a whole rather than by individual companies, had the director's approval for the appointment of R.M. Ennis, who had worked at the Mines Branch prior to becoming mill superintendent of Pronto Uranium Mines Ltd., and after his untimely death, by C.S. Stevens as industry liaison officers. Downes also appointed H.W. Smith as his assistant in planning of the division's research projects, and in 1967 Downes formed the section of information liaison officers to which he appointed Smith and Stevens. V.F. Harrison joined this group in 1969 and Honeywell in 1972. Stevens died in 1972 and Smith remained in the group until his retirement in 1974. This group formally joined the Technology Information Division in 1975, with Harrison being the information officer on extraction metallurgy and mineral processing.

An important part of the original information bank in the division was related to uranium hydrometallurgy, but later the scope was enlarged to include base metals as well as articles of interest to the entire staff. In 1971, steps were taken to transform the manual system into a computerized data base. Following some experimentation, two Fortran programs were developed MANAGE FILE - for creating the data base of code words and index numbers from source cards and the additions or deletions of records from the data base SEARCH FILE - for searching the base using code words and numbers: "A data base management and information retrieval system employing computer programs MNGFLE and SRHFLE" by F.J. Kelly (MB TB 178, 1973).

As regards the mining information office, this was created shortly after A.S. Romaniuk joined the Mines Branch in 1966. He spent a preliminary period in the Fuels & Mining Practice Division in preparing a "state-of-the-art" review on foreign practice in backfilling, a function considered within the sphere of responsibility of information officers. Romaniuk then made a study of accession and retrieval systems consistent with the restricted availability of funds. He found that by comparison with physical metallurgy, largely provided by the American Society for Metals, access to information on mining was weak. As key word control was required, Romaniuk worked on a thesaurus: "Thesaurus of mining terms" (MB IC 225, 1969). Because of exchanges with France then taking place in coal mining as well as to encourage bilingualism in the absence of suitable dictionaries, Romaniuk compiled a glossary of mining terms: "English-French glossary of mining and related terms" (MB IC 245, 1970). In 1968 he was joined by Pauline Weidmark and in 1969 by a student, G.M. Blondeau, who earned a degree at Queen's the same year and an M.A. later at Guelph and who became the principal abstractor. In 1971, R.J.R. Welwood, mining engineer, joined the group. By 1973 the number of reports and documents indexed in the mining file was about 8,500 and the Termatrex Optical Coincident retrieval system which Romaniuk selected had an expected limit of about 10,000 items. A paper was presented to the Ninth International Symposium on Techniques for Decision-Making in the Mineral Industry in 1970. This symposium was sponsored by the CIM: "A centre for mining information" by A.S. Romaniuk (Proc Conference, Special CIM Vol No. 12, 1971).

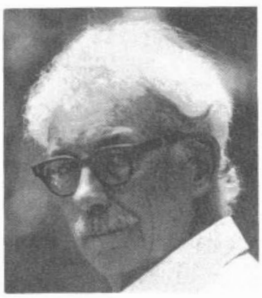
Provision was made to examine computerized systems and in this regard several programs were examined by Dr. J. Soukup (1971 - 1973) in which he was assisted by L. Geller and W.F. Chow (Waterloo University student). Some 25 programs were written to test the system: "System and programs for computerized processing of abstracts" by J. Soukup, L. Geller, W.F. Chow (Scientific Bull CM 75-1, CANMET 1975).

Though the mining information service commenced in 1967, it was not until 1972 that it formally became the Mining Information Centre with A.S. Romaniuk as head, who could take credit for the initiative shown by his group and himself in developing a viable and useful facility. Dr. Irene Slowikowski was attached to the centre. The extraction metallurgy and mineral processing data bases were to be converted to the use of a thesaurus similar to the one produced for the mining information. PMRL had a good base in the METADEX system, which was also in use by NRC. C.F. Dixon became information officer for physical metallurgy in 1975. Later R.J.C. MacDonald transferred from the Extraction Metallurgy Division to become information officer in the broad area of mineral processing and G.W. Taylor was recruited for energy information. The information centre became the Technical Inquiries Section of the Technology Information Division formed in 1975 to embrace the whole information field which included the libraries, and the Editorial-Publications Section. Dr. J.E. Kanasy was appointed chief of this division in January 1976, earlier as a consultant he had reviewed the information and library services of the branch.

Somewhat parallel with development of the Mining Information Centre, the Mining Research Centre, formed in 1967, acquired three experienced mining engineers: T.W. Verity (1967 - 1971), A. Dubnie (1967 - 1975) (deceased) and A.L. Job (1967 -). The first two from the Mineral Resources Branch, which in 1967 turned over the responsibility in mining engineering to the Mines Branch, dealt with various technological problems but more particularly with those related to the systems engineering program which Coates was developing. Verity undertook the initial tunnelling project sponsored by the OECD: "The operation of mechanical tunnel-boring machines in Canada" by T.W. Verity (MB IC 256, 1970). He also undertook a number of studies

T.W. Verity

A. Dubnie



A.L. Job

connected with ground control including sprayed concrete: "Ground support with sprayed concrete in Canadian underground mines" (MB IC 258, 1971).

Dubnie had considerable prior experience with explosives and drilling. For four years he was with the explosives group and helped Darling in one or two projects: "A proposed method for measuring noxious gases from explosives" by A. Dubnie and J.A. Darling, (MR Int Rep 70/89). He also worked with Gyenge on drilling (see previous references).He studied northern mining problems with particular reference to unit operations in permafrost (MB TB 148, 1972). A joint study by him with W.A. Gow and H.H. McCreedy of the Extraction Metallurgy Division was carried out on in situ bacterial leaching at Agnew Lake, Ontario. Coates and Dubnie published an internal report on mining technology in Canada in 1967. Dubnie proceeded to publish technical bulletins on the same subject for 1972-73: "Mining technology in 1972" (MB TB 180, 1973) and companion report "Mining technology - statistics 1972 and 1973 developments" (MB TB 188, 1974). Dubnie also published a comprehensive review on open pit mining "Surface mining practice in Canada" (MB IC 292, 1972). He started on a detailed re-assessment of radioactive ore resources in 1975 but succumbed to illness which he had valiantly stood up to for several years.

Job's scope was wide in character as will be seen from examples of various reports he published: "Transport of solids in pipelines with special reference to mineral ores, concentrates and unconsolidated deposits - a literature survey" by A.L. Job (MB IC 230, 1969); and in internal reports: marine mining (70/52); mine lighting (70/110); bibliographies on noise and lighting (72/43); noise in mines (72-101); productivity and costs in coal mines related to thickness, inclination and faulting of the seams (literature survey 73/64); marine mining bibliography (73/104); the impact of deep sea nodule mining - which nation will be most affected? (73/164); fatalities and employment in the Canadian mining industry and certain other selected industries, 1960-1971 (74/21); survey of published cost indices and machinery/equipment costs applicable to the Canadian mining industry (74/120); past and projected employment, production and productivity in the Canadian mining industry, 1945-2000 (74/129); land use by the Canadian mining industry (75/2) and heat generation and dust explosions in mining sulphide ores (75/35). Job succeeded Welwood as mining information officer in the Technology Information Division in 1975.

Exchange of information and staff outside Canada was practised by the Mines Branch throughout its history but particularly since World War II. With inauguration of the mining research program in 1951, the Fuels Division was interested in French and Soviet experiences in outbursts and bumps that occurred in coal mines of those countries and relevant information was sought from France and the U.S.S.R. Reports in other languages were also of interest to the mining research section: Swedish on account of advances in rock mechanics in hard rocks comparable with those of Canada; Polish because of controlled subsidence in mining thick seams in urban areas and modernization of their coal mining enterprises; Japanese - undersea mining and hydraulic mining. The Bureau of Translation's texts were literal and they did require considerable time for their completion. With the coming of Dr. H. Frisch to the Mines Branch in 1960 the system was accelerated by his scanning of the material with assistance from the technical staff, particularly Casey and Vary. This was done mostly for mining but assistance was given to other divisions, particularly Mineral Processing.

In 1965 a five-year agreement was signed by Dr. Harrison on behalf of the department and by Dr. A.M. Samarin, deputy chairman for the USSR Committee on Coordination of Scientific Research for areas of mutual technological interest. This was reported to be the first such agreement after the NRC Scientific Agreement some years earlier. Subjects for exchange of informa-

Visit of Mines Branch group to Skochinsky Institute, Moscow, 1972. Irena Slowikowski, T.S. Cochrane, A.S. Romaniuk and Dr. A.V. Dokoukin, director of the institute tion as well as for visits to laboratories and industry were: mining, mineral processing, coal and structural materials. For the next ten years or so within the period 1967 to 1972, many exchange visits were made mainly from the Soviet side. Dr. I. Slowikowski joined the Mines Branch in 1968 and participated in the monitoring and scanning work as well as in exchange visits. Dr. Frisch died suddenly in 1970. After a short experience in the disciplines of the branch, Dr. Slowikowski developed considerable skill not only in translation but in the more difficult task of interpretation, and accompanied a number of the missions to the USSR. The original departmental agreement was not extended and the exchanges were arranged through the Department of Industry, Trade and Commerce under the Non-Ferrous Metals Ad Hoc Group of Canada/Soviet Mixed Commission for the Industrial Application of Science and Technology.

Convey was the Canadian chairman of this group until he left the branch in 1973 to become senior departmental advisor, metallurgy, when Vic Haw replaced him. It had been hoped that, aside from the exchange visits, there would in time be developed a continuous exchange of information with relevant research organizations in the Soviet Union and other "socialist" countries, but this has been only partially achieved up to this point.

Libraries

The library remained at 40 Lydia Street under the administrative direction of the chief of the Mineral Resources Division until the transfer in 1956 of the division to the responsibility of the director-general of Scientific Services, Dr. G.S. Hume. The library was then divided between the division and the Mines Branch - all resource documents including the Mineral Inventory were allocated to the Mineral Resources Division, whereas reference books and documents relating to research and development in the sciences and engineering remained with the Mines Branch. The Mineral Resources Division stayed at 40 Lydia Street until 1959, when the headquarters building at 588 Booth was completed.

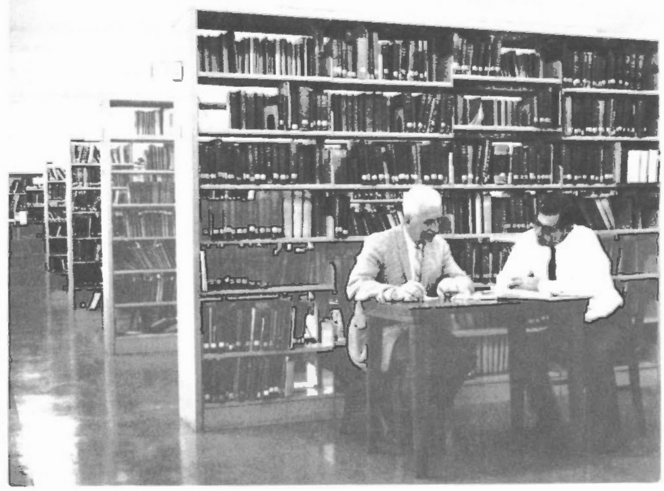
Madeleine Saulter (1930 - 1963), the head librarian, and Marjorie Rice (1940-1968) together with a staff of five other persons, had the task of moving the library to 555 Booth Street in 1958 with the assistance of the Technical Services Division. The facilities in the new building were the best in the library's history, with about 10,000 sq ft of space including stack storage for periodicals. However, soon the inadequacy of storage was again experienced, requiring stack space in the basement.

A branch library with a literary clerk in charge, Beatrice Cain (1953 - 1973), replaced by Rena Mills (1948 -) was established in the Physical Metallurgy Division. From the sixties, small satellite libraries with technical staff in charge were serviced by the Ottawa Library at Elliot Lake Mining Research Laboratory, Western Regional (Coal Preparation) Laboratory at Edmonton, and later at the Western Mining Office in Calgary.

A chronic shortage of professional librarians was experienced up to the late sixties when a sufficient number of graduates in the comparatively recent university discipline became available. In part the shortage was due to the upsurge in the demand for librarians for the new post-war universities and institutions. In this period, the establishment, not counting summer positions of the library, was seven, four of whom were professional librarians. This complement was the same as it was in the fifties. No reference librarian was available for some twelve years from 1958 until the appointment of Krizstina Nagy in 1970. The position of the library as at 1962 was described in a paper by F.T. Rabbitts, who acted in an informal capacity as the director's representative on the advisory committee on the needs of the library: "The Mines Branch Library" by F.T. Rabbitts (CIM Bull, pp 228-290, April 1962).

In 1962 the library had approximately 65,000 volumes which included textbooks and bound serials, but this was exclusive of reports and various documents. At that date the library subscribed to about 700 serials. By 1975 there were over 100,000 volumes, and the serial subscriptions were about double at 1400. In cataloguing, consideration was given to changing to the Library of Congress classification system. However, this change would have entailed considerable disruption; hence, adaptation of the Dewey decimal system was continued.

In the late sixties, considerable emphasis was given by the newly formed Science Council of Canada to the general question of technical and scientific information. In the Report No. 6 of the Council entitled, "A Policy for scientific and technical information dissemination", September 1969, the Council supported the principle that "any information service should be based on existing expertise and that the aim should be to link such services into a network of systems operated under decentralized control". Furthermore, it was the opinion of the Science Council that the concept of "optimum utilization of information systems" would involve inter alia "specialized collections of information developed by the leading groups in a particular field or discipline have much more value than centralized collections put together in a location remote from the principal activity which they are to support". In this context the Mines Branch



P.E. Hughes and J.A. Vezina using facilities of the Mines Branch Library (Photo - Andrews-Hunt)

Library had the full support of the National Science Library (NRC), later renamed the Canada Institute for Scientific and Technical Information. The Mining Information Centre, later broadened to all the technological fields applying to the mineral and metal industries, was formed as a separate entity to the library but very closely related to it. It may be pertinent to observe in succinct terms that the Information Centre was considered to be an interpretive information group requiring state-of-the-art reviews and explanatory statements as a part of their function compared with the library, being a repository of information with a capability of information retrieval from various sources including the interlibrary loan system.

Two of the long-term librarians, Madeleine Saulter who retired in 1963 with 33 years service, and Marjorie Rice who resigned in 1968 with 28 years service - both gave of their best in the difficult years of change. Gloria M. Peckham joined as one of the post-war specially trained librarians in 1963, and became head librarian in 1968. She worked hard with her associates in building up the national standing of the library in the subjects of Mines Branch specialization. In 1975 there were four established librarian positions, the same number as in 1955. However, the number of clerical positions had increased to eight making a total of twelve. In addition to the chief librarian were Krizstina Nagy (1970 -) and J. Ho (1971 -) in charge of cataloguing, assisted by Mrs. Arlie Hobson (1967 -).

The library became a component of the Technology Information Division in 1975.

Gloria Peckham

Krizstina Nagy

Editing

The editing and production of reports and scientific papers remained a weakness of the branch despite dedicated but numerically inadequate staff, though offset reproduction from camera-ready copy was efficiently supervised by Marian Thompson (1955 - 1967) and by Dorothy E. Derouin (1967 - 1975). The position worsened when the Mineral Resources Division separated from the branch because the typing pool and editorial facilities had been provided by that division. Incidentally, the Mineral Resources Division maintained its traditional promptness in the processing of reports.

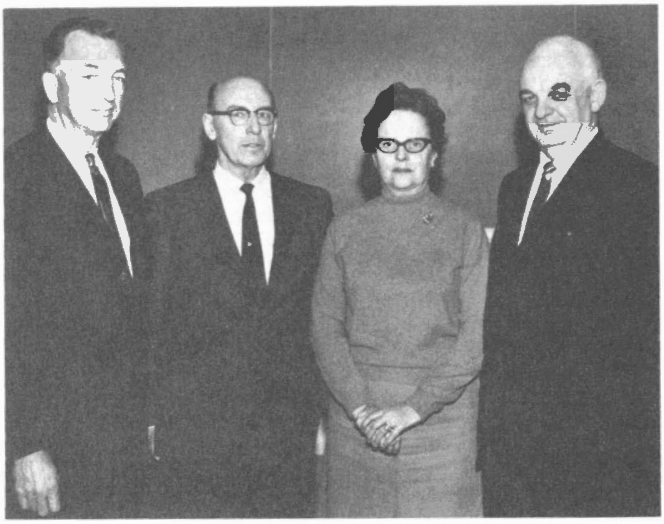
As mentioned earlier in this chapter, most publications other than monographs and special volumes had to be edited by Shannon, who was punctilious in his work. Incidentally, Shannon demonstrated his verve by earning a B.A. degree in English at Carleton University in 1956 and then taking a further course in Public Administration for which he prepared a final term essay on "Evolving the first Canadian Department of Mines, 1907" (March 14, 1959).

As all Mines Branch reports and scientific papers were published essentially on the responsibility of the branch director, they had to be authorized for publication by his office. This task fell to Wilbert Norrish, who had been transferred from the Bureau of Mines headquarters in 1947 when the wartime mineral projects were moved from the Mines and Geology Branch headquarters. Norrish was very diligent in his work as he was in all his activities, as for example, in the distribution with Nola Ferguson of the mail, and attending on behalf of the director various administration-oriented meetings. With decentralization of the Mines Branch, the mail distribution required considerable attention, a task very well performed by Nola Ferguson after Norrish's retirement in 1962. In May of that year Norrish had served the government fifty years, 26 with the Bureau of Mines and the Mines Branch and 24 years with the Department of Interior as land surveyor. In the light of this remarkable record Dr. Convey asked him, as a contemporary of Sid Ells, to write a biographical preface to Ells' "Recollection of the development of the Athabasca oil sands" (MB IC 139, 1962). Incidentally, Ernie Martindale was also a land surveyor in the Department of the Interior, but he retired in 1953, being somewhat older than Norrish.

Rabbitts returned to the Mines Branch in 1961 and succeeded Norrish in 1962 as executive assistant to the director. Aside from the editorial tasks, Rabbitts had interests, as mentioned earlier, in the various aspects of the technical information field, and, from the middle sixties, in the new trends in government policy on program management. He voluntarily took a course on industrial accounting in a first effort in the branch to bring financial accountability into R & D programs. In this connection the Technical Services Division had started on a costing system, as mentioned earlier. Rabbitts published his thesis "Cost and managerial control in research and development - a review" (Admin Rep AD 67-3).

The chairman of the branch editorial committee was T.H. Hawkins. A guide used by authors for the preparation of Mines Branch publications was revised from time time, the last revision being the fifth issued in 1970 (Report ADM 70-2). To minimize delays in releasing division reports to industry, an editing language training program was carried out by A. Willis, training officer of the Development and Training Section of the Personnel & Organization Branch of the department during the two years, 1968-69 and 1969-70. In the first year there were nine participants, six of whom continued into the second year.

In 1972, Rabbitts transferred to the Metals Reduction and Energy Centre as coordinator of programs for Dr. J.H. Walsh, who was manager of the centre. K.M. Brown substituted for Rabbitts in editing until he retired in 1973. Chris Mamen, a mining engineer with considerable experience in the industry, followed by 19 years as editor of the Canadian Mining Journal, was appointed head, Editorial and Publications in 1974. In 1975 his group became a component of the Technology Information Division.



Administration recipients of 25-year service pins, left to right: E. Rabbitts, D. Livie, Dorothy Derouin, John Convey

Administration

The adminstration staff of the Mines Branch remained substantially the same during the period of Dr. Convey's tenure of the director's position, almost for the whole period of the Department of Mines and Technical Surveys and into the period of the Department of Energy, Mines and Resources.

Nola Ferguson, who had started in 1948 as secretary with C.S. Parsons, continued for the whole period while Dr. Convey was director to 1973 and carried on under Dr. Coates when he became director; she possesses the important qualities of loyalty, discretion and competence. T.H. Hawkins was appointed the branch administrative officer in 1951, succeeding Heatherington (1935 - 1950). Hawkins by nature was a courteous and cooperative person and accepted the autonomous status the director gave the divisions. He was very helpful in the extensive preparatory work required in the organization of the Sixth Commonwealth Mining and Metallurgical Congress in 1957 in Canada. D.M. Livie, after a pre-war and wartime career in the Army, joined the Mines Branch in 1947, initially with the Mineral Resources Division, becoming administrative officer in the Physical Metallurgy Division in 1948. He was transferred to the director's office as assistant administrative and financial officer in 1954. He guided the financial and housekeeping affairs of the branch well, having to face, particularly at the end of his career, many changes in financial procedures. He succeeded Hawkins as chief administrative officer of the branch when the latter retired in 1970. M.J.B. Bradley joined the branch in 1949 as clerk in charge of the confidential files in Administration with A.D. Mayotte (1949 - 1961) and H.N. Pickford (1949 - 1966). In 1954 he was appointed administrative officer of the Physical Metallurgy Division. He is known for his pleasant and helpful personality. Bradley joined Livie in 1970 as assistant administrative officer being replaced by R. Reardon (1968 -). In 1974, Livie retired and the position was divided between administration and finance, Bradley becoming the chief administrative officer.

