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PAPER 60-33

A PRELIMINARY STUDY OF CANADIAN METALLOGENIC PROVINCES

(Report, and 3 maps)

A. H. Lang

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A PRELIMINARY STUDY OF CANADIAN METALLOGENIC PROVINCES

By

A. H. Lang

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CONTENTS

<u>Illustrations</u>

A PRELIMINARY STUDY OF CANADIAN METALLOGENIC PROVINCES

INTRODUCTION

This paper and the maps accompanying it form a preliminary attempt to consider the applicability of the concept of metallogenic provinces to Canada, to suggest the degree to which the data now available permit delimiting them, and to experiment with methods of representation.

A tendency for certain metals or minerals to be confined to, or be most abundant in particular regions has long been noted by students of mineral deposits in various countries. Belief that such distributions are not mere accidents of prospecting led to the concept of 'provinces' called metallogenic or analogous names. Most authorities accept the general idea of such provinces but show much divergence in terminology, in application, and in explanation of their existence. Different writers have called them 'metallogenic', 'metallogenetic', 'metallographic', 'metalliferous', or 'minerogenetic' (Turneaure, 1955, p. 40)[1]—the latter is an attempt to provide a more appropriate name when the discussion is extended to non-metalliferous as well as metalliferous minerals. Of these names, metallogenic and metallogenetic are more commonly used, particularly when only metals are being considered; metallogenic is used in this publication because it is shorter.

Some writers use the term 'province' for fairly small areas, and at the other extreme some use it for such vast divisions as Precambrian shields and the stable regions of continents. A province may be described in terms of one or two metals, or of all the metals it is known to contain, or, distinction may be made between mineralogical or geological classes of deposits. Most writers take into consideration both economically important deposits and minor mineral occurrences, but some refer only to economic deposits; others include reference to metals that occur merely in trace amounts.

Several greatly different speculations have been advanced to explain the diversity in the distribution of metals or minerals. Most are in one of the following categories: (1) that the distribution of

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[1] Names or dates in parentheses refer to publications listed in the References.

elements in the original crust of the earth was sufficiently different to account for the present observations; (2) that certain elements may have become available in the deeper parts of the crust at certain times as a result of some process such as atomic transformation, and that a relationship between such times and those of tectonic disturbances might exist; (3) that certain metals are associated with specific kinds of igneous rocks, such rocks being more abundant in certain regions than in others; (4) that the distribution of metals at and near the surface of a region is related to the geological history of the region, which determines such factors as suitable environment for sedimentary or igneous processes of concentration, tectonic features, and depth of erosion.

In Canada differences have been recognized for many years between the mineral deposits found in certain large geological regions. Until the last few years, however, except for important pioneer work in part of the Northwest Territories by Jolliffe (1952) and Lord (1951), little was done to outline or describe areas as metallogenic provinces or subprovinces. Notable contributions were made, however, for various parts of the country, by several geologists who called attention to areas and belts characterized by one or more metals or types of deposits, without specific reference to metallogenic provinces.

Recent Work

A few years ago the Geological Survey of Canada began planning work specifically designed to clarify and augment knowledge of Canadian metallogenic provinces. It was believed that any advances made would have a practical application in the selection of areas for prospecting or for the study of mineral deposits, as well as having a possible academic value. The Survey had to decide whether it would be best to begin with a small area that showed evidence of being a distinct metallogenic unit and to study and sample it intensively, or to begin by assembling available data on a country-wide scale. This matter was settled for the time being by a request from the International Geological Congress that certain data be compiled for a metallogenic map of the world. To obtain suggestions as to what might be included in this map and how it might be depicted, each country was asked to compile a map for iron deposits and a composite one showing producing deposits of all metals and minerals in its territory. Although adherence to a few stipulations was requested, each country was left largely free to experiment. In addition to compiling these two maps, the Geological Survey of Canada decided to prepare maps for other individual metals — as many maps as staff, time, and available data permitted, because this would provide some information fairly quickly, whereas detailed study of one or more selected areas would be slow. Also, compiling available data on a small scale would help in selecting areas for further work and in indicating what subjects should be investigated. The compilations, begun under supervision of the writer late in 1957, resulted in the following manuscript maps:

Beryllium, by F.M. Vokes
Copper, by E.D. Kindle (producing mines)
Chromium, by K.A. MacLeod
Gold (Placer), by C.R. McLeod
Gold (Lode), by A.G. Johnston and K.A. MacLeod
Iron and Titanium, by G.A. Gross
Lead and Zinc, by D.R.E. Whitmore (producing mines)
Lithium, by R. Mulligan
Manganese, by R.G. Bowler
Mercury, by D.R.E. Whitmore
Molybdenum, by F.M. Vokes
Nickel and Cobalt, by A.G. Johnston
Niobium, by F.M. Vokes
Tin, by D.R.E. Whitmore
Tungsten, by E.D. Kindle and H.W. Little
Uranium, by A.H. Lang
Vanadium, by R.G. Bowler

The maps for uranium, beryllium, molybdenum, and iron were published as Maps 1045A-M1, 1045A-M2, 1045A-M3, and 1045A-M4 respectively. Publication of some others is anticipated. In the cases of copper, lead, and zinc, the huge number of small mineral occurrences has so far prevented compiling more than the positions of deposits that are producing or have produced. Silver was not treated separately because it most commonly accompanies gold and lead-zinc occurrences. A map showing platinum occurrences was not prepared in this series because one had already been compiled (No. 1746, out of print) and few additional occurrences had been reported. Maps for other minor metals have not yet been undertaken.