J.E.H. Bowles, brother of K.W. Bowles, both grandsons of Dr. Haanel, served in the Bureau of Mines and in the Mines Branch from 1946 to 1957, as will be noted from the following brief biography. He joined the Mines and Geology Branch of the Department of Mines and Resources in 1936 where he was in charge of the distribution of maps and reports. In 1940 he joined the R.C.A.F. and served in Canada and overseas. In 1946 he rejoined the department in the Mineral Resources Division, filling the vacancy in the economics section created by the retirement of J.M. Casey. Jeff Bowles was appointed personnel officer of the Bureau in 1948, a position he held until 1955. By that time the number of innovations developed in the branch required the full-time attention of a patent officer. Accordingly, he was appointed to this position, which was transferred to headquarters of the department in 1957. He established close working relations with Canadian Patents and Development Limited (CPDL), whom he joined in 1966 though retaining a liaison office in the department. He completed his versatile career in 1972.

Betty Macfarlane (1937 - 1972), later Mrs. W. Hutchings, replaced Bowles as personnel officer in 1955 and continued until 1968, when Personnel was centralized under the Personnel and Organization Branch, which was a headquarters unit responsible for branch personnel officers, the first appointed to the Mines Branch being J.A. Payne and L.F. Matheson. During the period Betty Hutchings was the personnel officer she demonstrated her concern for the welfare of employees by helping those with difficulties.

M.J.B. Bradley

J.E.H. Bowles

Because of branch involvement in subjects of a classified character governmentally and of a confidential nature industrially, it was decided to appoint a security officer. Accordingly, P.E. Hughes, a retired officer of the RCMP, was appointed in 1958. During his term of office from 1958 to 1975, there were no breaches of security. He discharged his duties conscientiously and unobtrusively. Later his duties were enlarged to include preventive measures in safety and he worked closely with the safety committees of the divisions. His former organization could feel proud of this officer.

Research "Fall-Out"

The twenty years or so represented in the narrative of Chapter 6 produced a long and sustained R & D effort and probably the largest research direct or indirect "fall-out" in the history of the Mines Branch. It is not only the formal or informal reports and papers which communicated the R & D, but also the unrecorded dialogues which took place between the research staff, other specialists and their associates with the stream of engineers and scientists from Canada and other countries who continually visited the branch.

In the early post-war years, the so-called Third World was assisted in research and development under the Colombo Plan. The branch had a share of research trainees under this plan. The NRC had a generous plan for post-doctorate research fellowships from 1948 in their own laboratories, and from the fiscal year 1956-57 in the laboratories of the Department of Mines and Technical Surveys and other resource departments. There was a two-way advantage in this scheme.

An increasing number of exchanges was conducted with research organizations of the Western World and from the sixties with some in the Eastern World. The most generous with their time and facilities were our U.S.A. counterparts.

Dr. Convey continually spoke to audiences on the merits of doing more Canadian research. He made, particularly with Haw, comprehensive analyses of research and development in the Canadian mineral and metal industries as mentioned previously. The last of the applied research reports prepared for the National Productivity Council, which was the forerunner of the Economic Council of Canada, was on Research Associations in the U.K., a subject which was first brought forward in Canada when the NRC was formed after World I: "A study of cooperative research in the United Kingdom and its application to Canadian conditions" by John Convey and V.A. Haw, Report to the National Productivity Council (Applied Research Report NPC-4, Mines Branch, October 1963).

The Canadian Carbonization Research Association, formed in 1965, was probably closest in style to the British R.A.'s. Its continuous success may be attributed to the degree of involvement in its technical management by member company representatives.

Universities were first assisted by providing summer vacation employment not only to undergraduates but also to graduate students and faculty staff in laboratories or in the field. Grants-in-aid for university research were started informally in 1962 with rock mechanics projects receiving a total of $10,000. The Canadian Advisory Committee on Rock Mechanics (CACRM) was formed in 1963 with Coates as the first chairman and Haw as the first secretary. The committee also contributed its advice on the grants-in-aid up to 1969, with a total distribution of $450,000. Mineral processing was the next beneficiary, starting in 1963 with $10,000. A committee of the Mineral Processing Division made recommendations on the grants to the director. By 1969 the grants-in-aid for the two disciplines exceeded $100,000 per annum. It may be significant to note in parenthesis that no requests from Canadian universities were made on grants-in-aid for research on fossil fuels, a weak area in Canadian expertise. From 1969, the distribution of grants-in-aid was made by a committee of the National Advisory Committee on Mining and Metallurgical Research (NACMMR). The grants-in-aid program for geology and geological sciences came into force in 1951 and was administered by the Geological Survey, on whose committee there were a number of external geologists mainly from the academic world. In the case of the Mines Branch, Dr. Convey was in favour of a small industry group but this did not work out that way. Much difficult preparatory work was done by Vic Haw, who was appointed Secretary of NACMMR, which originally had three principal objectives: to coordinate mining and metallurgical research in Canada, to advise on research in the Mines Branch, and to administer grants-in-aid to universities. The deputy minister was appointed as chairman, with the director as vice-chairman. The first membership consisted of 21 members representing industry, universities, federal and provincial agencies, and two members at large, and the first meeting was in 1968. The first aim, namely the coordination of research in Canada, was difficult to achieve, and the committee was probably too large. Better results were obtained later with sub-committees. The principal difficulty was probably the number of industries represented and the wide scope of the research and development work of the Mines Branch.

The expertise of the director and individual officers of the branch was sought by specific universities, and requests were made to serve as members of university advisory boards or as part time lecturers in their specific fields. In addition, the director and many of the officers were continually advising various government agencies. Some of the expertise was sought because of the particular officer's unique knowledge, for example the Bank of Canada for Dr. Gillieson's intimate knowledge of spectroscopy; Canadian Standards Association in relation to the hospital hazards safety code for G.K. Brown's knowledge of explosibility of anaesthetic and other gases. Above all, the doors of the Mines Branch were always open for informal discussions with the research staff on results of a research project or a scientific or technological problem.

The long list of technical committees in which Mines Branch personnel was involved included a high proportion of national and international standardization organizations, which invited Mines Branch participation to develop standards often requiring a long period of cooperative research and testing. The remainder of the national and international technical committee membership arose from invitations aimed at using the expertise of individual Mines Branch technical personnel.

An unsolicited view of the Mines Branch contribution to industry was given in report No. 11 of the Science Council of Canada: "Background to invention" by Andrew H. Wilson (Special Study No. 11, Science Council of Canada, 1970). In discussing "fall-out" from federal laboratories other than NRC, which is discussed separately, the following is said on page 67 of the report: "Most of the companies visited were active in fields of science and engineering covered by federal laboratories but few of them had used "fall-out" from federal laboratories in the form of ideas, information or hardware, except as it came to the attention of individuals through personal contacts."*

*"If there was one exception to this rule it was the Mines Branch of the Department of Energy, Mines and Resources. There was a general enthusiasm for the work of this branch in the sections of industry which it serves."

Recipients of 25-year service pins, left to right: front row - Betty Hutchings, Rena Mills, Nola Ferguson, Margo Muirhead, back row - T. Hartley Hawkins, T.W. Wlodek and Phil Hughes

CHAPTER 7

PLANNING, PROGRAMMING AND BUDGETING
EMPHASIS ON TECHNOLOGY

DEPARTMENT OF ENERGY, MINES AND RESOURCES (1966 -)

The reader of Chapter 6 would have noticed that many R & D projects were continued into the seventies whereas the era of the Department of Mines and Technical Surveys terminated in 1966. This was in part to avoid interruption in the description of the project and also in part because during Dr. Convey's tenure of office to 1973 there were no basic reorganizations of the branch or of its programs other than increased emphasis from the middle sixties given to protection of the environment. We must therefore take some steps backwards in time to October 1966 when the Department of Energy, Mines and Resources was formed (See Chapter 2). The main change had been the clear identification of the department with the area of energy which had been included in the technical responsibility for the mineral resources of the predecessor departments.

An extract from the first Annual Report, 1966-67 of the Department of Energy, Mines and Resources relating to the activities of the Energy Development Group formed in the department stated that it "...will also examine the various forms and sources of energy - coal, oil, gas, hydroelectric and nuclear - and work towards effective coordination and implementation of energy policies. Examples of such federal efforts in the field of electricity are the participation, with the provinces of Nova Scotia and New Brunswick, in the study of the tidal power potential of the Bay of Fundy; the federal-provincial agreement on the Nelson River power development whereby the federal government will build a 600-mile transmission line costing $170 million and lease it to Manitoba Hydro; participation in the control bodies for proper implementation of the Columbia River Treaty; and a study of the proposed Trans-Canada transmission grid.". At that time there was no national concern about the pending shortage of oil; however, it was fortunate there was a department of the federal government responsible for energy when the crisis arose in 1973.

As indicated earlier in Chapter 6, the public euphoria over Canada's prosperity and growth had died down by the end of the sixties and protection of the environment was becoming an important issue. Water, though a renewable resource, was first included in the responsibility of the Department of Energy, Mines and Resources (EMR). When the Department of Environment was created in 1970 all research and development on water as a resource, including marine sciences, was transferred to the new department except for water use in hydroelectric development which remained the responsibility of the Energy Sector of EMR.

Technology rather than science was emphasized and the technology was to be developed in the context of a social responsibility to minimize destructive or negative effects on the environment. Programs were initiated in all departments of government to define their objectives and responsibilities clearly as well as to introduce the concepts of non-permanency and priorities of programs and projects. For EMR, three programs were devised: Mineral and Energy Resources Program (MERP), Earth Science Program (ESP) and an Administration Program. The mission and objectives of the Mines Branch were governed by MERP which is still in place. Considerable writing and rewriting of the main and subsidiary objectives were carried out. At first MERP was a single program but after 1975 it was recognized that the utilization modes of the two resource groups were very different, deserving separate though parallel objectives. The present objective for energy reads: "To assure the availability and to promote the effectiveness of energy resources in Canada with due regard for the social and economic goals"; for minerals, the same wording applies except for substituting mineral resources for energy resources.

Annual program reviews were initiated enabling the effectiveness of projects to be evaluated and ranked for priority. Of the divisional chiefs, Haw showed the most interest and provided the most assistance to the director, who had the burden of converting the array of informal programs and projects into a new program system. Rabbitts was also very helpful and prepared several reports on Mines Branch programs for the National Advisory Committee on Mining and Metallurgical Research (NACMMR) as well as a detailed analysis of the activities for the program reviews.

At this time, management skills were considered by senior personnel of some departments to require upgrading. Accordingly, a Management Grid Development

Program was introduced from the United States and a large number of senior officers became involved in it.

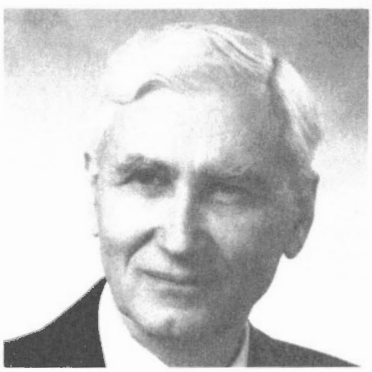
The government, possibly concerned by pronouncements of the "Club of Rome" and possibly interested in evaluating the place of science in the nation, created the Science Council of Canada from the earlier Science Secretariat in the Privy Council's office. It also appointed in 1967 a special Senate Committee on Science Policy under the chairmanship of Senator Maurice Lamontagne. This committee continued functioning for several years.

Branch environmental improvement seminars reporting R & D in this area by the component divisions of the Mines Branch, which had started in some of the divisions many years back, were resumed in 1970 with E.R. Mitchell as convener. Four such seminars were held until 1973. A fifth seminar on the theme "conservation" was not held but the report was circulated to maintain the continuity both for those interested within the branch as well as to provincial agencies (Report Adm 74-1).

The NACMMR suggested that a factual report on environmental control in the mining and metallurgical industries be undertaken. Dr. Convey agreed to assist and Rabbitts was placed in charge of a small task force consisting of himself, Banks, Sirois and Stevens to collect relevant information. The response of the industry was excellent and a report was issued in January 1971. An interesting fact came to light in that the amount of land disturbed by mining was estimated at only 130,000 acres, a portion of which had already been reclaimed. Farmland in Canada amounted to 172 million acres and land disturbed by highways was about 30 million acres, all this in a total land area of Canada of 2280 million acres: "Environmental control in the mining and metallurgical industries in Canada" by F.T. Rabbitts, G.N. Banks, L.L. Sirois and C.S. Stevens (Special Mines Branch report of a survey carried out on behalf of NACMMR, Mines Branch, January 1971).

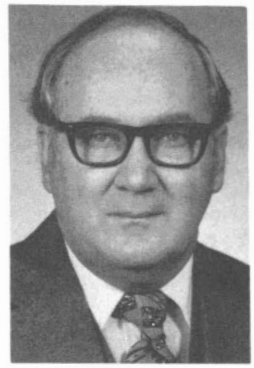
Changes in Organization

In 1967 the Fuels and Mining Practice Division was divided into two centres: the Fuels Research Centre under Dr. D.S. Montgomery as chief, and the Mining Research Centre under Dr. D.F. Coates as chief. This was foreseen when the old Fuels Division was



D.S. Montgomery

D.F. Coates



J.H. Walsh

renamed Fuels and Mining Practice Division in 1959 because of the disparate nature of the disciplines in the two areas. Reynolds retired in 1971 with 36 years service and was replaced as administration officer by G. Mann, RCAF veteran. E.C. Tupper who joined the Mines Branch in 1958 had some years at Bedford Institute but returned in 1966, and was appointed administration officer in the new Mining Research Centre in 1967.

Ignatieff was appointed deputy director, a newly established position; this position and several others in the branch were designated in the new class of research manager. In October 1969, a further centre was created combining energy and metals known as the Metals Reduction and Energy Centre with Dr. J.H. Walsh as manager and D.J. McIntyre administration officer. This concept revived the early efforts of primary metallurgical processing by Haanel, and prior to World War II by Hardy, which was aborted by the large investment in and important priority for physical metallurgy during World War II. Actually the director had wanted more research on primary ferrous metallurgy but for various reasons it was late in starting.

The Metals Reduction and Energy Centre was composed of three groups: the Western Regional Laboratory in Edmonton on coal preparation and later with an addition of the gas-heated moveable-wall coke oven donated by the Algoma Corporation for technical-scale carbonization tests, the Metallurgical Fuel Engineering group in the Bells Corners complex in Building 2 and the Pyrometallurgical group of the Extraction Metallurgy Division. The latter was to be transferred to Bells Corners but this did not eventuate.

Greater emphasis was given to the fuels side because of the large involvement of staff and facilities in the evaluation of Canadian coal resources and realization of the high cost of energy in metal ore reduction. This centre as a separate group lasted until July 1974, when Walsh was appointed science advisor to the assistant deputy minister in the Science and Technology Sector.

Other small changes took place in the Mines Branch in the early seventies. In the Extraction Metallurgy Division in 1971, Gow was appointed assistant chief and H.H. McCreedy head of the Hydrometallurgy Section. In the following year, 1972, the section was divided into Ore Treatment and Solution Treatment with G.M. Ritcey, who joined the Extraction

Metallurgy Division in 1967, becoming head. Dr. Ingraham resigned in 1972 to take up an appointment with the Department of Environment. He was replaced by Dr. A.W. Ashbrook, who joined the Chemical Analysis Section in 1970.

In 1971, Dr. R.L. Cunningham transferred from the Physical Metallurgy Division to the Mineral Sciences Division, of which he became the chief in 1972. Ignatieff retired in 1972 and Vic Haw succeeded him as deputy director.

Dr. K.W. Downes and H.M. Woodrooffe retired in December 1974 with 27 and 28 years' service respectively in the Mines Branch. Dr. Convey, as mentioned at the outset of Chapter 6, had at 22 years from 1951 to 1973, the longest service as director of the Branch. He spent a little more than a year at department headquarters as senior advisor in mining and metallurgy, retiring from the department in 1975 with a total of nearly 27 years. Dr. Convey was the general chairman of the 10th Commonwealth Mining and Metallurgical Congress in Canada in 1974 and the technical organization was based on Mines Branch facilities. V.A. Haw was in charge of the technical program, Dr. M.J. Lavigne was secretary of the Congress, Patricia Stevenson was in charge of publicity and liaison and Chris Mamen, editor. Convey stayed on for a further year to wind up the administrative affairs of the Congress.

Mineral and Energy Resources Program (MERP)

MERP was classified in the Government Planning, Programming and Budgeting Guide as part of the economic development function of government. Incidentally, mineral and energy resources with the other natural resources of Canada were aptly described as national wealth in several issues in the sixties of "Canada, The Annual Handbook". The change from a purely institutional reporting of activities of the Mines Branch to formal program reporting was initiated in 1970: "List of current Mines Branch projects" compiled by F.T. Rabbitts (Report ADM 70-4, 1970). He stated that priority was given to environmental improvement (the first Mines Branch seminar on the environment was held in 1970), metals reduction and energy (centre formed October 1969) and scientific and technical information (Mining Information Centre formed 1970). Protection of the environment, particularly in regard to clean air, was more closely associated with the energy component of MERP than with the minerals component. One could thus say that in this initial period the priority of the Mines Branch was, on the whole oriented to energy. However, no particular shift of resources was made until about 1975.

The combining of minerals and energy caused some administrative difficulties related to allocation of funds; fossil fuels were on their own but nuclear fuels embraced both energy and minerals. The program in-house had to be divided between minerals and energy. No accurate figures were available of the number of staff dedicated to energy projects. During the existence of the Fuels and Mining Practice Division the proportion engaged in fuels research to the total branch staff was about 20 per cent; by 1975 it was in excess of 25 per cent, and some of the shift in manpower and funds took place between 1973 and 1975. Furthermore, a higher proportion of external contracts, particularly after 1975, was devoted to energy projects. Between 1973 and 1975 the branch transformed into a matrix system of program management as will be mentioned later.

MERP was divided into three main activity areas:

- Supply - this included quality evaluation of reserves, mineral recovery or mineability, and technology related to the mining process.
- Processing - beneficiation of bulk minerals, concentration of disseminated minerals, and refining of hydrocarbons.
- Utilization - combustion with pollution abatement, primary fabrication of metals, recycling of metal and industrial mineral wastes, utilization of metals under severe Arctic climatic conditions, and transportation, particularly pipelines.

As mentioned earlier, for the sake of continuity and clarity, many projects have already been described in Chapter 6. The projects that now follow have not been mentioned before and are reported briefly in the context of MERP activities divided in two parts: energy and minerals.

Energy Supply

Coal Resource Evaluation

Because of the revival of the Western coking coal industry, a renewed R & D thrust in long-term underground mining was inaugurated in 1969; also an accurate estimate of lignite reserves in Saskatchewan was required mainly in relation to the thermal-electric needs of the province.

The Western Office was opened in Calgary in 1969 in the Institute of Sedimentary and Petroleum Geology of the Geological Survey with Barron taking charge; Bielenstein and Grant transferred from Elliot Lake, and S.R. Cook from the Rock Mechanics Laboratory in Ottawa. The long-term view of mining thick seams was invoked. The thick seams of Lorraine in the northeast of France and of Loire in the central region provided opportunities for detailed studies during 1970 to 1972 through the courtesy of Charbonnages de France, first by a preliminary visit by Cochrane in 1970 and by a one-month sojourn by Coates in 1971. These visits were followed by a three-month study in 1972 by a group headed by Barron with Prof. L. Juteau of Ecole Polytechnique, G. Raymond and J.M. Couetdic, the latter joining the group in France and later spending several months with the mining group in Alberta. These investigations were reported in the technical literature as follows: "Underground mining of thick coal seams" by T.S. Cochrane (Trans CIM, vol 75, pp 160-170, 1972). This paper described thick seams in various countries of the world; another paper was prepared jointly with G. Ellie, chief mining engineer of Charbonnages de France: "Three mining methods for vertical, inclined and thick coal seams used in France" by D.F. Coates, T.S. Cochrane and G. Ellie (Trans CIM, vol 75, pp 96-102, 1972); Barron made a detailed analysis of longwall mining of the thick, flat seams of the Blanzy (Saône et Loire) coalfield in France: "The mining of thick, flat coal seams by a longwall bottom slice with caving and drawing" by K. Barron (MB TB 189, 1974).

In 1973, mining consultant J. Battarel from the SOFREMINES organization in Paris spent some time in

Western Canada reviewing mining conditions at the Grande Cache mine of McIntyre, and at the Coleman and Kaiser mines in the Crowsnest area. This entire project was based on the hope that the transfer of French mechanical mining technology suited to thick seams could be tried in a joint demonstration project in Canada. This required, of course, a cooperative undertaking with one of the mines. This did not eventuate as the industry was satisfied with the relatively shallow hydraulic mining method that was on trial at the Kaiser mine. There was a general feeling that deep mining could be postponed as large deposits of coal were still available at shallow depths. Battarel also made a report on underground hydraulic mining and gave advice on methods used in France of estimating mineable coal.

Some study was undertaken by the Western group mainly by Dr. M.Y. Fisekci (1971 -) on methane and its characteristics of outflow from coal; also a cooperative study with the Kaiser company was started later on the spontaneous combustion of coal in hydraulic mines and other sites.

Since 1972 a jointly financed program between the Province of Saskatchewan and Canada was undertaken to evaluate the coal-bearing Ravenscrag formation in areas of southern Saskatchewan such as Estevan, Willow Bunch, Wood Mountain and Shaunavon (Cypress). Several agencies of both governments were involved in this important project which continues at this writing. The Department of Mineral Resources and the Saskatchewan Research Council represented Saskatchewan, with S.H. Whitaker being the project coordinator. T.E. Tibbetts was the project leader for CANMET in relation to the sampling and analytical work, geologists from the GSC, and representation from the Energy Sector contributed from the Department of Energy, Mines and Resources. This extensive investigation involved the drilling of several hundred boreholes and the analyzing of some 4900 samples in the Ottawa laboratories by W.J. Montgomery and his staff: "Quality evaluation of Saskatchewan lignite resources" by T.E. Tibbetts (CIM Bull, Oct 1975). The quantity evaluation was carried out by Saskatchewan officials and the indications were that the reserves would be less than those of the earlier federal estimates. It was hoped that the complete investigation would provide data on coal thicknesses, strip ratios, and a mining exploitation index to identify optimum mining areas.*

In 1974, by arrangement with the Department of Regional Economic Expansion and the Nova Scotia Government, a drilling, sampling and analytical joint program was developed for the Springhill and Stellarton areas on the mainland and on the west coast of Cape Breton Island to evaluate the reserves of coal in these areas. CANMET was responsible for the sampling and analytical work which was done mostly by D.J. O'Brien at the Point Edward Laboratory in North Sydney which had functioned from 1965, initially in Glace Bay and then in North Sydney, mostly on sampling and sample preparation of coal supplied to federal government plants. This avoided the transportation of large bulk samples to Ottawa. The laboratory was responsible to T.E. Tibbetts.

*A joint publication by Saskatchewan and EMR titled "Quality occurrence of coal in southern Saskatchewan, Canada" Vol 1 by J.H. Dyck, C.T. McKenzie, T.E. Tibbetts and S.H. Whitaker, was issued in 1979. (Available from the Saskatchewan Research Council)

Sulphur Forms in Bitumen and Heavy Oils

The sulphur forms of light fractions derived from bitumen and heavy oils such as gasoline and diesel oil were known, whereas the heavy fractions, for example gas oils, were not. The study of sulphur compounds was important scientifically particularly in relation to the origin of the low-grade hydrocarbons because of environmental concerns related to emissions and spills of high-sulphur oils and bitumen. Accordingly, in 1969 research was started in developing improved gas chromatographic techniques coupled with mass spectrometry, the latter being introduced into the Fuels Research Centre in 1967. Various inorganic materials were studied for use as column packing in the separation of sulphur compounds and petroleum fractions. Lithium chloride on siliceous materials was found to be particularly effective for separating sulphur compounds. Two research reports on this phase were published: "Evaluation of lithium chloride-diatomaceous silica systems for gas chromatography of petroleum sulphur compounds" by A.E. George (NRC Postdoctorate Fellow, Mines Branch from 1973) G.T. Smiley (1969 -) and H. Sawatzky (MB RR 249, 1972); "The evaluation of lithium chloride-coated porous silica for gas chromatrographic separation of petroleum fractions" by H. Sawatzky, A.E. George and G.T. Smiley (MB RR 260, 1972).

A two-step gas chromatographic technique was used on five samples of two heavy crudes and three fuel oil spill samples from the Arrow and Irvine Whale wrecks off the Maritimes. This indicated that the method was suitable for identifying spills: "A gas liquid-gas solid chromatographic method for the identification of sources of oil pollution" by A.E. George, G.T. Smiley, D.S. Montgomery and H. Sawatzky (MB RR 267, 1973).

The sulphur compounds from the gas oil fractions were derived from Athabasca oil sands, Cold Lake oil deposit, Lloydminster field, and a Cretaceous light oil from a deep reservoir near Calgary. Predominant sulphur compounds in these gas oil fractions were benzo and dibenzo-thiophenes: "Sulphur compounds in oils from the Western Canada tar belt" by D.M. Clugston, A.E. George, D.S. Montgomery, G.T. Smiley and H. Sawatzky (MB RR 279, 1972).

These heavy hydrocarbons were studied for thermal maturation and compared with the lighter Medicine River oil from the reservoir near Calgary. The thermal maturation increased in the following order: Athabasca, Cold Lake, Lloydminster, and Medicine River: "Geochemical investigation of oils in the Western Canada tar belt" by D.S. Montgomery, D.M. Clugston, A.E. George, G.T. Smiley and H. Sawatzky (MB RR 270, 1973).

Uranium Reserves Evaluation

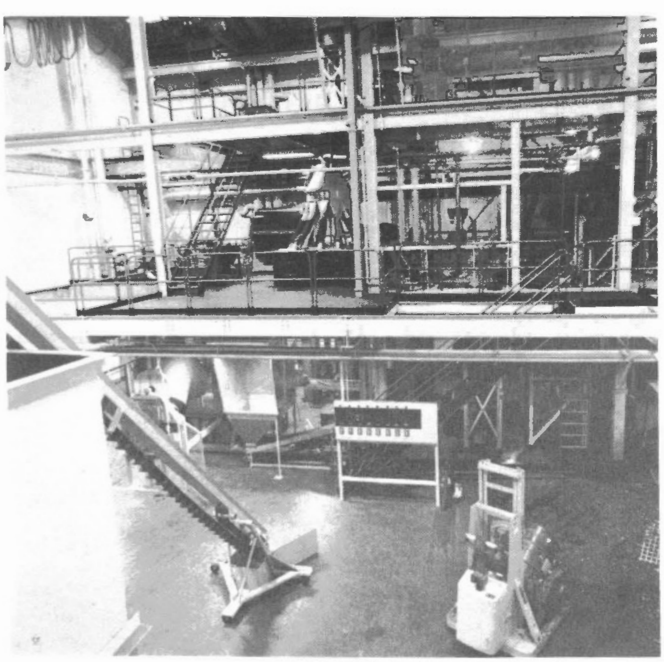
An urgent program of uranium reserves reappraisal was started in 1974, first in the Elliot Lake area. Ore reserves were reappraised in the light of world prices and increased production costs. Welwood from the Mining Information Centre was transferred to this program which was departmental in character and included the Geological Survey and the Energy Policy Sector. Some preliminary work in rock mechanics was started on the problems which could be encountered in underground nuclear waste repositories.

Energy Processing

Coal

In 1972 and 1973 a cooperative project between Devco and the Mines Branch was carried out with a 10-ton per hour compound water cyclone plant designed and constructed by Visman and his group at the Western Regional Laboratory. The plant was re-erected at Devco's new coal mine at Lingan in Cape Breton Island and was operated for several months. The technical feasibility of producing metallurgical-grade coal with a content of sulphur not exceeding 1.2 per cent, and a middling for thermal power stations was demonstrated. Data from the EMR plant provided important information on cleaning characteristics of the Harbour seam at Lingan for use in the design of a full-scale plant which was in the course of construction. An updated description of the EMR compound water cyclone process was published in 1971: "Coal washery design - I: The EMR process by J. Visman (MB TB 141, 1971). The use of electronic computers enabled the evaluation of recirculating loads in the system: "Coal washery design II: The computation of recirculating loads" by Jacqueline L. Picard (MB TB 142, 1971). The application of the EMR process as a bulk cleaning method of friable high-rank coals in stages at a plant which had been in operation for a long time was described in a paper prepared at the 6th International Preparation Congress in Paris: "Integrated process for beneficiation of friable smalls" by J. Visman and D. Riva (Canmore Mines Ltd.) (Proc 6th Intl Coal Prep Congr Paper E6, 1973). A further contribution to the statistical field was made by J. Visman and Jacqueline L. Picard in "Guide to engineering statistics" (MB IC 233, 1970).

In 1974, by arrangement with the Nova Scotia Department of Mines, a plant using cyclones of the EMR type was installed at Stellarton, Nova Scotia, to recover reject coal from old washery waste piles estimated to contain thermal coal valued at $2.5 million. In 1975 the processing of 125,000 tons of dump material was achieved with a recovery of 35,000 tons of saleable coal.



10-ton per hour compound water cyclone plant (EMR Process) Western Regional Laboratory, Edmonton

The cleaning of lignites from high clay content areas was investigated and it was found that the combination of desliming and gravity separation with compound water cyclones would produce a satisfactory thermal grade product. Research was carried out on lignites to overcome a principal disadvantage of this class of coal because of its high sodium content which lowered the ash fusion temperature. By adding calcium chloride to the pulp undergoing cleaning, about half of the sodium was removed, increasing the fusion temperature by about 200°F. A Canadian patent on "Process for treatment of lignite and similar low-rank coals" was issued to van Cruyningen, Visman, Charbonnier and Walsh. Development of a clarification process aimed at reducing the size of settling facilities for coal washery effluents was continued at WRL; this employed flocculation, prethickening with cyclones and bottom fed thickening.

Bitumen and Heavy Oils

By the end of the sixties when the Fuels Research Centre was established in the Bells Corners complex, hydrocracking of bitumen, heavy oils and residues with the formation of pitch instead of coke was intensively studied as an alternative strategy. Bench-scale research was conducted from 1971 to 1974 on thermal and catalytic hydrocracking to determine the effect of operating variables. Six research reports were issued in the series: "Hydrocracking of residual oils and tars" - RR 246, 253, 256, 261, 263 and 273; the authors being E.C. McColgan, R.G. Draper, B.I. Parsons, P.S. Soutar, J.M. Denis and M. Rethier. This work indicated that hydrocracking produced in excess of 10 per cent more liquid distillate product than by coking. A pilot-plant study of thermal catalytic hydrocracking was conducted in 1973 with encouraging results in that a high percentage of the pitch (91%) was converted to distillable products whereas the mineral matter and metals (nickel and vanadium) were retained in the small amount of pitch residue. The amount of pitch residue can be varied in practice to suit the requirements of energy which can be supplied by the pitch. In this study, M.P. Pleet and R.W. Beer were the chief technicians and the analytical work was done by R.G. Draper and B.I. Parsons and their staffs. "A pilot scale investigation of thermal hydrocracking of Athabasca bitumen" by W.H. Merrill, R.B. Logie and J.M. Denis (MB RR 281, 1973).

The second step in refining is the treatment of the distillates from the hydrocracking step to reduce sulphur and nitrogen to acceptable levels and to decrease the aromatic hydrocarbon content.

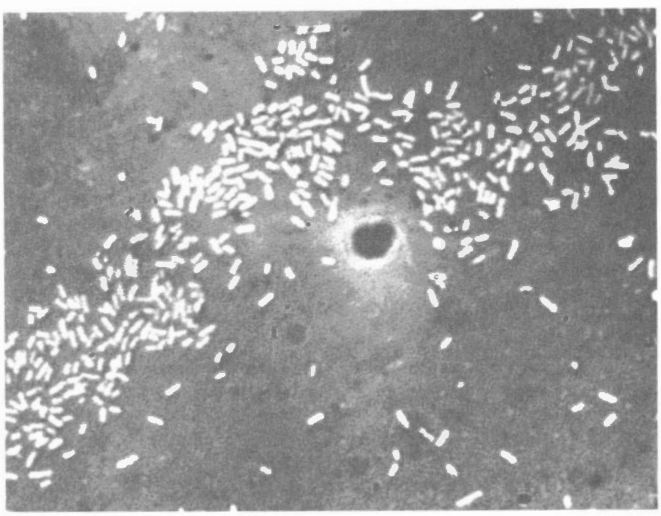
Although vapour-phase catalysts were available on this continent there was a dearth of suitable liquid-phase catalysts. A considerable effort was made in 1975 to develop low cost catalysts such as coal, using it as a "getter" or catalyst support, or alternatively to develop a low-cost catalyst that could effectively be rejected in the pitch after passing through the liquid-phase reactor once. Two research reports were written on this subject: "Evaluation of

M.P. Pleet and R.W. Beer of Fuels Research Centre supervise continuous run of hydrocracking plant

catalysts for the liquid-phase hydrogenation of refinery vacuum residuum" by W.A.O. Herrmann and K.W. Bowles (MB RR 280, 1973), and "Hydrocracking Athabasca bitumen in the presence of coal, Part I: a preliminary study of the changes occurring in the coal" by M. Ternan, B.N. Nandi and B.I. Parsons (MB RR 276, 1974).

Uranium

Increased attention to uranium processing was renewed in the Extraction Metallurgy Division from about 1966 when nuclear based electric power could be competitive with fossil fuels. Projects undertaken were related to preconcentration of low-grade ores, bacterial leaching of iron sulphide-bearing ores and techniques for the development of mathematical models of processes which could be used either for process control or for the specification of optimum process conditions: "Leaching of uranium from Elliot Lake ore in the presence of bacteria" by V.F. Harrison, W.A. Gow and K.C. Ivarson (Can Mining Journal, pp 64-67, May 1966). A state-of-the-art report on uranium processing was published in 1969: "The treatment of Canadian uranium ores - a review" by W.A. Gow and G.M. Ritcey (Trans CIM, vol 72, pp 361-370, 1969) and "Bacteria-based processes for the treatment of low-grade uranium ores" by W.A. Gow, H.H. McCreedy, G.M. Ritcey, V.M. McNamara, V.F. Harrison and B.H. Lucas. The recovery of uranium (Proceedings of the International Atomic Energy Agency, pp 195-211, Vienna, 1971).

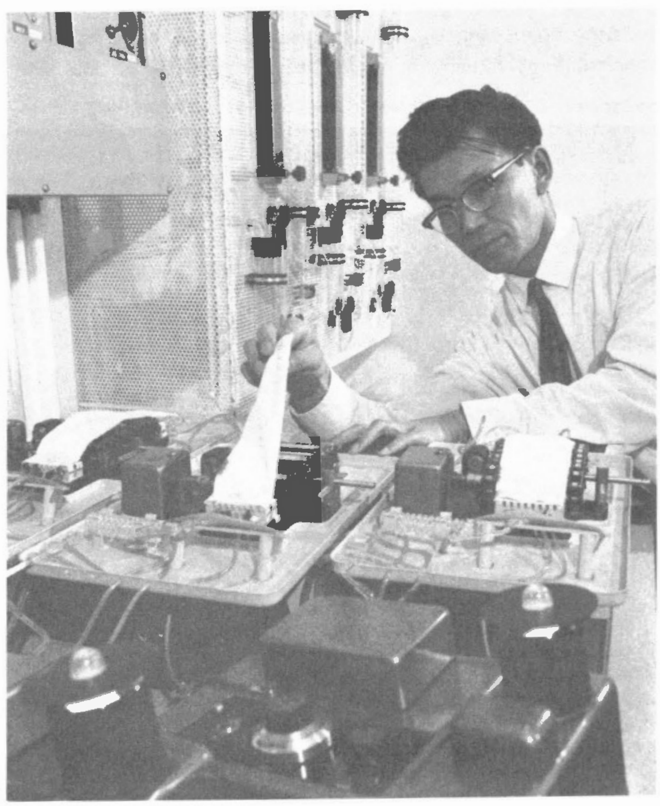


Bacteria thiobacillus ferroxidans (x 4300) used in uranium leaching

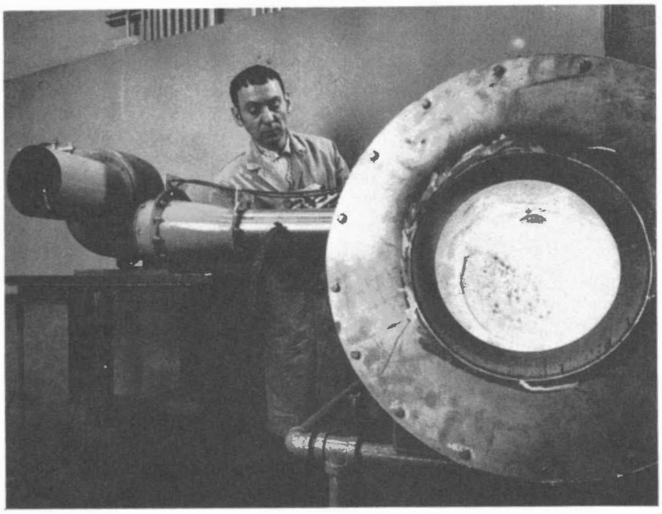
<u>Energy Utilization</u>

Combustion

As indicated earlier under fuels, combustion was the principal use of fossil fuels in the process of energy production. In this activity, conservation and pollution control played a dominant role from the late sixties, though as mentioned previously, suppression of smoke from coal in the era when it was in general use had always been the aim of the Mines Branch combustion program. With the department's formal recognition of the importance of the protection of the environment,



G.K. Lee works on continuous monitoring of combustion source pollutants



D.G. Savignac tests after-burner of research coke oven

a report on air pollution was prepared in English and French: "Air pollution: causes and control" by H. Whaley, F.D. Friedrich, G.K. Lee and E.R. Mitchell (English and French texts) (MB IC 211, 1968). Mitchell was sensitive to a combustion engineer's responsibility for pollution and published three information circulars for general public information: "Only people pollute" by E.R. Mitchell (MB IC 268, 1971); "Inventories of national and individual air pollution" by E.R. Mitchell (MB IC 269, 1971), and "Fuel consumption and air pollution trends in Canada, 1965-1980" by E.R. Mitchell (MB IC 279, 1971).

The research projects of the Canadian Combustion Research Laboratory were essentially directed towards improvement of combustion efficiency to achieve optimum environmental improvement. These were as follows:

(a) Suppressing the main pollutants - sulphur and nitrogen oxides, carbon monoxide and smoke - within the flame: "Automated system for continuous monitoring of CO_2, CO and O_2 in boiler flue gas" by R.K. Jeffrey (1968-) and G.K. Lee (MB TB 115, 1969), and by the same authors: "Automated system for continuous monitoring of SO_2, NO_2 and NO_x in boiler flue gas" (MB TB 131, 1970).
(b) Improving the efficiency of collecting fly ash.
(c) Controlling emissions from stacks by selecting the necessary heights for adequate atmospheric dispersion of pollutants. This work resulted in a CSA standard. Helicopter surveys in several different physiographic locales were made: "Dispersion of multiple plumes from a large thermal generating station" by H. Whaley, L. Shenfeld, G.K. Lee, M.S. Hirt and S.J. Djurfors (Proceedings of the 8th World Energy Conference, Bucharest, Roumania, 1972; MB RS 119); "Plume dispersion research at natural-gas sulphur-extraction plants" by G.K. Lee, H. Whaley and J.G. Gainer (MB RR 265, 1973); and "Plume dispersion from a thermal power station on the shore of a large lake" by H. Whaley and G.K. Lee (Journal of the Institute of Fuel, pp 242-250, vol 47, Dec. 1974).
(d) A patented design for an air-swirl generator was developed. This could be fitted to existing residential burners to produce a soot-free (blue) flame from house heating oil.

The laboratory assisted other groups in the branch in pollution abatement problems.

Coal Slurries

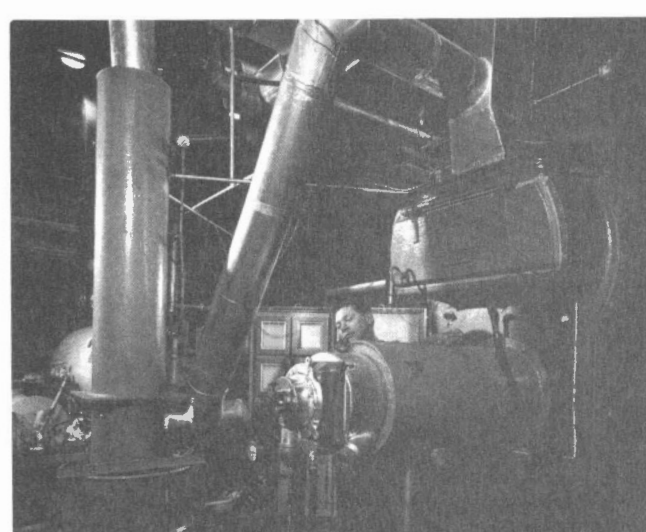
Coal slurry technology was revived through the trend toward greater use of coal in industry. On-going R & D in the combustion of coal-in-oil slurries demonstrated that this fuel was an acceptable substitute for oil in industrial boilers.

Coal-in-water slurries were again studied in relation to transportation of coal mined by hydraulic methods, and for intermediate distances. Studies were done earlier at the Western Regional Laboratory which were related to the problem of "reconstitution" of coking coal after water slurry pipelining to allow coking in the conventional carbonization process.

Incineration and Waste Heat Utilization

Thermal destruction of the prohibited pesticide, DDT, suspended in oil, was developed and the data were used for large-scale demonstration at the DRB Proving Grounds at Suffield, Alberta: "Thermal destruction of DDT in an oil carrier" by H. Whaley, G.K. Lee, R.K. Jeffrey and E.R. Mitchell (MB RR 225, 1970). Research was continued on the destruction of DDT in powder form: "Thermal destruction of DDT-bearing powders" by G.K. Lee, F.D. Friedrich, B.C. Post (1961-) and H. Whaley (MR RR 234, 1971).

Friedrich developed ideas on the design of equipment for incineration of city wastes and recovery of heat therefrom: "Equipment for incineration of municipal waste" by F.D. Friedrich (MB TB 134, 1971) and "Incineration of polymers - a combustion engineer's viewpoint" by the same author (MB TB 135, 1971).



B.C. Post operates a combustion system for thermal destruction of DDT

Feasibility studies on district heating, incineration and waste heat utilization resulted in recommendations for design of heat recovery boilers, combined coal-garbage combustion processes, etc.

Fluidized-Bed Combustion

At this narrative's conclusion the new technology of fluidized-bed combustion was being studied with a "hot" model. The advantage of this technology over fixed-bed combustion is the high rate of heat-transfer within the furnace. This allows the utilization of small-size, variable, and low-grade fuel such as colliery rejects; in addition, sulphur could be contained, through the addition of limestone to the fluid bed.

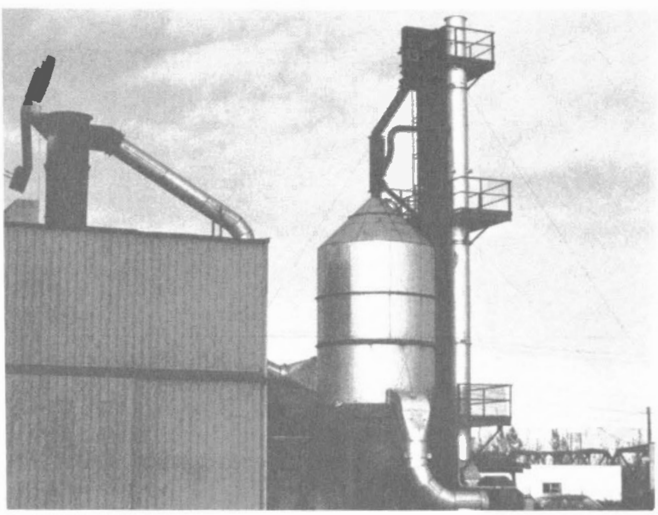
Cupola Emissions

A sampling technique was developed by the Physical Metallurgy Division and applied to six foundries over a twelve-week period: "Sampling and characterization of cupola emissions" by R.D. Warda and R.K. Buhr (MB RR 266, 1974). A second project by the Physical Metallurgy Research Laboratories was the development of a packed-bed simulator for studying particulates and gaseous emissions from cupolas and pyrometallurgical processes in general.

Pipelines and Metal Use in Arctic

An important contribution by the division was made starting in 1970 on pipeline metallurgy with a special facility developed for these studies. Attention was given particularly to the requirements of Arctic climate because of the number of future pipelines which would be built in Northern Canada. Gertsman, before his illness, addressed a large number of American Society for Metals chapters on "metals and alloys for Arctic use". He mentioned the publication of a monograph on metals and alloys for use in the Arctic, which was then in preparation. The volume was published early in 1976: "Metals and alloys for Arctic use" by staff of Physical Metallurgy Research Laboratories (edited by R.C.A. Thurston) (CANMET Report 76-1, 1976).

M. Letts cuts test sample from large diameter commercial gas pipe



Packed-bed filter and stack at Thor Foundry Ltd., Winnipeg

Mineral Supply

Mining

In the light of Canada's mineral production being derived from open pit mining to the extent of 70 per cent, Coates concluded after several years of observation and encouraging benefit-cost studies that higher recoveries could be obtained from steeper pit wall angles without endangering the safety factor of the pit. Accordingly, a major effort was launched in 1972 in field and office studies using a large proportion of external contracts to evaluate a number of parameters on which data were lacking. The aim was to produce an engineering manual on pit slopes for all minerals including coal. This project took about five years and cost about $4 million of which about 40 per cent was contributed by the Canadian mining industry.

Because of the importance of this project, the results are projected beyond the 1975 limit of this narrative (148). Following publication in 10 main chapters and 16 supplements, industry seminars were organized for briefing and discussion. The initial indications were that the 26-volume manual was well received and can be considered as an outstanding achievement. Provision was made to publish further supplements from time to time.

Mine stability was the principal aim in the ground control project of the mining program, and particular attention was paid to base metal mines because of the proportion derived from underground mining. As limits of open pit mining are passed, stability problems arise in the first stages of underground mining. Thus in 1974 a cooperative project was started with Ecstall Mining Company; a series of model studies using the finite element technique was conducted and the effect of regional tectonic stresses on mine excavation was incorporated in the models.

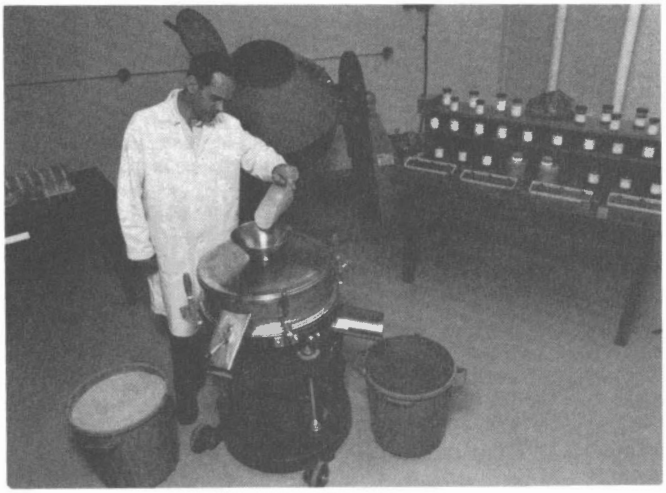
An extraction of about 65 per cent was being achieved in the initial period of mining in the Elliot Lake mines and consideration was given to a study of optimization of recoveries without affecting stability. Deep mining methods used at depths in excess of 3000 feet such as cut-and-fill were to be closely investigated.

CANMET, in conjunction with the Geological Survey, the Earth Physics Branch, AECL and INCO Metals Limited started on the design of a repository for nuclear wastes. A simulated, heated chamber was to be excavated at Sudbury. CANMET was to supply the expertise on rock mechanics.

Analytical Methods and Reference Materials

In Chapter 6 reference was made to the considerable research and development in analytical methods and to the participation of the Mineral Sciences Division's laboratories in national and international standardization methods. In the late sixties, research was conducted on the platinum group metals. In the seventies the "Canadian Certified Reference Materials Project" was formalized and developed for metallic minerals and metals which were divided into three groups - ores and concentrates analyzed mostly by chemical methods, radioactive ores by radiometric methods, and metal alloys by spectrographic methods. These reference materials were available for purchase by interested parties.

Laser-theodolite mounted on GSC-type monument at Kidd Creek open pit mine. Used to measure distance and angles in connection with ground movement monitoring



D. McIntosh prepares ore samples for use as certified reference material

A comprehensive methodology of analyzing ores and rocks was compiled and published in a ring binder form by Elsie Donaldson in the last issue of the Mines Branch Monograph series. "Methods for analysis of ores, rocks and related materials" by Elsie M. Donaldson (MB Mono 881, 1974).

Mineral Processing

Base Metals and Iron Ore

Emphasis was placed on improving the recovery of base metals from the complex finely disseminated silver-bearing ores of New Brunswick which yielded recoveries of about 65 per cent. It was expected that improved extraction methods could increase recovery to 85 per cent. A combination of flotation and hydrometallurgical methods is being tried out at this writing and arrangements are being considered for external contracts.

As regards iron ore beneficiation, research was revived on the treatment of the low-grade ore from the area of Peace River, Alberta. Flotation, gravity concentration and high-intensity magnetic concentration were tried but the recoveries were only in the 50 per cent range. A pyrometallurgical method in which a pellet was fabricated from the ore in intimate contact with the reactive char was made from a Western subbituminous coal; this produced a pig iron (D.A. Reeve and J.H. Walsh, MB RR 277, 1974).

Aluminum

Because of large price increases in imported bauxite due to political uncertainties in the producer countries, North American aluminum production looked for possible substitutes. CANMET was invited to participate in this inquiry as it did in World War II. Some research was undertaken by the industrial minerals group: "Extraction of alumina from Canadian and American anorthosite by the lime-soda-sinter process" by D.H.H. Quon (1975-), Industrial Minerals Laboratory (CANMET Report 76-26, 1976).

Industrial Minerals - Clays and Phosphate Rock

A substantial increase in the metallurgical use of pellets bonded with bentonite and corresponding increases in its price suggested improved possibilities in beneficiating the low-grade Canadian bentonite deposits. Similarly, it was felt that low-grade Canadian kaolin might be able to compete with imported material. The deposits were to be reviewed for this purpose.

Deposits of phosphate rock were to be re-examined as possible substitutes for imported material. These three minerals accounted for more than $20 million in imports.

Waste Recovery

A survey of mining wastes such as mineral processing rejects for possible use in construction and ceramics was being compiled on a provincial basis: "Mineral waste resources of Canada, Report No. 1 - Mining wastes in Ontario" by R.K. Collings (CANMET Report 76-2, 1976).

Regarding metal waste, an on-line sorting apparatus was being developed by the Physical Metallurgy Division to separate non-magnetic alloys from automobile shredding operations. In regard to recycling of copper alloys, the division intended to investigate the trade's restrictive attitude towards the use of copper waste.

Mineral Utilization

Transportation, Metallurgical Improvements

Two projects were being investigated in the Physical Metallurgy Division: weldable rail with superior wear properties, and the evaluation of metals, particularly of high-strength steels and aluminum alloys which might be used in producing lighter automobiles, thus reducing the demand in energy.

Matrix Management

The matrix two-arm-management system which Coates tried out in the decentralized laboratories of the Mining Research Centre was put into effect for the whole branch in 1975.

In essence this was an appropriate management technique which superimposed the program on the functional or discipline/commodity oriented units known as divisions or centres. This system easily permitted the blending of external research contracts with in-house research - a situation encouraged by the government in its make-or-buy policy. As mentioned in Chapter 3, Haanel used an approximation of this approach for more rapidly developing the expertise of a small in-house staff by hiring consultants and contracting research to universities.

On the functional side, there was a reorganization which essentially amalgamated the three divisions of related minerals research and development work: Mineral Processing, Extraction Metallurgy, and Mineral Sciences - into the Mineral Sciences Laboratories (MSL). The name "division" or "centre" was dropped for all "laboratory" divisions, and "Fuels" was changed to "Energy" as follows: Mining Research Laboratories (MRL), Energy Research Laboratories (ERL), Physical Metallurgy Research Laboratories (PMRL). The Technical Services Division remained the same. The library, technical information and editorial services were brought together in the Technology Information Division in 1975.

A Research Program Office was initiated in 1975 and the first appointments were:

Minerals Research Program:

Director - W.A. Gow
Activity leader, Supply - Dr. D.G.F. Hedley
Activity leader, Processing - L.L. Sirois
Activity leader, Utilization - Dr. D.W.G. White

Energy Research Program:

Director - Dr. D.S. Montgomery
Activity leader, Supply - E.D. Dainty
Activity leader, Processing - D.K. Faurschou
Activity leader, Utilization - Dr. E. Smith

A contracts officer and an economist were also appointed to the Program Office in the persons of G.W. Riley of the Mineral Processing Division and G.S. Bartlett respectively.

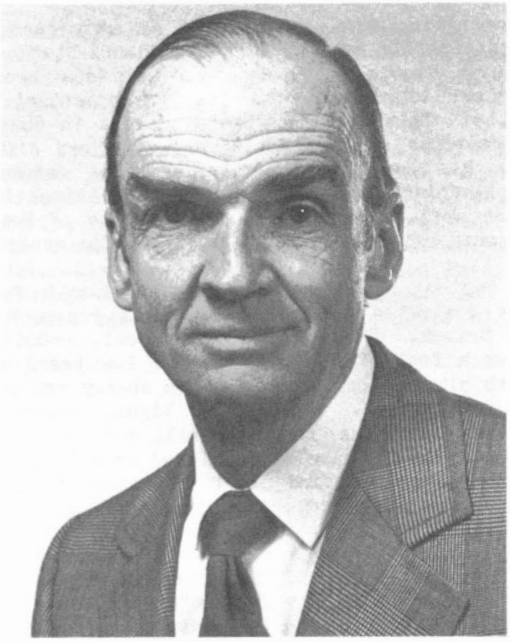
To provide opportunities for the technical and professional staff to become acquainted with management methods, provision was made to rotate the staff from the functional units to the Program Office and to the office of the assistant deputy minister, Science and Technology.

The positions of the director and deputy director were elevated to director-general and deputy director-general in 1975, with Dr. Coates and Vic Haw the incumbents.

DONALD FRANCIS COATES, SIXTH DIRECTOR OF THE MINES BRANCH (CANMET)

Dr. Coates was born in Prince Albert, Saskatchewan in 1923. He interrupted his university studies in 1943 to join the R.C.A.F. He graduated from McGill University with a B.Eng. in 1948, M.Eng. in 1954, and Ph.D. in Mining Engineering in 1965. A Rhodes Scholar in 1948, he received an M.A. in Political Economy from Oxford University, England, in 1954.

He was an assistant professor of Engineering at McGill University from 1951 to 1957, director of Carleton University School of Engineering from 1957 to 1959, and a research consultant from 1959 to 1963, during which time he was associated with a number of mining research projects of the Mines Branch.



Donald Coates, Sixth Director of Mines Branch (CANMET)

Dr. Coates joined the Department of Mines and Technical Surveys in 1963 as head of the Mining Research Section and in 1967 he became chief of the Mining Research Centre. One of his many accomplishments was the publication of "Rock mechanics principles", which gained international recognition as, besides English and French texts published in Canada, Spain requested publication for Spain and Spanish speaking countries. In 1974, the Central Southern Institute of Mining and Metallurgy in the People's Republic of China started to translate this volume into Chinese.

In November 1973 Dr. Coates was appointed director of the Mines Branch, becoming director-general in 1975, the year the name of Mines Branch was changed to the Canada Centre for Mineral and Energy Technology (CANMET). In this capacity he supervises research and development programs on the production, processing and utilization of minerals, fuels and metals.

He was awarded a Fellowship of the Royal Society of Canada in 1969 and of the New York Academy of Sciences in 1972, and recently a Doctorate of Engineering degree, Hon. causa, University of Ottawa. Dr. Coates was guest lecturer at the University of Arizona in 1968 and an adjunct professor from 1973 to 1976; he was also guest lecturer at the University of California, Berkeley in 1969, and part-time professor at McGill University from 1965 to 1973 and at Ottawa University from 1970 to 1973. He was a Member of the Board of Directors, Centre for Resource Studies of Queen's University, 1974 to 1978. He was Chairman of the Canadian Advisory (later Canadian National) Committee on Rock Mechanics from 1963 and 1978, and Member of Council, International Society for Rock Mechanics from 1966 to 1978, as well as Member of the International Organizing Committee, World Mining Congresses, 1973 to date. He is a member of several scientific and professional organizations and societies in Canada and overseas.

Dr. Coates is a highly competent and dedicated engineer and research scientist with a considerable grasp of economics who is continuing a personal contribution to research and development work in rock mechanics. Two major R & D projects demonstrate his intellectual capabilities: the world-calibre treatise on rock mechanics and the comprehensive scientific and engineering guide to openpit mining. Dr. Coates demonstrated his organizing capabilities in reorganizing the Mines Branch in less than two years to a program orientation in accordance with the government and departmental requirements. His introspected and reticent characteristics are in sharp contrast with the relaxed ways of his predecessor, Dr. Convey.

Concluding Remarks

This historic account has endeavoured to present the research and development conducted during three quarters of this century in a continuing institution of five successive federal government departments - Interior; Mines; Mines & Resources; Mines & Technical Surveys; and Energy, Mines & Resources. This work contributed to the solution of problems of production, processing and product improvement as well as promoting conservation of the variety of mineral resources. The narrative has also tried to give some indication of the economic status of some of these resources.

In a territorially large country like Canada, with an area of nearly four million square miles, one could expect that a reasonably large proportion of the world's minerals would be found, and in fact there is an impressive array of some 60 minerals available in this country which are either economic or potentially so. However, they are unevenly distributed across the regions and a large proportion is of low grade and complex composition requiring costly processing and refining. A glaring example of the uneven mineral distribution is the concentration of metal ores in Ontario and Quebec with the absence of fossil fuels, and the reverse in Alberta where fossil fuels are abundant but metals are poorly represented. Even the highly successful Ontario steel industry is still supplied by imported coal and some iron ore from the United States. Though Ontario possesses iron ore resources, they are of low grade and limited in quantity in comparison with Quebec and Labrador. The latter were known to the Geological Survey from the turn of the century but required considerable investment in the post-war era to finance the production capacity of large open pits and transportation facilities for a large iron ore industry in Canada. The foregoing is given as an example of the circumstances Canada had to face in developing a basic industry that represents the sinews of a country's industrialization.

Future historians will probably record the 20 to 25 post-war years as the period of the fastest growth rate in Canada. All resources in varying degrees prospered during this period with exportable surpluses creating wealth for a comparatively small population living in a large land mass.

The mineral industry was the pace setter with an eightfold increase in value of production at a time when costs were reasonably stable. The mineral exports represented about one third of the total merchandise exports. The total value of mineral production in the twenty years from 1947 amounted to about \$42 billion (unadjusted) compared with approximately \$12 billion in the previous 61 years to 1946. This indicates a tenfold increase in the 20 post-war years without taking into account the modest rate of inflation during this period. In physical terms the quantity of mineral ores mined or quarried rose from about 100 million tons per annum in 1950 to about 375 million tons in the late sixties. The figures are approximate as waste rock was included for the open pit asbestos mining in the early period, but they do indicate the accelerated rate of depletion.

This rate of growth was brought about largely through demands arising from the reconstruction and renewal following World War II. In the mid-sixties as Canada was beginning to feel relieved that U.S.A. mineral exports were starting to diminish, the Third World and the Soviet Union and their associates took over and became increasingly our competitors. It should be remembered that although wages are lower in most parts of the world than in North America, machines which essentially increase productivity and lower costs are becoming available to the whole world.

Reference has been made to the low grade and complexity of mineral resources of Canada. This unfortunately is true of all classes of minerals. It might be said that the "raison d'être" of Mines Branch existence was the growing realization in the early years of this century that Canada was endowed with a mineral patrimony of considerable variation in quality.

The present position in ferrous metals is that most of the Canadian iron ore has to be beneficiated to increase the iron content of the feed to maintain a high productivity of ironmaking blast furnaces which havè become high cost investments. Two important additive or alloy metals in steel are manganese and chromium which occur in Canada but these ores are of low grade. Considerable effort by the Mines Branch was made during the war periods to use domestic ores but these were not able to compete in peace-time. Nickel on the other hand is one of the important additives in which Canada is a leading world producer.

In base metals such as copper, zinc and lead, the main problems are related to the complexity of the ores which are composed of a mixture of sulphides of these metals, intimately associated with unwanted minerals and impurities which affect recovery of the vendible components. Many of these ores also contain gold and silver which contribute in an important way to Canadian precious metals production. As grades fall and world prices rise, coupled with attempts to contain sulphur emissions from smelters, there will be an increased tendency for the cheaper physical methods of separation to be replaced by more costly chemical extraction though yielding higher recoveries.

The history of gold mining in Canada as recounted in this narrative has been an "up and down" story. In 1941 Canada produced over five million ounces which helped to finance the war effort, yet by 1948 the Emergency Gold Mining Assistance Act had to be passed to keep these mining communities operating. At this period the mines could not operate profitably at the world price of gold of $35.00 U.S. per ounce. Costs in relation to grade of ore even at today's inflated prices do not allow a substantial increase of the country's gold production.

Industrial minerals such as ceramic clays, phosphate rock and high-grade silica have been vulnerable to competition from cheaper and in many cases better quality minerals available in the United States. Large areas of Canada have undergone surface erosion in geological times with the loss of potential surface deposits. This fact is also evidenced in some of the coal deposits of the Maritimes. Whereas the United States has remarkably well developed Carboniferous (Pennsylvanian) coal deposits, the Maritimes have not been as well endowed, and, in the case of New Brunswick, only one thin seam is available for exploitation.

Various problems of Canadian fossil fuels and others dominated the story of fuels research at the Mines Branch. However, Canadian coal, considered by many as a fuel of the past only a few years ago, has come to play an important role in energy and metallurgical application. The era of light, easily refined petroleum resources seemingly will not last for long, and reliance will have to be placed on oils and bitumen requiring a complex and costly refining technology for all the numerous products on which we have become so dependent.

Uranium is one of the minerals which is plentiful in Canada, not only in the large, low-grade deposits in Ontario for which extraction technology has been developed and improved upon, but also in the higher grade though mostly smaller deposits in Saskatchewan and occurrences which continue to be investigated.

At this epoch, open pit mining predominates in Canada, though as mentioned earlier Canada has the largest number of underground metalliferous mines in the world. Increasingly, mineral wealth will have to be obtained from greater depths, resulting in costly mining even if the present degree of mechanization were to be substantially increased.

The size of Canada provides reasonable assurance of continued supplies of mineral wealth. As Canada's own requirements will probably remain small compared with the export potential until the population is substantially increased, the well-being of mining and allied industries will depend on the economic conditions prevailing in the world as a whole as well as on developments in the "Third World" related to their mineral production capabilities. Continuous study of Canada's mineral resources by geologists, engineers, research scientists and mineral economists, supplemented by as much knowledge retrieval on mineral industries of the world as circumstances allow, is of paramount importance to forecasters and decision-makers.

Everyone agrees that our present existence is dominated by science and technology, yet wide sections of the society are not equipped to comprehend much that is said or written by technical specialists. The public and the media consider it their right to know at least the effects of application of specific technologies. For example, part of the difficulty with the nuclear energy field has been its complex technology which was not understood by the layman, and what a human does not understand he usually fears. A larger number of interpretative science writers would of course help to overcome this difficulty, but the present number is insufficient to adequately cover the field of science and technology. Furthermore, the complexity of and rapid changes in technology, related to resources and the industrial domain can be expected to grow. Long lead times, particularly for larger projects, as clearly evidenced by the nuclear and heavy oil (bitumen) plants in the energy field, can also be anticipated. The assembly of capital equipment and skills, not the least in the engineering trades, will become major undertakings.

To a small extent the same difficulty is present in government as there has been an increase in generalists in the decision-making bureaucracy. The scientist particularly, is usually careful in making generalizations and tends to make qualified statements, whereas the decision-maker prefers the generalized case. Misunderstandings may arise from this situation. Imprecise or loose use of words can also produce misunderstanding as has happened in the misuse of the terms "resource" and "reserve" in relation to oil referred to earlier in the narrative.

In the context of complex and evolving technology it is becoming important to develop articulate communication between the knowledgeable researchers and the decision-makers. If specialized jargon has to be used, a glossary of symbols, acronyms and abbreviations should be added as is being increasingly done by scientific authors. Above all there should not be two solitudes - the specialist and the decision-maker.

KEY TO ABBREVIATIONS

AD Administrative or Administration (report)
ADM
ADM Assistant Deputy Minister
AECL Atomic Energy of Canada Ltd.
AFA American Foundrymen's Association
AGA American Gas Association
AIME American Institute of Mining Engineers
AN Ammonium Nitrate
ANFO Ammonium Nitrate Fuel Oil (Mixture)
ASM American Society for Metals
ASTM American Society for Testing and Material

BCR Bituminous Coal Research (Association) Pittsburgh, USA
BET Brunauer, Emmett and Teller Method (for determination of total surface area of a porous body by measuring volume of gas (normally nitrogen) absorbed on the surface of the body)

CACRM Canadian Advisory Committee on Rock Mechanics
CAMPEDS Canadian Mining Personal Dust Sampler
Can Ceram Soc Canadian Ceramic Society
Can Journal Chem Eng Canadian Journal of Chemical Engineering
Can Metall Quarterly Canadian Metallurgical Quarterly
Can Min Journal Canadian Mining Journal (or CMJ)
CANMET Canada Centre for Mineral and Energy Technology (the former Mines Branch)
Can Phys Canadian Physics
CCFR Commonwealth Committee on Fuel Research
CCRL Canadian Combustion Research Laboratory
CE Construction and Equipment (Section)
CEAL Canadian Explosive Atmospheres Laboratory
CEEIF Combustion Engine Emissions Investigating Facility
CERCHAR Centre d'Études et Recherches des Charbonnages de France
CERL Canadian Explosives Research Laboratory
CG Carbonization and Gasification (Section)
CGSB Canadian Government Specifications Board
CIL Canadian Industries Ltd.
CIM Bull The Canadian Mining and Metallurgical Bulletin (of the Canadian Mining and Metallurgical Institute)
CMI Canadian Mining Institute
CNC Canadian National Committee
Conf Conference
CPDL Canadian Patents and Development Limited
CPR Canadian Pacific Railway
CSA Canadian Standards Association
CSIRO Commonwealth Scientific and Industrial Research Association (Australia)
CWC Compound Water Cyclone

DDT Dichloro-diprenye - trichloromethane
DND Department of National Defence
DR Divisional Report or Director's Report

ED Engineering Design (Section)
EGMA Emergency Gold Mining Assistance Act
EMD Extraction Metallurgy Division (of Mines Branch)
EMR Department of Energy, Mines and Resources
Engl English (Language)
ERL Energy Research Laboratories (of CANMET)

FMP Fuels and Mining Practice Division (of Mines Branch)
FP Fuel and Power (Section)
Fr French (Language)
FRC Fuels Research Centre (of Mines Branch)
FRL Fuel Research Laboratories (of Mines Branch)

GSC Geological Survey of Canada

HPC High Pressure Chemistry (Section)

i/c or I/C In charge
IC or Info Circular Information Circular (of Mines Branch)
ICI Imperial Chemical Industries Ltd.
IEC International Electrotechnical Commission
IFRF International Flame Research Foundation
IM Information Circular (of Industrial Minerals Division)
INCO International Nickel Co. or International Nickel of Canada Ltd. or INCO Ltd.
IR Investigation Report or Internal Report
ISI Impact Strength Indices
ISO International Standards Organization

LF Liquid Fuels (Section)
LW Lightweight

MB Rep Mines Branch Report
Mech Mechanical Engineering (Section)
MERP Mineral and Energy Resources Program (of CANMET)
Min Bull Mineral Information Bulletin (of Mineral Information Resources Division)
Mono Monograph (of Mines Branch)
MPD Mineral Processing Division (of Mines Branch)
MR Information Circular (of Mineral Resources Division)
MRC Mining Research Centre (of Mines Branch)
MRL Mining Research Laboratories (of Mines Branch and CANMET)
MRSG Maritimes Region Study Group
MS Memorandum Series (of Mines Branch)
MSD Mineral Sciences Division (of Mines Branch)
MSL Mineral Sciences Laboratories (of CANMET)

NACCMR National Advisory Committee on Mining and Metallurgical Research
NCC National Capital Commission
NRC National Research Council

OECD	Organization for Economic Cooperation and Development
OEEC	Organization for European Economic Cooperation
P&C	Physical and Chemical (Survey)
PET	Petroleum Engineering (Section)
PDF	Post Doctoral Fellow (of NRC)
Phys Rev	Physical Review
PMD	Physical Metallurgy Division (of Mines Branch)
PMRL	Physical Metallurgical Research Laboratories (of Mines Branch and CANMET)
POS	Peat and Oil Shales (Section)
PPB	Planning - Programming - Budgeting
PRE	Petroleum Reservoir Engineering (Section)
Prep	Preparation
Proc	Proceedings
psi	pounds per square inch (pressure)
psig	pounds per square inch gauge
RBS	Research on Bituminous Substances (Section)
RCA	Research Council of Alberta
RCAF	Royal Canadian Air Force
RCMP	Royal Canadian Mounted Police
RCN	Royal Canadian Navy
RCNR	Royal Canadian Naval Reserve
RCNVR	Royal Canadian Naval Volunteer Reserve
R & D	Research and Development
Rev Sci Instr	Review of Scientific Instruments
RICS	Report of Investiations of the Carbonization Section (of Mines Branch)
RML	Rock Mechanics Laboratory (of CANMET)
RR	Research Report (of Mines Branch)
RS	Reprint Series (of Mines Branch)
SC	Sub-Committee
SIMPED	Safety in Mines Personal Dust Sampler
Sum Rep	Summary Report (of Mines Branch)
TB	Technical Bulletin (of Mines Branch)
TC	Technical Committee
TIS	Technical Information Service (of NRC)
TM	Technical Memorandum (of Mines Branch)
TNT	Trinitrotoluene
Trans Can Min Inst	Transactions of the Canadian Mining Institute
Trans CIM	Transactions of the Canadian Institute of Mining and Metallurgy
TP	Technical Paper (of Mines Branch) or Topical Report
tpd	tons per day
TSD	Technical Services Division (of Mines Branch and CANMET)
Twp	Township
UNESCO	United Nations Educational, Scientific and Cultural Organization
USBM	United States Bureau of Mines
WRL	Western Regional Laboratory

REFERENCES

Chapter 1

1. Reading the rocks by M. Zaslow. Published by Macmillan Company of Canada Limited, Toronto, Ontario, in association with the Department of Energy, Mines and Resources and Information Canada; 1975.

2. Zaslow, op.cit., p 139 and Report of the Select Committee appointed by the House of Commons to obtain information as to geological surveys. Appendix No. 8, Appendix to Journals of the House of Commons, Session 1884, vol XVIII.

3. Zaslow, op.cit., p 249 and Journal of the Canadian Mining Institute, vol 5, 1902; p 597.

4. Annual report of the Department of the Interior for the year 1900/1; p ii.

Chapter 2

5. Annual report of the Department of the Interior for the year 1903/4; Part VIII, p 3.

Chapter 3 - Part I

6. Annual report of the Department of the Interior for the year 1902/3; Part VIII, p 8.

7. Ibid. 1903/4; Part VIII, p 5.

8. Ibid. 1905/6; Part VIII, p 4.

9. Report of the Commission appointed to investigate the different electrothermic processes for the smelting of iron ores, and the making of steel, in operation in Europe by Eugene Haanel; Mines Branch Report 3 (Engl), 1904; Report 4 (Fr), 1905.

10. Report of the experiments at Sault Ste. Marie, Ontario, under government auspices, in the smelting of Canadian iron ores by the electrothermic process (this includes Preliminary Report No. 16A, published in 1906), by Eugene Haanel; Mines Branch Report 16, 1907.

11. Report of the Commission appointed to investigate the zinc resources of British Columbia and the conditions affecting their exploitation by W.R. Ingalls et al.; Mines Branch Report 12; 1905.

12. Annual report of the Department of the Interior for the year 1904/5; Part VIII, p 6.

Chapter 3 - Part II

13. Summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1910; p 28.

14. Summary report of the Mines Branch of the Department of Mines for the 9 months ending December 30, 1908; p 1.

15. Report on the mining and metallurgical industries of Canada 1907-08, Mines Branch Report 24, 1907-08.

16. Iron ore occurrences in Canada;
Vol I - Description of principal iron ore mines;
Vol II - Description of iron ore occurrences.
Compiled by E. Lindeman and L.L. Bolton with an introduction by A.H.A. Robinson; Mines Branch Report 217; 1917 and 1918 respectively.

17. Summary report of the Mines Branch of the Department of Mines for the year ending December 31, 1913; p 4.

18. Summary report of the Mines Branch of the Department of Mines for the fiscal year 1907-8; p 5.

19. Peat and lignite: their manufacture and uses in Europe by E. Nyström; Mines Branch Report 19, 1908.

20. Investigation of peat bogs and peat fuel industry of Canada during the season 1908/9; (Bulletin No. 1) Mines Branch Report 30, 1909.

21. An investigation of the coals of Canada with reference to their economic qualities as conducted at McGill University under the authority of the Dominion Government by J.B. Porter, R.J. Durley, and others; 6 volumes; Mines Branch Report 83 (Engl), 1912; Report 308 (Fr), 1914-1917. Extra volume: Weathering of coal by J.B. Porter assisted by others; Mines Branch Report 338 (Engl), 1915.

22. Peat, lignite and coal: their value as fuels for the production of gas and power in the by-product recovery producer by B.F. Haanel; Mines Branch Report 299 (Engl), 1914; Report 300 (Fr), 1917.

23. Results of 41 steaming tests conducted at the Fuels Testing Station, Ottawa, by John Blizard and E.S. Malloch; (Bulletin 27) Mines Branch Report 496, 1920.

24. Joint report on the bituminous, or oil-shales of New Brunswick and Nova Scotia, also, on the oil-shale industry of Scotland by R.W. Ells;
Part I - Economics, with Appendix on Scottish industry by W.A. Hamor;
Part II - Geological position and character of the oil shale deposits of Canada with Appendix on oil shale found on Melville Island; Mines Branch Report 55 (Engl), 1909-1910; Report 56 (Fr), 1914.
(Part II is Geological Survey Branch Report 1107).

25. Summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1909; p 13.

26. Ibid. 1912; p 14.

27. Recollections of the development of the Athabasca oil sands by S.C. Ells; Mines Branch Information Circular 139, 1962.

28. Summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1912; p 11.

29. Petroleum and natural gas resources of Canada; Vol I - Technology and exploitation; Vol II - Description of occurrences (also printed separately in 2 parts - E and W Canada); by F.G. Clapp and others; Mines Branch Report 291 (Engl), 1915; Report 292 (Fr), 1917.

30. Summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1909; p 131.

31. Ibid. p 9. See also Appendix III, p 157, "Copy of report on the prevention of mine explosions: prepared by three foreign experts for the U.S. Geological Survey, and published October 22, 1908".

32. Summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1914; p 13.

33. The copper smelting industries of Canada by A.W.G. Wilson; Mines Branch Report 209, 1913.

34. Summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1909; p 74.

35. Pyrites in Canada: its occurrence, exploitation, dressing and uses by A.W.G. Wilson; Mines Branch Report 167, 1912.

36. Lode mining in Yukon: an investigation of quartz deposits in the Klondike division, by T.A. MacLean; Mines Branch Report 222, 1914.

37. Development of chemical, metallurgical and allied industries in Canada in relation to the mineral industry by A.W.G. Wilson; Mines Branch Report 597; with 9 separate charts and diagrams, 1924; also published in 2 volumes, Vol I - Chemical industries; Mines Branch Report 598; Vol II - Metallurgical and allied industries; Mines Branch Report 599.

38. Molybdenum: metallurgy and uses and the occurrence, mining and concentration of its ores, by V.L. Eardley-Wilmot, Mines Branch Report 592, 1925.

39. Chrysotile-asbestos: its occurrence, exploitation, milling and uses by F. Cirkel with appendix: the testing of heat-insulating materials by F. Bacon; Mines Branch Report 69 (Engl), 1910; Report 86 (Fr), 1910.

40. Gypsum in Canada: its occurrences, exploitation and technology by L.H. Cole; Mines Branch Report 245 (Engl), 1913; Report 246 (Fr), 1916.

41. Report on the salt deposits of Canada and the salt industry by L.H. Cole; Mines Branch Report 325 (Engl), 1915; Report 326 (Fr), 1917.

42. Mica: its occurrence, exploitation and uses by H.S. de Schmid; Mines Branch Report 118 (Engl), 1912 (2nd edition); Report 264 (Fr), 1914.

43. Report on the building and ornamental stones of Canada by W.A. Parks;
Vol I - Ontario; Mines Branch Report 100 (Engl), 1912; Report 100A (Fr), 1912;
Vol II - Maritime Provinces; Mines Branch Report 203 (Engl), 1914; Report 280 (Fr), 1916;
Vol III - Province of Quebec; Mines Branch Report 279 (Engl), 1914; Report 389 (Fr), 1916;
Vol IV - Provinces of Manitoba, Saskatchewan and Alberta; Mines Branch Report 388, 1916;
Vol V - British Columbia; Mines Branch Report 452, 1917.

44. Feldspar in Canada by H.S. de Schmid; Mines Branch Report 401 (Engl), 1916; Report 402 (Fr), 1918.

45. Phosphate in Canada by H.S. Spence; Mines Branch Report 396 (Engl), 1920; Report 397 (Fr), 1921.

46. Graphite by H.S. Spence; Mines Branch Report 511 (Engl), 1920; Report 512 (Fr), 1921.

47. Barium and strontium in Canada by H.S. Spence; Mines Branch Report 570, 1922.

48. Report on the clay resources of southern Saskatchewan by N.B. Davis; Mines Branch Report 468, 1918.

49. Report on structural materials along the St. Lawrence River between Prescott, Ontario and Lachine, Quebec by J. Keele and L.H. Cole with appendices on Pleistocene and Ordovician sands; Mines Branch Report 549 (Engl), 1922; Report 550 (Fr), 1924.

50. Report on road materials along the St. Lawrence River from the Quebec boundary line to Cardinal, Ontario by R.H. Picher with appendices:
1 - Rock out-crops;
2 - Character of boulder deposits of field stones;
3 - Character of gravel deposits;
4 - Commercial development of gravel deposits;
(Bulletin 32) Mines Branch Report 530, 1920.

51. Mineral springs of Canada;
Part I - The radioactivity of some Canadian mineral springs with 2 appendices by J. Satterly and R.T. Elworthy; (Bulletin 16) Mines Branch Report 435, 1917;
Part II - The chemical character of some Canadian mineral springs; by R.T. Elworthy; (Bulletin 20) Mines Branch Report 472, 1918.

52. Description of the laboratories of the Mines Branch of the Department of Mines; Ottawa, (Bulletin 13) Mines Branch Report 406, 1916.

Chapter 4

53. Sodium sulphate of Western Canada: occurrences, uses and technology by L.H. Cole; Mines Branch Report 646, 1926.

54. Silica in Canada: its occurrence, exploitation and uses;
Part I - Eastern Canada by L.H. Cole; Mines Branch Report 555, 1923,
Part II - Western Canada with Appendix on recent developments in the silica industry in Eastern Canada by L.H. Cole; Mines Branch Report 686, 1928.

55. Talc and soapstone in Canada by H.S. Spence; Mines Branch Report 583, 1922.

56. Feldspar by H.S. Spence; Mines Branch Report 731, 1932.

57. Abrasives: products of Canada, technology and application by V.L. Eardley-Wilmot:
Part I - Siliceous abrasives: sandstones, quartz, tripoli, and volcanic dust, Mines Branch Report 673 (Engl), 1927; Report 674 (Fr), 1930;
Part II - Corundum and diamonds, Mines Branch Report 675 (Engl), 1927; Report 676 (Fr), 1931;
Part III - Garnet, Mines Branch Report 677 (Engl), 1927; Report 678 (Fr), 1931;
Part IV - Artificial abrasives and manufactured abrasive products and their uses, Mines Branch Report 699 (Engl), 1929; Report 700 (Fr), 1934.

58. Diatomite: its occurrence, preparation, and uses by V.L. Eardley-Wilmot; Mines Branch Report 691, 1928.

59. Mica by H.S. Spence; Mines Branch Report 701, 1929.

60. Chrysotile asbestos in Canada by J.G. Ross; Mines Branch Report 707, (Engl), 1931; Report 708 (Fr), 1934.

61. Canadian limestones for building purposes by M.F. Goudge; Limestones of Canada, their occurrence and characteristics (regarded as Part I); Mines Branch Report 733 (Engl), 1933; Report 778 (Fr), 1937;
Part II - Maritime Provinces; Mines Branch Report 742, 1934;
Part III - Quebec; Mines Branch Report 755 (Engl), 1935, reprinted 1962; Report 758 (Fr), 1935;
Part IV - Ontario; Mines Branch Report 781, 1938;
Part V - Western Canada; Mines Branch Report 811, 1946.

62. The gypsum industry in Canada by L.H. Cole; Mines Branch Report 714, 1930.

63. The salt industry in Canada by L.H. Cole; Mines Branch Report 716, 1930.

64. The granite industry of Canada by F.G. Carr; Mines Branch Report 846 (Engl), 1955; Report 852 (Fr), 1957.

65. The Ore Testing and Research Laboratories, Mines Branch, Ottawa by W.B. Timm; Mines Branch Memorandum Series 32, 1928; New Pyrometallurgical Laboratory for test and research on iron and steel by W.B. Timm and T.W. Hardy; Mines Branch Memorandum Series 38, 1929; The Mineragraphic Laboratory, Mines Branch, by W.B. Timm and M.H. Haycock; Mines Branch Memorandum Series 58, 1933.

66. Selective flotation as applied to Canadian ores by C.S. Parsons; Mines Branch Memorandum Series 29, 1927.

67. The Fuel Research Laboratories at Ottawa and the scope of their investigations by B.F. Haanel; The Canadian Mining and Metallurgical Bulletin, October 1929; also New Fuel Research Laboratories by B.F. Haanel; Mines Branch Memorandum Series 34, 1928.

68. Peat: its manufacture and uses by B.F. Haanel (Final report of the Peat Committee appointed jointly by the Governments of the Dominion of Canada and the Province of Ontario). With 3 appendices:
A - Investigation of drying conditions obtained during the manufacture of peat fuel at the Alfred peat bog by H.A. Leverin;
B - Preliminary report on the relations of the maceration of the drying qualities of peat by R.E. Gilmore;
C - Manufacture of carbonized peat at Dumfries, Scotland by J.O. Roos of Hjelmsäter; Mines Branch Report 641, 1926.

69. Fuel briquetting by R.A. Strong, E. Swartzman and E.J. Burrough; Mines Branch Report 775, 1937.

70. The preparation, transportation, and combustion of powdered coal by J. Blizard; Mines Branch Report 564, 1921, with appendix: Boiler tests with pulverized coal by H. Kreisinger and J. Blizard.

71. Bituminous sands of northern Alberta: occurrence and economic possibilities, report on investigations to the end of 1924 by S.C. Ells; Mines Branch Report 632, 1926.

72. Analyses of Canadian crude oils, naphthas, shale oil and bitumen by P.V. Rosewarne, H.McD. Chantler and A.A. Swinnerton; Mines Branch Report 765, 1936.

73. Report on some sources of helium in the British Empire by J.C. McLennan and others; (Bulletin 31) Mines Branch Report 522, 1920.

74. Story of the early days of the extraction of helium gas from natural gas in Canada 1915-1920 by J. Satterly, University of Toronto; Mines Branch Information Circular 105, 1959.

75. Helium in Canada by R.T. Elworthy; Mines Branch Report 679, 1926.

76. Ceramic testing and research laboratories, Ottawa by H. Fréchette; Mines Branch Memorandum Series 26, 1926.

77. Industrial waters of Canada: report of investigations 1934 to 1943 by Harold A. Leverin; Mines Branch Report 819, 1943 (revised 1947).

78. Notes on flotation practice in Canada by B.W. Holman; The Mining Magazine, London, vol 38, January (p 21) and February (p 82), 1928.

Chapter 5

79. Investigations of Canadian coals including their testing, classification and utilization by B.F. Haanel and R.E. Gilmore; Engineering Institute of Canada, Semi-centennial Meeting, June 1937.

80. Tests on the liquefaction of Canadian coals by hydrogenation by T.E. Warren and K.W. Bowles; Mines Branch Report 798, 1940.

81. Conditions and practices in the Canadian coal mining industry by A. Ignatieff, A. Brown and F.L. Casey; Canadian Mining Journal, 1951; pp 55-65, August; pp 74-81, September; pp 67-75, October.

82. Peat moss deposits in Canada by M.A. Leverin; Mines Branch Report 817, (Engl) 1946; Report 821 (Fr), 1947.

83. Peat moss in Canada by A.A. Swinnerton; Mines Branch Information Circular 104 (Engl and Fr), 1958.

84. Drilling and sampling of bituminous sands of northern Alberta in 3 volumes:
Vol 1 - Results of investigations (1942-1947);
Vol 2 - Detailed drilling and sampling records;
Vol 3 - Cross-sections and plans of areas drilled; Mines Branch Report 826, 1949.

85. Summary of investigations on New Brunswick oil shales; Mines Branch Report 825, 1948.

86. Analyses of Canadian crude oils by H. McD. Chantler, P.B. Sealy and F.E. Goodspeed; Mines Branch Report 832, 1951.

87. Natural gas reserves of the Prairie Provinces by G.S. Hume and A. Ignatieff; Special report of the Geological Survey of Canada, 1950.

88. Natural gas reserves of the Peace River area of British Columbia and Alberta by G.S. Hume and A. Ignatieff; Department of Mines and Technical Surveys, 1952.

89. Talc, steatite and soapstone; pyrophyllite by H.S. Spence; Mines Branch Report 803, 1940.

90. Preliminary report on brucite deposits in Ontario and Quebec and their commercial possibilities by M.F. Goudge; Mines Branch Memorandum Series 75, 1939.

91. Stabilized roads by R.H. Picher; Mines Branch Report 800 (Engl); Report 801 (Fr), 1940.

92. The physical properties of Canadian building brick by J.G. Phillips; Mines Branch Report 816 (Engl and Fr), 1947.

93. The physical properties of Canadian structural tile by J.G. Phillips and J.A. Kirkendale, Mines Branch Report 822 (Engl); Report 823 (Fr), 1947.

94. The constitution of bone china by P.D.S. St. Pierre:
Part I - High temperature phase equilibrium studies in the system tricalcium phosphate -alumina-silica; Mines Branch Technical Paper 2, 1953;
Part II - Reactions to bone china bodies; Mines Branch Technical Paper 7, 1954;
Part III - High temperature phase equilibrium studies in the system tricalcium phosphate-anorthite-silica; Mines Branch Technical Paper 12, 1955.

Chapter 6

95. A report to the National Productivity Council on Research and Development in the Canadian Mineral Industries by John Convey and V.A. Haw; Applied Research Report NPC-2, 1963.

96. The function of the Mines Branch Radioactivity Division by E.A. Brown; CIM Bull, pp 760-763, December 1953.

97. Review of uranium treatment plants by A. Thunaes in "The milling of Canadian ores"; 6th Commonwealth Mining & Metallurgical Congress, 1957.

98. Milling at Gunnar Mines by R.H. Light; Can Min Journal, pp 141-143, June 1956.

99. Treating Blind River uranium ores by leaching, ion exchange precipitation by R.P. Ehrlich A.G. Roach and K.D. Hester; Journal Metals, pp 628-633, September 1959.

100. Canada's stake in uranium (in 3 parts: Geology, Mining and Milling); edited by C. Mamen, Canadian Mining Journal, pp 69-162, June 1956.

101. Treatment of uranium leach plant solutions by liquid-liquid extraction to produce high purity uranium products by R. Simard, A.J. Gilmore, V.M. McNamara, H.W. Parsons and H.W. Smith; Can Journal Chemical Engineering, pp 229-234, December 1961.

102. Recovery of metal grade thorium concentrate from uranium plant ion exchange effluents by amine solvent extraction by R. Simard; Mines Branch Technical Bulletin 13, 1960.

103. Pilot plant testing of uranium ores at the Mines Branch, Ottawa by W.A. Gow, W.H. Smith and R. Simard; Trans CIM, vol 60, pp 70-75, 1957.

104. Manual of analytical methods for the uranium concentrating plant by J.C. Ingles; Mines Branch Monograph 866, 1959.

105. The radiation laboratory of the Mines Branch, 1947-1959 by G.G. Eichholz; Mines Branch Information Circular IC 113, 1959.

106. The uranium industry - its history, technology and prospects by J.W. Griffith; Mineral Report 12, Mineral Resources Division, 1967.

107. Air oxidation acid pressure leach investigations of uranium-bearing ores from Elliot Lake, Ontario, by V.F. Harrison and W.A. Gow; Mines Branch Technical Bulletin 3, 1959.

108. Effects of furnace atmospheres on the sintering behaviour of uranium dioxide by A.H. Webster and N.F.H. Bright; Mines Branch Research Report R 2, 1958.

109. Physics and Radiotracer Subdivision of the Mines Branch, 1959-1963 by G.G. Eicholz; Mines Branch Information Circular IC 150, 1963.

110. Mineral Physics Section, Mineral Sciences Division, Mines Branch, 1963-1967 by J.D. Keys; Mines Branch Information Circular IC 192, 1967 and 1968.

111. Technical review of ore dressing investigations on Canadian titaniferous ores conducted at CANMET from 1950 to 1975 by D. Raicevic; CANMET Report 76-34, 1976.

112. Titanium - its physical metallurgy and potentialities by H.V. Kinsey; Trans CIM, vol 56, pp 201-210, 1953.

113. Survey of the titanium alloys, their application and their processing and manufacturing technology by H.V. Kinsey; Mines Branch Technical Bulletin TB 80, 1966.

114. Methods for the analysis of ilmenite, titanium-bearing slags and other electric furnace slags; parts I to IV by A. Hitchen, part V by A. Hitchen and G. Zechanowitsch; Mines Branch Technical Bulletins 120, 121, 124, (all 1970) and 168, 169, (both 1973).

115. Hydrogen sulphide route to sulphur recovery from base metal sulphides:
Part I by H.W. Parsons and T.R. Ingraham;
Part II by R.F. Pilgrim and T.R. Ingraham;
Part III by D.A. Reeve and T.R. Ingraham; Mines Branch Information Circulars 242, 243, and 244, (all 1970).

116. Bibliography of CANMET (formerly Mines Branch) iron ore investigations, 1940-1975 by G.O. Hayslip; Mineral Sciences Laboratories Report MRP/MSL 76-16(LS), 1976.

117. Technical review of ore dressing investigations on Canadian chromite ores conducted at CANMET from 1918 to 1976 by D. Raicevic, CANMET Report 76-39, 1976.

118. Properties of sand-cast magnesium alloys; in 8 parts, all Mines Branch Research Reports:
Part 1 - Binary magnesium-zinc alloys by B. Lagowski and J.W. Meier; R 9, (1958) 1964;
Part 2 - Metallography of magnesium-zinc alloys by B. Lagowski; R 22, (1958) 1964;
Part 3 - Effect of titanium additions to magnesium-zinc alloys; R 56, (1960) 1964;
Part 4 - Mg-Ag,Mg-Ag-Zr and Mg-Ag-Zn-Zr alloys; R 63, (1960) 1964;
Part 5 - Mg-Zn-Ag-Zr alloys; R 140, 1964, all three parts by B. Lagowski and J.W. Meier;
Part 6 - Effect of pouring temperature and holding time; R 152, 1965;
Part 7 - Effect of wall thickness on tensile properties of Mg-Al-Zn alloy castings, R 153, 1965, both parts by A. Couture and J.W. Meier;
Part 8 - Foundry characteristics of magnesium-zinc-silver-zirconium casting alloys; by B. Lagowski and J.W. Meier; R 161, 1965.

119. Industrial minerals research in the laboratories of the Mines Branch, Ottawa by M.F. Goudge; Trans CIM, vol 60, pp 260-267, 1957.

120. Industrial minerals of Newfoundland by G.F. Carr; Mines Branch Report 855, 1958.

121. Fluorspar by C.M. Bartley; Mines Branch Information Circular 127, 1961.

122. The barium minerals industry in Canada by J.S. Ross; Mines Branch Information Circular 126, 1960.

123. Bentonite in Canada by J.S. Ross, Mines Branch Monograph 873, 1964.

124. (1) Flotability of eleven common non-metallic minerals by R.A. Wyman; Mines Branch Technical Bulletin 70, 1965;
(2) Flotability of twenty-one non-metallic minerals by R.A. Wyman; Mines Branch Technical Bulletin 108, 1969;
(3) Flotability of ten non-metallic minerals (a supplement to TB 108) by R.A. Wyman and J.H. Colborne; Mines Branch Technical Bulletin 186, 1974.

125. (1) Ceramic clays and shales of British Columbia by J.G. Brady and R.S. Dean; reprinted from Journal of Can Ceram Soc, vol 32, 1963 as Mines Branch Technical Bulletin 54, 1963;
(2) Composition and properties of ceramic clays and shales of Quebec by J.G. Brady and R.S. Dean; Mines Branch Research Report R 187, 1967; (French text - Mines Branch Research Report R 188, 1967);
(3) Ceramic clays and shales of Ontario by J.G. Brady and R.S. Dean; Mines Branch Research Report R 175, 1968;
(4) Mineralogy of the ceramic clays and shales of the Atlantic Provinces by R.S. Dean; CANMET Report 75-8, 1975;
(5) Cursory mineralogical investigation and examination of ceramic clays and shales of the Prairie Provinces by R.S. Dean; CANMET Internal Report MRP/MSL 78-169, 1978;
(6) Ceramic clays and shales of the Atlantic Provinces by K.E. Bell, J.G. Brady and L.K. Zengals; CANMET Report 78-21, 1978.

126. Preliminary report on coated lightweight concrete aggregate from Canadian clays and shales:
Part I - Alberta, Mines Branch Memorandum Series 117, 1952;
Part II - Saskatchewan and Manitoba, Mines Branch Memorandum Series 120, 1952;
Part III - Ontario, Mines Branch Memorandum Series 121, 1952;

Part IV - New Brunswick, Nova Scotia and Prince Edward Island, Mines Branch Memorandum Series 122, 1952; All four parts by J.G. Matthews;
Part V - Quebec, Mines Branch Memorandum Series 126, (Engl), 1953, 126F (Fr,) 1954;
Part VI - British Columbia, Mines Branch Memorandum Series 128, 1954 (both parts by H.S. Wilson).

127. Accelerated tests for determining the 28-day compressive strength of concrete by V.M. Malhotra, N.G. Zoldners and R. Lapins*, Mines Branch Research Report R 134, 1964 (* of Francon Limited, Montreal).

128. Non destructive methods for testing concrete by V.M. Malhotra; Mines Branch Monograph 875, 1968, reprinted 1971.

129. Industrial water resources of Canada, all except No. 14 and 15 by J.F.J. Thomas:
No. 1 - Scope, procedure, and interpretation of survey studies, Mines Branch Report 833, 1953;
No. 2 - Ottawa River drainage basin, 1947-48; Mines Branch Report 834, 1952;
No. 3 - Upper St. Lawrence River - central Great Lakes drainage basin in Canada; Mines Branch Report 837, 1954;
No. 4 Columbia River drainage basin in Canada, 1949-50; Mines Branch Report 838, 1953;
No. 5 - Skeena River drainage basin, Vancouver Island, and central areas of British Columbia; Mines Branch Report 839, 1953;
No. 6 - Fraser River drainage basin, 1950-51; Mines Branch Report 842, 1954;
No. 7 - Saskatchewan River drainage basin, 1951-52; Mines Branch Report 849, 1956;
No. 8 - Mackenzie River and Yukon River drainage basins in Canada, 1952-53; Mines Branch Report 856, 1957;
No. 9 - Churchill River and Mississippi River drainage basins in Canada, 1952-54; Mines Branch Report 858, 1958;
No. 10 - Nelson River drainage basin in Canada, 1953-56; Mines Branch Report 861, 1959;
No. 11 - Atlantic Provinces, and Saint John River drainage basins in Canada, 1954-56; Mines Branch Report 864, 1960;
No. 13 - Lower St. Lawrence River drainage basin in Canada, 1955-60; Mines Branch Monograph 869, 1962;
No. 14 - Upper Great Lakes drainage basin in Canada, 1957-63 by J.F.J. Thomas and R.M. Gale; Mines Branch Monograph 870, 1965;
No. 15 - Hudson Bay, Labrador and Arctic drainage basins, 1959-65 by J.F.J. Thomas and R.M. Gale; Water Quality Laboratory, Inland Waters Directorate, Department of the Environment, 1973.

130. Fuel research facilities in Canada by R.E. Gilmore and A.E. Cameron; Trans CIM, vol 54, pp 75-84, 1951.

131. Fifty years of fuel testing and research by A.A. Swinnerton; Mines Branch Memorandum Series 136, 1957.

132. Analyses of Canadian coals and peat fuels by J.H.H. Nicolls; Mines Branch Report 831, 1952.

133. Evaluation of Canadian commercial coals: Nova Scotia and New Brunswick, 1971 by T.E. Tibbetts and W.J. Montgomery; Mines Branch Information Circular 287, 1972.

134. Evaluation of Canadian commercial coals: Saskatchewan, Alberta and British Columbia, 1971 by T.E. Tibbetts; Mines Branch Information Circular 291, 1972.

135. Chemical analyses of the ash of Canadian coals by W.J. Montgomery, J.Z. Skulski, G.C. Anderson and J.G. Jorgensen; Mines Branch Information Circular 248, January 1970.

136. Symposium on the science and technology of coal; Special Centennial volume published by Mines Branch, Department of Energy, Mines and Resources, Ottawa, 1967.

137. The cold water process for the recovery of the bitumen from the bituminous sands of Alberta in 4 parts:
Part I - Sampling procedure and analytical methods for the control and evaluation of the pilot plant operation by F.E. Goodspeed, J.G. Holland, R.G. Draper and H. McD. Chantler; Fuel Research Laboratory Report 260, 1957;
Part II - Tabulated summary of all the analytical results associated with the control and evaluation of the pilot plant operation, by same authors as Part I; Fuel Research Laboratory Report 264, 1957;
Part III - The evaluation of the surface active agents for use in the cold water separation process by D.S. Montgomery and M.P. Pleet; Mines Branch Investigation Report 54-81, 1958;
Part IV - Diluent recovery, dehydration and coking of the wet diluted bitumen by F.L. Booth, R.E. Carson, C.J. Burrough and T.E. Warren; Technical Memorandum Report 208/58, 1958.

138. Proceedings of Athabasca Oil Sands Conference, Edmonton, September 1951.

139. Analyses and characteristics of oil samples from ... by R.P. Charbonnier, R.G. Draper, W.H. Harper and A. Yates, 1969. All Mines Branch Information Circulars:
...New Brunswick, Newfoundland and Nova Scotia; IC 215;
...Quebec, IC 216; (Tables Bilingual)
...British Columbia and Northwest Territories, IC 220;
...Manitoba, IC 221;
...Ontario, IC 228;
...Saskatchewan, IC 231;
...Alberta, IC 232.

140. Study of the Athabasca bitumen from Abasand Quarry, Alberta, Canada by M.L. Boyd and D.S. Montgomery; all Mines Branch Research Reports:
Part 1 - R 78, 1961;
Part 2 - R 88, 1961;
Part 3 - R 104, 1962.

141. Study of sedimented organic matter and its natural derivatives by L.H. King, F.E. Goodspeed and D.S. Montgomery with appendix by M.M.F. Millson; Mines Branch Research Report R 114, 1963.

142. A combustion handbook for Canadian fuels:
Vol 1 - Fuel oil by F.D. Friedrich; Mines Branch Monograph 877, 1969;
Vol 2 - Gaseous fuels by F.D. Friedrich and A.C.S. Hayden; Mines Branch Monograph 879, 1973;
Vol 3: - Coal (in 2 parts) F.D. Friedrich and A.C.S. Hayden; Mines Branch Monograph 882, 1974.

143. Jet piercing research project by Mines Branch Staff; Mines Branch Investigation Report 62-27, 1962.

144. Proceedings of the Boyer Conference - First conference, on fuel technology in Canada, May 1963; Queen's Printer, 1964.

145. Rock mechanics principles by D.F. Coates, 1965, Mines Branch Monograph 874 (Revised English editions 1967 and 1970. French edition, "Principes de la mécanique des roches").

146. Incremental design in rock mechanics by D.F. Coates and M. Gyenge; Mines Branch Monograph 880, 1973.

147. Pillar loading by D.F. Coates (in 4 parts); all Mines Branch Research Reports:
Part I - Literature survey and new hypotheses; R 168, 1965;
Part II - Model studies; R 170, 1965;
Part III - Field measurements; R 180, 1966;
Part IV - Inclined workings; R 193, 1966.

Chapter 7

148. Pit slope manual and supplements, all CANMET Reports, all 1977 except Chapter 1 (1976):
Chapter 1, Summary, also in French (Sommaire), Report 76-22;
Chapter 2, Structural geology, Report 77-41; Supplement 2-1, DISCODAT computer program, Report 77-18; Supplement 2-2, Domain analysis program, Report 77-19; Supplement 2-3, Geophysics for open pit sites, Report 77-22; Supplement 2-4, Joint mapping by terrestrial photogrammetry, Report 77-23; Supplement 2-5, Structural geology case history, Report 77-24;
Chapter 3, Mechanical properties, Report 77-12, Supplement 3-1, Laboratory classification tests, Report 77-25; Supplement 3-2, Laboratory tests for design parameters, Report 77-26; Supplement 3-3, In situ field tests, Report 77-27; Supplement 3-4, Selected soil tests, Report 77-28; Supplement 3-5, Sampling and specimen preparation, Report 77-29;
Chapter 4, Groundwater, Report 77-13; Supplement 4-1, Computer manual for seepage analysis, Report 77-30;
Chapter 5, Design, Report 77-5; Supplement 5-1, Plane shear analysis, Report 77-16; Supplement 5-2, Rotational shear sliding: analysis and computer programs, Report 77-17; Supplement 5-3, Financial computer programs, Report 77-6;
Chapter 6, Mechanical support, Report 77-3; Supplement 6-1, Buttresses and training walls, Report 77-4;
Chapter 7, Perimeter blasting, Report 77-14;
Chapter 8, Monitoring, Report 77-15;
Chapter 9, Waste embankments, Report 77-01;
Chapter 10, Environmental planning, Report 77-2; Supplement 10-1, Reclamation by vegetation, Vol 1 - Mine waste description and case histories, Report 77-31, Vol 2 - Mine waste inventory by satellite imagery, Report 77-58.
The following computer programs are also available:
Set 1, Financial analysis;
Set 2, Rotational shear analysis,
Set 3, Sliding stability analysis;
Set 4, Groundwater seepage,
Set 5, Analysis of structural geological data (DISCODAT);
Set 6, Analysis of structural geological domains.

Note: Pit Slope Project officers were successively D.F. Coates, M. Gyenge, and R. Sage who were assisted in managing the program by G. Herget, B. Hoare, G. Larocque, D.R. Murray and M. Service. Authors were also drawn from universities and consultants.

APPENDIX

MEMBERS OF THE MINES BRANCH STAFF, INCLUDING THE EXPLOSIVES DIVISION AND DOMINION OF CANADA ASSAY OFFICE, VANCOUVER, EMPLOYED FOR 10 YEARS OR MORE FROM 1901 TO DECEMBER 31, 1975

Every effort has been made to avoid omissions but personnel records are incomplete; any omissions are much regretted.

The letter (E) signifies service partly or wholly with the Explosives Division, the letter (V) signifies service at the Vancouver Assay Office. The hyphen (-) after the first date signifies that the person was still with the branch at the end of 1975.

LADIES OF THE MINES BRANCH COMMUNITY

BARON, Miss L.	1942 - 1964
BECKER, Miss V.G.	1927 - 1956
BERRIGAN, Mrs. C.M.	1955 -
BOTTOMLEY, Mrs. R.J.	1954 - 1960, 1971 -
BOYD, Dr. M.L.	1948 - 1975
BRABAZON, Mrs. E.E.	1965 - 1975
BROWN, Mrs. G.D.	1954 - 1956, 1963 -
BYRNES, Mrs. A.J. (E)	1937 - 1958
CAIN, Mrs. B.P.	1953 - 1973
CAMERON, Miss H.F.	1921 - 1940
CASSIDY, Mrs. A.M.	1952 - 1962
COTIE, Mrs. M.E.	1963 -
CUTHBERTSON, Miss E.K.	1934 - 1945
DAVIDSON, Miss B.R.	1911 - 1937
DELANEY, Miss A.M.	1924 - 1936
DOLAN, Miss M.J.	1953 -
DONALDSON, Mrs. E.M.	1951 -
DOYLE, Miss E.N.	1945 - 1972
FAUTEUX, Mrs. L.A.	1926 - 1944
FERGUSON, Miss N.A.	1948 -
GAFFNEY, Miss P.A.	1964 -
GIBSON, Miss D.E.	1947 - 1973
GILLIES, Mrs. S.M.	1965 -
GOODSPEED, Miss F.E.	1945 - 1965
GUIBORD, Miss M.P.	1956 -
HANDFORD, Mrs. L.R.	1955 - 1965
HARDY, Mrs. A.M. (E)	1947 - 1969
HEWSON, Mrs. V.	1948 - 1961
HUGHES, Mrs. P.M.	1960 -
HUTCHINGS, Mrs. E.S.	1937 - 1972
KANE, Mrs. M.A.	1946 - 1967
KELSO, Mrs. M.D.	1960 -
KOSOWAN, Miss A.	1953 - 1970
LAZUK, Mrs. D.M.	1956 - 1973
LECLAIR, Mrs. C.M	1950 - 1964
MacCORMACK, Miss M.A.	1949 -
MacGREGOR, Miss G.C.	1907 - 1940
MARION, Mrs. I.F.	1959 -
MARK, Miss E.	1961 -
MARTINEAU, Mrs. G.I.	1960 -

MAURER, Mrs. E.B.	1947 - 1964
McCANN, Miss L.M.	1915 - 1938
McCONNELL, Miss D.R.	1954 - 1965
McDIARMID, Mrs. V.M.	1956 -
McDONALD, Mrs. M.	1959 -
McLAREN, Mrs. N.M.	1960 -
McLEISH, Miss R.L.	1908 - 1950
MILLS, Miss R.H.	1948 -
MINER, Mrs. M.L.	1956 - 1975
MOLOUGHNEY, Mrs. A.M.N.	1946 - 1956
MUIRHEAD, Miss M.E.	1950 - 1972
NG-YELIM, Miss J.	1958 -
NIELD, Mrs. P.F.	1947 - 1957
NUTHERS, Mrs. M.H.	1959 -
O'DRISCOLL, Mrs. B.J.	1954 - 1965
OGILVIE, Mrs. O.P.R.	1913 - 1937
ORME, Miss J.	1901 - 1945
OUDERKIRK, Mrs. C.A.	1964 -
PECKHAM, Miss G.M.	1963 -
PEPPER, Miss E.	1922 - 1943
PICARD, Miss J.L.	1953 -
PURDY, Mrs. A.I.	1954 - 1972
RALPH, Miss M.S. (E)	1919 - 1956
REED, Dr. D.J. (Mrs.)	1955 - 1973
REID, Miss M.F.	1929 - 1946
RICE, Miss M.M.	1940 - 1968
ROLKO, Mrs. V.H.E.	1951 - 1957, 1966 -
ROUTLIFFE, Mrs. E.P.	1957 -
SAULTER, Miss M.	1930 - 1963
SIMPSON, Mrs. E.	1958 - 1972
SLINN, Miss D.E.	1923 - 1950
SMITH, Mrs. P.A.	1964 -
STEVENSON, Mrs. P.L.	1949 - 1975
STEWART, Miss D.M.	1913 - 1945
ST. GERMAIN, Mrs. M.B.Y.	1948 -
TEGANO, Mrs. J.G.	1963 -
THOMPSON, Mrs. M.	1955 - 1967
VARETTE, Mrs. D.M.	1956 -
WELCH, Miss K.T.	1949 -

GENTLEMEN OF THE MINES BRANCH COMMUNITY

ACRES, W.R.	1942 - 1973
AHMED, Dr. S.M.	1965 -
ALEXANDER, G.E.	1951 -
ALLAN, W.H.	1951 - 1965
ALLISON, R.	1912 - 1927
AMBROSE, J.	1930 - 1956
ANDERSON, A.K.	1916 - 1953
ANDERSON, G.C.	1950 -
ANREP, Aleph von	1908 - 1918
ARMSTRONG, H.W.	1936 - 1972
ATKINSON, J.E.	1953 -
AUBRY, R.E.N.	1943 -
AYERS, G.D.	1950 -
BADGER, S.R.M.	1930 - 1966
BAILEY, R.P.	1961 - 1975
BAINE, H.E.	1911 - 1933
BAKER, A.J.	1948 - 1967
BAKER, E.A.	1948 - 1961
BALTZER, C.E.	1923 - 1965
BANKS, G.N.	1953 -
BANKS, J.C.	1947 - 1975
BARDWELL, K.O.	1959 -
BARKLEY, D.J.	1953 -
BARNABY, R.L.	1958 - 1974
BARNES, W.T.	1919 - 1946
BARRETT, T.A.	1917 - 1951
BARRON, Dr. K.	1960 -
BART, H.H.	1951 - 1970
BART, J.H.	1951 -
BARTLEY, C.M.	1957 - 1974
BEAUCHAMP, E.C.	1944 -
BEAUPRE, A.	1943 - 1962
BEAUPRE, J.L.	1950 -
BEAUSEJOUR, R.	1930 - 1954
BEDNAR, J.	1958 -
BEER, H.L.	1927 - 1954
BEER, R.W.	1959 -
BEHNKE, G.C.	1945 - 1971
BELANGER, A.	1946 - 1971
BELANGER, P.E.	1949 -
BELL, D.R.	1956 -
BELL, K.E.	1960 -
BERRY, T.F.	1948 -
BESS, F.	1928 - 1957
BETTENS, A.H.	1951 -
BIEFER, Dr. G.H.	1960 -
BINETTE, R.J.	1955 -
BISSON, L.F.	1936 - 1948
BLACK, F.C.	1947 -
BLACKBURN, N.G.	1947 - 1964
BLAIS, L.J.	1956 -
BLAIS, M.	1945 -
BLANCHARD, F.C.	1965 -
BLEAKNEY, H.H.	1930 - 1935, and
	1952 - 1965
BOISONNAULT, A.J.	1948 -
BOND, J.C.	1947 - 1968
BOOTH, F.L.	1945 - 1975
BOSWELL, F.W.	1949 - 1960
BOTHAM, J.C.	1948 -
BOTT, W.H.	1947 -
BOUVIER, J.A.F.	1951 -
BOWLES, J.E.H.	1946 - 1957
BOWLES, K.W.	1931 - 1971
BRABAZON, G.R.	1942 - 1965
BRACKENBURY, E.B.	1949 -
BRADLEY, J.F.	1949 - 1963
BRADLEY, G.J.	1953 -
BRADLEY, J.H.B.	1948 -
BRADLEY, M.J.B.	1949 -
BRADY, E.L.	1954 -
BRADY, J.G.	1952 -
BRANNEN, J.	1948 - 1958
BRANNEN, J.M.	1959 -
BREDIN, R.H.	1961 -
BRENNAN, A.R.	1948 - 1966
BRETHOUR, F.W.	1945 - 1966
BRIGGS, D.C.	1958 -
BRIGHT, Dr. N.F.H.	1953 - 1974
BRINDAMOUR, D.	1943 - 1969
BRINDAMOUR, H.J.	1941 - 1972
BROUSE, S.R.	1956 - 1970
BROWN, A.	1949 - 1962
BROWN, D.A.	1964 -
BROWN, G.A.	1949 -
BROWN, G.K.	1948 - 1975
BROWN, K.M.	1961 - 1973
BROWN, N.B.	1938 - 1960
BROWN, T.R.	1953 - 1968
BROWNLEE, A.S.	1945 - 1975
BRUCE, R.W.	1948 -
BUCHANAN, R.M.	1955 -
BUCK, J.T.	1944 - 1960
BUCKMASTER, R.W.	1955 - 1972
BUHR, R.K.	1953 -
BUISSON, A.H.	1915 - 1950
BURNS, W.K.	1948 - 1970
BURROUGH, E.J.	1927 - 1963
BURSTOW, F.W.	1915 - 1940
CABRI, Dr. L.J.	1964 -
CADIEUX, A.	1947 - 1957
CAIRNS, F.J.	1920 - 1943
CAMPBELL, R.A.	1950 -
CAMPBELL, W.P. (E)	1928 - 1937, and
	1937 - 1955
CAMPBELL, W.P.	1947 -
CANNON, J.J.R.	1930 - 1946
CARDIFF, J.D.	1946 - 1966
CARMODY, R.V.	1945 -
CARNOCHAN, R.K.	1920 - 1940
CARON, J.G.	1960 -
CARON, V.L.	1948 -
CARRIERE, J.G.H.	1949 -
CARSON, R.E.	1948 -
CASEY, F.L.	1941 -
CASEY, J.M.	1909 - 1946
CERE, E.	1960 -
CERE, W.H.	1956 - 1971
CHANTLER, H. McD.	1924 - 1958
CHARBONNIER, Dr. R.P.	1954 -
CHARETTE, D.J.	1946 -
CHARLEBOIS, R.A.J.	1953 - 1973
CHARTRAND, E.	1913 - 1956
CHASE, W.L.	1942 - 1966
CHAURET, R.	1961 -
CHILDE, C.H.J.	1964 -
CLEMENT, L.A.	1954 -
COATES, Dr. D.F.	1963 -
COCHRANE, T.S.	1951 -
COLBORNE, J.H.	1952 -

COLE, L.H.	1910 - 1949
COLEMAN, C.J.	1927 - 1967
COLLIN, L.P.	1923 - 1938
COLLINGS, R.K.	1952 -
CONNELL, G.P.	1923 - 1936
CONNOLLY, G.	1920 - 1937
CONNOR, M.F.	1907 - 1918
CONNORS, E.F.	1945 -
CONSTANTINEAU, A.	1953 - 1964
CONTRACTOR, Dr. G.P.	1957 - 1972
CONVEY, Dr. John	1948 - 1973
COOK, J.R.	1957 - 1969
COOK, S.R.	1960 -
CORNISH, R.W.	1930 - 1960
COSTANZO, R.A.	1948 - 1963
COTTINGHAM, E.	1914 - 1946
COUSINEAU, F.X.	1930 - 1956
COUTURE, A.	1951 -
COYNE, B.P.	1917 - 1919, and 1921 - 1950
CRAIG, R.R.	1947 - 1949, and 1956 -
CRAWLEY, Dr. A.F.	1965 -
CRERAR, P.A.	1944 - 1955
CROBAR, G.E.	1959 - 1969
CUMMING, D.M.	1957 -
CUNNINGHAM, M.	1945 - 1969
CUNNINGHAM, Dr. R.L.	1942 -
CUSTEAU, J.W.	1929 - 1965
DAFOE, I.A.	1945 - 1961
DAINTY, E.D.	1962 -
DALTON, J.L.	1964 -
DARKE, E.F.	1961 -
DARLING, J.A. (E)	1951 -
DAVID, I.B.	1940 - 1961
DAVIE, A.	1917 - 1938
DAVIS, A.	1919 - 1937
DAVIS, K.G.	1961 -
DAVIS, T.E.	1944 - 1960
DEAN, Dr. R.S.	1961 -
DELORME, C.A.	1943 - 1955
DENIS, J.M.	1963 -
DENNIS, G.J.W.	1956 -
DERRY, B.M.	1914 - 1930
DERRY, C.A.	1930 - 1972
DESJARDINS, L.E.	1955 -
DESJARDINS, R.	1953 -
DEVINE, E.H.	1948 - 1969
DEVINE, N.M.	1958 - 1975
DIBBS, Dr. H.P.	1958 - 1972
DIER, F.	1913 - 1931
DINGLEY, W.	1945 -
DION, J.L.	1964 -
DIXON, C.F.	1954 -
DJINGHEUZIAN, L.E.	1948 - 1966
DONAHOE, R.H.	1951 -
DOWLING, D.F.	1947 - 1969
DOWNES, Dr. K.W.	1947 - 1974
DRAPER, R.G.	1949 -
DUNN, M.J.	1956 - 1970
DUNN, T.J.	1913 - 1937
DUPUIS, J.P.	1962 -
EARDLEY-WILMOT, V.L.	1921 - 1951
EDWARDS, J.O.	1948 -
EELES, Dr. E.G.	1957 - 1970
EGAN, W.J.	1930 - 1942
EICHHOLZ, Dr. G.G.	1948 - 1963
ELLIOTT, S.A.	1927 - 1952
ELLIS, J.A.	1946 -
ELLIS, W.A.	1937 - 1953
ELLS, S.C.	1911 - 1945
ELWORTHY, R.T.	1914 - 1927
EMMETT, J.R.	1955 -
ENSELL, G.	1926 - 1947
FARNHAM, G.S.	1925 - 1946
FARNHAM, M.M.	1913 - 1946
FARQUHAR, J.B. (V)	1901 - 1932
FAURSCHOU, D.K.	1951 -
FAWCETT, A.B.	1946 -
FAYE, G.H.	1950 -
FEGREDO, Dr. D.M.	1962 -
FELTRIN, M.	1929 - 1965
FERRIGAN, P.	1943 - 1969
FICKO, L.A.	1948 - 1960, and 1967 -
FITZPATRICK, E.L.	1955 -
FLANSBURY, J.P.	1941 - 1967
FLEMING, R.	1937 - 1947
FLETCHER, M.C. (E)	1921 - 1950
FLEURY, J.L.	1962 -
FLEURY, L.C.F.	1953 - 1971
FLOOD, T.H.	1916 - 1949
FLOOD, W.J.	1924 - 1946
FORD, G.N. (V)	1909 - 1933
FORTUNE, J.H.	1908 - 1931
FOUHSE, R.G.	1958 -
FOURNIER, J.A.	1937 - 1954
FRASER, H.S.	1946 - 1975
FRECHETTE, H.	1908 - 1946
FRECHETTE, L.P.	1953 -
FREDERICK, J.E.	1947 - 1967
FREEMAN, C.	1954 -
FREEMAN, C.H.	1913 - 1953
FRESQUE, C.	1912 - 1960
FRIEDRICH, F.D.	1957 -
FRISCH, Dr. H.	1960 - 1970
FRYZUK, P.	1961 -
FYDELL, J.F.	1949 -
GADBOIS, M.	1947 - 1972
GAGNON, P.E.	1965 -
GAMEY, R.H.	1948 - 1964
GARRISON, J.G.	1958 - 1974
GAUTHIER, R.J.	1965 -
GELLER, L.B.	1959 -
GERTSMAN, S.L.	1946 -
GILLESPIE, P.T.	1939 - 1951
GILLIESON, Dr. A.H.	1959 - 1975
GILMORE, A.J.	1948 -
GILMORE, R.E.	1917 - 1919, and 1923 - 1954
GLAUDE, C.H.	1929 - 1973
GODARD, J.S.	1908 - 1913, and 1922 - 1931
GOUDGE, M.F.	1923 - 1959
GOURGON, E.	1941 - 1970
GOW, W.A.	1946 -
GRANT, A.V.	1947 - 1974
GRANT, F.	1952 -
GRAVELLE, A.	1913 - 1937
GRAVES, H.A.	1947 - 1958
GRAY, Dr. W.M.	1953 -
GRENON, W.J.	1948 -
GUENETTE, H.	1946 - 1960
GUENETTE, R.C.	1950 -
GUEST, R.J.	1948 -
GUILFOYLE, J.A.	1953 -

GUINDON, H.P.	1961 -
GYENGE, M.	1962 -
HAANEL, B.F.	1905 - 1946
HAANEL, Dr. E.	1901 - 1920
HALL, W.A.	1957 -
HAMILTON, D.L.	1960 - 1975
HAMILTON, R.I.	1945 -
HAMON, E.J.	1955 -
HANDY, G.E.	1946 -
HANES, F.E.	1956 - 1974
HANSON, A.J.	1955 -
HARBEC, J.	1956 -
HARDY, H.R.	1953 -1966
HARDY, T.W.	1914 - 1919, and 1928 - 1934
HARPER, W.H.	1927 - 1969
HARRINGTON, A.E.	1949 - 1969
HARRISON, F.	1919 - 1936
HARRISON, V.F.	1947 -
HARTMAN, F.H.	1959 - 1975
HAVERCROFT, W.E.	1947 - 1975
HAW, V.A.	1950 - 1959, and 1961 -
HAWKINS, T.H.	1951 - 1970
HAYCOCK, Dr. M.H.	1931 - 1965
HAYES, S.J.	1941 - 1969
HAYSLIP, G.O.	1948 -
HEATHERINGTON, G.W.	1935 - 1950
HEBERT, A.	1953 -
HERBERT, C.R.	1927 - 1946
HERBERT, J.A.	1951 -
HERNANDEZ, P.	1948 -
HERRMANN, Dr. W.A.O.	1956 -
HERWIG, S.L.	1946 -
HICKSON, R.P.	1927 - 1947
HINTON, J.G.	1930 - 1957
HINTON, W.	1925 - 1938
HITCHEN, A.	1952 -
HOBBS, A.C.	1930 - 1962
HOBBS, K.L.	1964 - 1975
HOLE, J.C.	1962 -
HOLMAN, S.	1917 - 1954
HONEYWELL, W.R.	1948 - 1973
HORWOOD, Dr. J.L.	1947 -
HUDSON, J.G.S. (E)	1908 - 1929
HUDSON, H.P.	1921 - 1969
HUFFMAN, H.R.	1948 - 1960
HUGHES, P.E.	1958 - 1975
HUGHSON, M.R.	1952 -
HUNT, G.A.	1952 -
HUOT, R.B.	1955 -
HUTCHINGS, W.	1943 - 1964
HUTCHINGS, W.G.	1954 - 1966
IGNATIEFF, A.	1947 - 1972
INGLES, J.C.	1949 - 1951, and 1952 -
INGRAHAM, Dr. T.R.	1953 - 1972
INMAN, W.R.	1946 - 1969
JAMES, H.C.	1948 - 1975
JENKINS, W.S.	1930 - 1964
JOANISSE, L.	1941 - 1953
JOANISSE, P.E.	1929 - 1931, and 1936 - 1947
JOHNSTON, J.D.	1925 - 1960
JOHNSTON, N.O.	1952 -
JOHNSTON, R.A.	1927 - 1941
JOLY, F.	1913 - 1936
JONES, R.J.	1945 - 1957
JONGEJAN, Dr. A.	1957 -
JORGENSEN, J.G.	1955 -
JOSLING, C.A.	1948 -
JOY, L.O.	1950 -
JUBB, Dr. J.T.	1965 -
JUNEAU, E.	1913 - 1940
KAIMAN, S.	1946 -
KANE, J.	1925 - 1945
KAPELLER, F.	1960 -
KAYE, A. (V)	1906 - 1932
KELLY, F.J.	1959 -
KELSO, R.A.	1952 -
KENT, G.A.	1955 -
KING, A.D.	1949 -
KINSEY, H.V.	1942 -
KIRKCONNELL, J.R.	1930 - 1947
KLINE, C.F.	1957 -
KNIGHT, G.	1965 -
KNIGHT, R.F.	1958 -
KOBUS, R.S.	1960 -
KORNELSEN, E.D.	1948 - 1968
KOSOWAN J.A.	1942 -
KOWALCHUK, E.	1962 -
KRITSCH, A.	1910 - 1936
KRITSCH, W.	1913 - 1956
KRZYZEWSKI, J.V.	1954 -
LABELLE, L.	1925 - 1965
LACELLE, M.	1963 -
LACHAPELLE, P.R.	1947 -
LAFLAMME, V.	1917 - 1945
LAFORTUNE, R.	1965 -
LAFRENIERE, D.	1915 - 1945
LAGOWSKI, B.	1956 -
LAKE, R.H.	1930 - 1974
LALIBERTE, J.A.	1924 - 1948
LALIBERTE, J.J.	1963 -
LALONDE, C.R.	1957 -
LANDON, J.E.	1958 - 1970
LANDRY, R.H.	1949 - 1973
LANG, W.I.	1951 - 1970
LANGLEY, C.	1916 - 1926
LAPOINTE, Dr. C.M.	1945 - 1971
LAROCHELLE, A.E.	1926 - 1966
LAROCQUE, G.	1959 -
LAROCQUE, J.E.	1947 - 1957
LARSEN, P.A. (E)	1958 -
LASALLE, E.M.	1950 - 1970
LAUDER, H.R.	1950 - 1970
LAUFER, Dr. E.E.	1965 -
LAVIGNE, Dr. M.J.	1948 - 1956, and 1973 -
LAW, C.	1947 -
LEE, G.K.	1958 -
LEFEBVRE, E.E.	1951 - 1974
LEFEBVRE, J.M.	1950 -
LEFEBVRE, O.	1950 - 1973
LEMIEUX, G.R.	1965 -
LENNON, H.T.	1941 - 1962
LEPAGE, S.T.	1950 -
LESTER, E.	1915 - 1944
LETOURNEAU, J.J.G.	1965 -
LEVERIN, H.A.	1906 - 1944
LEVESQUE, A.J.	1953 -
LEWORTHY, G.E.	1924 - 1946
LIGHTLE, H.R.	1945 - 1967
LINDEMAN, E.	1905 - 1915
LISTER, D.F.	1950 - 1961, and 1966 -

LIVELY, J.P.	1954 - 1965
LIVIE, D.M.	1947 - 1974
LLOYD, T.A.	1956 -
LOUTHOOD, B.	1957 - 1968
LUCAS, B.H.	1958 -
LUI, Dr. A.W.	1964 -
LUTES, L.	1916 - 1967
MABEE, H.C.	1911 - 1937
MacDIARMID, D.A.	1948 - 1975
MacDONALD, G.G.	1941 - 1952
MacDONALD, R.A.	1930 - 1948
MacDONALD, W.A.	1951 -
MacEACHERN, E.H.	1955 -
MacGIBBON, P.E.	1942 - 1953
MacLEOD, J.D.	1959 -
MacMARTIN, L.J.	1911 - 1925
MacPHEE, N.C.	1941 - 1957
MacPHERSON, D.R.	1951 -
MADGWICK, T.G.	1932 - 1946
MALETTE, M.J.	1955 -
MALHOTRA, V.M.	1962 -
MALLOCH, E.S.	1914 - 1947
MANTLE, A.W.	1910 - 1939
MARIER, P.	1954 - 1972
MARSH, F.W.	1950 -
MARTEL, J.G.R.	1947 - 1973
MARTINDALE, E.S.	1936 - 1953
MARTINEAU, W.A.	1946 - 1970
MATHIEU, G.I.	1960 -
MATTHEWS, S.	1948 - 1959
MAYOTTE, A.D.	1949 - 1961
McADAM, R.C.	1945 -
McCANN, H.V.	1938 - 1964
McCLELLAND, W.R.	1924 - 1956
McCOURT, V.A.	1947 - 1972
McCREE, J.S.	1930 - 1969
McCREEDY, H.H.	1954 -
McDONALD, R.D.	1955 -
McFARLANE, J.A.	1942 - 1963
McGOEY, J.T.	1965 -
McINTYRE, D.J.	1962 -
McLEISH, J.	1907 - 1941
McLEOD, W.	1960 - 1974
McMAHON, C.	1945 - 1973
McMAHON, J.F.	1925 - 1936
McMASTER, C.H.	1951 -
McNAMARA, V.M.	1954 -
MEIER, J.W.	1941 - 1970
MEIGM, G.H.	1950 - 1960
MELESKIE, K.R.	1961 -
MERCIER, H.	1927 - 1967
MERRILL, W.H.	1947 -
MIDDLETON, G.E. (V)	1901 - 1925
MILKS, H.	1958 -
MILLER, G.A.	1950 -
MILLIKEN, K.S.	1950 -
MILLSON, Dr. M.F.	1954 - 1967
MIRKOVICH, V.V.	1961 -
MITCHELL, Dr. C.M.	1948 -
MITCHELL, E.R.	1949 -
MOGAN, J.P.	1957 -
MOHR, C.B. (E)	1923 - 1950
MOLOUGHNEY, J.L.	1942 - 1955
MOLOUGHNEY, P.E.	1956 -
MONTGOMERY, Dr. D.S.	1948 -
MONTGOMERY, W.J.	1948 -
MONTONE, H.B.	1965 -
MONTURE, Dr. G.C.	1939 - 1956
MOODIE, H.	1930 - 1946
MOODIE, R.P.	1929 - 1946
MOORE, R.H.	1948 - 1969
MORAN, J.	1916 - 1940
MORAN, T.	1927 - 1951
MULFORD, P.E. (V)	1918 - 1933
MUNRO, D.A.	1956 -
MURPHY, G.W.	1957 - 1971
MURRAY, E.J.	1949 -
MURTON, A.E.	1944 -
NADON, L.C.	1949 - 1973
NANDI, Dr. B.	1963 -
NARRAWAY, R.V.	1953 -
NEATE, F.G.	1929 - 1941
NEBESAR, B.	1964 -
NEELANDS, R.E.	1945 - 1957
NELSON, G.L.	1956 -
NEVIN, J.T.	1950 -
NICHOLS, H.J.	1943 - 1958
NICKEL, Dr. E.H.	1953 - 1971
NICOLLS, J.H.H.	1914 - 1949
NOEL, G.J.	1955 -
NOLAN, G.W.	1948 - 1971
NOLAN, L.M.	1952 -
NOLAN, M.J.	1948 - 1974
NORMAN, D.M.	1961 -
NORRISH, W.H.	1936 - 1962
NORTON, C.H.	1924 - 1958
OAKLEY, P.E.	1953 -
O'BRIEN, F.J.	1950 -
O'BRIEN, W.	1924 - 1949
O'BRIEN, W.A.	1922 - 1950
O'CONNOR, H.J.	1948 - 1965
O'DONOVAN, P.	1947 - 1975
OFFORD, R.J.	1921 - 1958
O'GRADY, M.A.	1946 - 1970
O'HARA, J.B.	1929 - 1955
O'HARA, J.O.	1948 -
OLIVIER, B.G.	1945 - 1971
O'NEIL, J.E.	1956 - 1966
OVERTON, C.A.	1956 - 1969
OWEN, H.J.	1960 -
OWENS, D.R.	1954 -
PALEN, G.E.	1949 -
PALOMBO, D.P.	1954 -
PANTELIMON, P.	1948 - 1970
PAQUETTE, B.	1954 -
PARSONS, Dr. B.I.	1955 -
PARSONS, C.S.	1914 - 1918, and 1921 - 1951
PARSONS, D.E.	1950 -
PARSONS, H.W.	1959 -
PATRY, O.L.	1961 -
PEACOCK, A.J.	1946 - 1959
PEARSE, W.H.	1926 - 1942
PEDEN, D.C.	1945 -
PEREIRA, L.H.S.	1910 - 1934
PERRIN, L.A.	1956 - 1971
PERRY, J.A.	1945 - 1974
PETRUK, Dr. W.	1960 -
PHILLIPS, J.G.	1927 - 1956
PICHER, R.H.	1917 - 1954
PICKETT, D.E.	1954 - 1974
PICKFORD, H.N.	1949 - 1966
PILGRIM, R.F.	1948 -
PINARD, R.G.	1957 -
PLEET, M.P.	1948 -
PLOSENSKI, M.M.	1959 - 1974

PLOUFFE, A.	1943 - 1955
PLUNKETT, N.	1942 - 1957
POIRIER, J.L.	1928 - 1963
POLLARD, W.A.	1952 -
POST, B.C.	1961 -
POULIN, J.A.	1949 -
PREST, E.J.	1957 -
PRICE, K.T.	1958 -
PRINCE, Dr. A.T.	1946 - 1965
PRITCHARD, J.S.	1932 - 1947
PRITCHETT, E.A. (V)	1914 - 1932
PUGLIESE, R.J.	1956 -
PURDY, C.J.	1955 - 1971
QUINN, L.J.	1949 - 1974
QUINSEY, D.H.	1959 - 1970
RABBITTS, A.T.	1947 - 1953, and 1961 - 1974
RAICEVIC, D.	1965 -
RALPH, M.S.	1941 -
RAMEY, N.J.	1961 -
RANDALL, N. (E)	1940 - 1950
REAUME, G.A.	1926 - 1969
REEVES, J.E.	1956 - 1969
REID, W.	1914 - 1945
RENAUD, B.G.	1951 -
RENAUD, E.J.	1950 -
RENAUD, G.A.	1914 - 1956
RENAUD, H.J.	1930 - 1973
RETHIER, M.A.	1964 -
REYNOLDS, A.J.	1935 - 1971
REYNOLDS, T.M.	1927 - 1947
REZNICK, M.J.	1958 -
RICE, D.A.	1937 - 1963
RICHARD, E.	1916 - 1936
RICHARDS, E.J.	1928 - 1946
RICHARDS, L.C.	1953 -
RICHARDSON, A.E.	1927 - 1939
RICHARDSON, G.W.	1920 - 1930
RILEY, G.W.	1964 -
RIOPELLE, S.F.	1946 - 1971
RIPLEY, L.G.	1950 -
RIVINGTON, J.A.	1927 - 1947
ROBERTS, Dr. W.N.	1957 -
ROBERTSON, W.G.	1953 - 1972
ROBINSON, A.H.A.	1911 - 1938
ROBINSON, B.G.	1928 - 1945
ROBINSON, D. (V)	1907 - 1932
ROBINSON, J.E.	1929 - 1949
ROCQUE, K.A.	1950 -
ROEBUCK, D.W.	1960 - 1974
ROGERS, R.A.	1924 - 1956
ROGERS, Dr. R.R.	1944 - 1969
ROLOSON, F.P.	1948 - 1970
ROONEY, R.	1936 - 1961
ROSBOROUGH, P.G.	1951 - 1973
ROSEWARNE, P.V.	1921 - 1954
ROULEAU, J.N.	1945 - 1960
ROUTLIFFE, J.D.	1947 - 1973
ROWE, C.G.	1958 - 1972
ROWLAND, J.F.	1949 -
ROZENHART, C.J.F.	1953 -
SABOURIN, R.G.	1950 -
SABOURIN, V.	1946 - 1968
SADLER, A.	1919 - 1954
SAIDDINGTON, J.C.	1961 -
SALA, J.C.	1956 - 1970
SALLY, A.R.	1951 -

SAMSON, S.F.	1954 -
SATTHERTHWAITE, E.	1941- 1964
SAURIOL, L.N.	1952 - 1963
SAVIGNAC, D.G.	1963 -
SAWATZKY, Dr. H.	1959 -
SEBISTY, J.J.	1951 -
SEELEY, A.F.	1951 - 1964
SEELY, P.B.	1930 - 1965
SHAHEEN, L.E.	1954 -
SHANKS, D.I.	1950 -
SHANKS, G.W.	1953 -
SHANNON, P.E.	1929 - 1972
SHARPE, S.G.	1952 - 1975
SHAW, Dr. G.T.	1944 - 1972
SHELDRICK, D.A.	1954 -
SHERWOOD, J.G.	1951 -
SHIELDS, J.E.	1951 -
SICKMAN, E.H.J.	1962 -
SILVER, S.	1956 -
SIMARD, G.V.	1930 - 1947
SIMARD, J.P.	1960 -
SIMARD, R.	1948 - 1962
SIRIANNI, G.V.	1949 -
SIROIS, L.L.	1961 -
SKELLY, Dr. H.M.	1961 -
SKULSKI, J.Z.	1964 -
SMELSKY, G.	1952 -
SMITH, D.A.	1943 - 1953
SMITH, Dr. E.	1958 -
SMITH, E.D.	1952 -
SMITH, G.D.	1953 - 1975
SMITH, H.W.	1945 - 1974
SMITH, L.P.	1952 - 1963
SMITH, R.A.	1945 - 1958
SMITH, T.B.	1937 - 1955
SOLES, J.A.	1961 -
SOROCHAN, J.M.	1952 -
SPENCE, H.S.	1910 - 1949
SPENCE, N.S.	1953 - 1975
STANSFIELD, E.	1910 - 1921
STEFANICH, W.N.	1965 -
STEMEROWICZ, A.I.	1963 -
STEVENSON, D.A. (E)	1951 - 1967
STEWART, J.	1941 - 1968
STEWART, J.M.	1949 -
ST. LOUIS, A.V.	1960 -
STOTESBURY, J. (E)	1922 - 1942
STRONG, R.A.	1924 - 1945
SUGRUE, J.	1915 - 1944
SULLIVAN, J.D.	1950 - 1973
SULLIVAN, W.J.	1925 - 1946
SUTARNO, Dr. R.	1965 -
SUTHERLAND, E.	1942 - 1964
SVIKIS, V.D.	1953 - 1970
SWAIN, J.G.	1948 -
SWARTZMAN, E.	1928 - 1960
SWIMMINGS, C.	1937 - 1950
SWIMMINGS, E.A.	1944 - 1955
SWIMMINGS, E.K.	1953 -
SWINNERTON, A.A.	1921 - 1958
SYLVESTRE, J.G.	1948 -
TAILLEFER, J.P.	1965 -
TAYLOR, R.W.	1954 -
THIRKELL, V.R. (V)	1920 - 1932
THOMAS, G.	1950 - 1967
THOMAS, J.F.J.	1946 - 1965
THOMAS, L.O.	1941 - 1953
THOMPSON, E.A.	1918 - 1937
THOMSON, Dr. R.	1964 -

THURSTON, R.C.A.	1946 - 1975
TIBBETTS, T.E.	1952 -
TIMM, F.M.	1948 - 1961
TIMM, W.B.	1913 - 1950
TIMMS, E.R.	1963 -
TIMMS, F.C.	1954 -
TINGLEY, I.I.	1953 - 1964
TIPPINS, J.F.	1948 -
TODERAN, G.	1960 -
TODKILL, P.J.	1949 -
TOEWS, N.A.	1958 -
TOLL, R.W.	1935 - 1949
TOUCHETTE, E.H.	1953 - 1965
TRAILL, R.J.	1916 - 1955
TRAVERSY, V.	1942 - 1954
TRAVERSY, W.J.	1954 - 1965
TRIPP, D.F.	1955 -
TRUDEAU, E.J.	1944 - 1971
TUPPER, E.C.	1958 -
TWIDALE, M.A.	1958 - 1971
VALLEE, L.	1941 - 1966
VALLIERES, J.H.J.	1965 -
VANASSE, P.	1943 - 1973
VARY, C.A.	1949 -
VEZINA, J.A.	1960 - 1973
VIENS, G.E.	1945 -
VISMAN, Dr. J.	1951 -
WAIT, E.H.	1923 - 1957
WAIT, F.G.	1907 - 1931
WALLACE, G.G.	1951 -
WALSH, Dr. J.H.	1955 - 1974
WARA, W.	1951 - 1973
WARBURTON, H.E. (V)	1914 - 1929
WARD, J.J.	1952 - 1971
WARDLAW, H.E.	1950 - 1967
WARNER, H.W.	1930 - 1941
WARREN, H.D.	1950 - 1967
WARREN, Dr. T.E.	1929 - 1952
WATTS, G.T.	1955 - 1966
WATTS, H.L.	1938 - 1948
WEATHERALL, M.H.	1953 - 1964
WEBSTER, Dr. A.H.	1957 -
WEBSTER, C.H.	1946 -
WEINBERG, Dr. F.	1951 - 1967
WELD, H.M.	1948 -
WESTFALL, A.	1942 - 1968
WESTON, T.B.	1948 -
WESTWOOD, D.	1914 - 1942
WHALLEY, Dr. B.J.P.	1950 -
WHITE, Dr. D.W.G.	1957 -
WHITE, J.R.	1956 - 1970
WHITE, J.R.M.	1949 - 1974
WHITE, W.E.	1930 - 1961
WHITE, W.F.	1926 - 1953
WILKINS, A.L.	1949 -
WILLIAMS, Dr. A.J.	1954 -
WILLIAMS, J.G.	1916 - 1946
WILLS, G.A.	1953 - 1973
WILSON, Dr. A.W.G.	1909 - 1941
WILSON, H.S.	1952 -
WINER, A.A.	1962 -
WINTERTON, Dr. K.	1958 -
WLODEK, Dr. T.W.	1942 - 1970
WOODHOUSE, K.A.	1954 - 1964
WOODROOFFE, H.M.	1946 - 1974
WRAZEJ, Dr. W.J.	1951 - 1964
WRIGHT, I.F.	1948 - 1974
WYMAN, R.A.	1954 -
YANICK, F.	1940 - 1971
YAO, Dr. Y.L.	1950 -
YATES, A.	1950 -
YORK, J.H.	1929 - 1946
YOUNG, R.J.	1929 - 1957
YU, Y.S.	1965 -
ZAWADSKI, W.	1965 -
ZECHANOWITSCH, G.	1961 -
ZEMGALS, L.K.	1958 -
ZIMMERMAN, J.B.	1947 -
ZOLDNERS, N.G.	1957 - 1974
ZORYCHTA, H.	1951 - 1972
ZUMAR, H.	1931 - 1947

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