The data for each map, except the one for iron, were obtained from departmental files on mining properties and mineral identifications, and from reports of the Geological Survey, the Mines Branch, and provincial mining and geological agencies, the Annotated Bibliography of Economic Geology, the Bibliography of North American Geology, and many individual reports on specific metals or areas. Inevitably, companies or prospectors will know of additional occurrences that have not been mentioned in the literature or that were missed in studying it. A few occurrences reported confidentially could not be included. The coverage is believed to be sufficiently complete to provide a fairly satisfactory depiction of the present state of knowledge of the distribution of occurrences of the metals concerned. In the case of iron, the deposits shown were selected because minor occurrences of iron minerals are so widespread. A uniform 'cut-off' quantity for the smallest amount of a metal classed as an occurrence was not used for all maps because the maps are experimental.

A map showing medium and large producing and past-producing deposits, classified according to geological types, was prepared by W.D. McCartney and the writer, and submitted in manuscript form to the International Geological Congress.

Present Study

It was originally intended that, after publication of maps for individual metals, a 'composite' map would be prepared. The purpose of this would be to judge the degree to which the concept of metallogenic provinces based on several metals is applicable to Canada, and to try to outline and describe such regions more comprehensively and more accurately. Circumstances, however, made it possible for the writer to undertake a preliminary study of this kind and it was decided to publish the resulting maps in advance of those for the individual metals. This is regrettable in that much use was made of the unpublished compilations, but the decision was taken largely because it seemed the quickest way of making the data available. The number of compilers is too large to be included as joint authors of the present study, and in any case the writer must assume full responsibility for the manner of compiling the composite maps or of the opinions expressed. Credit to the other compilers must, therefore, be accorded by acknowledgment.

The writer's approach to the subject was first to assemble as much data as seemed practicable, in as empirical a way as possible, then to attempt an interpretation in a second, subjective phase of the study. Non-metalliferous minerals were not considered because, although they no doubt have a place in a full investigation of provinces, the metals provide more than enough problems for a preliminary study. To aid interpretation, maps were compiled on transparent 'cronaflex', on the same scale as the geological map of Canada. Areas containing occurrences were plotted with coloured inks. As it was impossible to obtain enough distinctive colours for all the metals for which information was available, two maps were made, one for major and one for minor metals. These maps were reproduced as Maps A and B accompanying this paper. Productive deposits were not indicated separately to avoid complicating the maps.

The islands in the Canadian Arctic region were not dealt with because few occurrences of metals have been found there.

The distinction between major and minor metals was made somewhat arbitrarily, but examination of statistics for recent metal production shows the value of the output of uranium, nickel, copper, iron, gold, lead, zinc, and silver to be much greater than that of other metals. Lead and zinc were combined because they commonly occur together. Cobalt was combined with nickel for the same reason. Silver, other than occurrences in the native state, was not treated separately because most of the silver production comes from gold or lead-zinc deposits; native silver was treated on Map B because occurrences in this form may have metallogenic significance. Selected iron occurrences, as shown on Map 1045A-M4, were plotted on the manuscript of Map A but were omitted from the published version for several reasons. The abundance of iron in the earth's crust is of a different order from other metals, except those in common rock-forming minerals, such as aluminum, magnesium, calcium, sodium, and potassium. Quantities of iron minerals such as are found as accessory minerals in igneous rocks, in sedimentary rocks derived from them, in sands, and found in other ways, are so common and so widespread that indicating them would serve little purpose. To outline selected areas containing larger concentrations would not be in keeping with the usage for other metals. However, iron occurrences are discussed in this paper.

The minor metals treated on Map B are those for which information was readily available, except that molybdenum was omitted. Map 1045A-M3 shows that molybdenum occurrences are so numerous and widespread in many large regions that it is difficult to specify molybdenum provinces for the metal in general, although smaller 'provinces' based on types of deposits may be suggested.

In deciding what constituted an occurrence the same conventions were adopted as for the maps of individual metals—namely, a reliably reported occurrence of a mineral regarded as a source for the metal concerned, not one in which the metal is a minor constituent; or, in those cases where assays instead of mineral identifications were reported, a minimum quantity. This was 0.1 per cent except in cases where there was a special reason for using a different amount, as in the case of uranium; a minimum of 0.05 per cent has been set by the Atomic Energy Control Board to define a uranium occurrence. Metals occurring in amounts less than these were not considered. Widely scattered occurrences were not included because the purpose of the compilation is to indicate places where at least some degree of concentration of occurrences is known. For the major metals, only areas where occurrences are fairly plentiful were included. For minor metals it was considered best to indicate areas where two or more occurrences are fairly close together, or possible belts where three or more occurrences are aligned, even if rather far apart. Such alignment is not necessarily significant, but is at least suggestive of genetic relationship. The limits of areas containing occurrences were generalized. Occurrences were scarcely ever distinguished according to types of deposits, such as veins, pegmatites, etc., because of limitations of the number of symbols and patterns that can be used successfully on a single map. Niobium occurrences were, however, divided into two classes; the reason for this is explained later.

One of the main weaknesses of this study is that comprehensive maps for occurrences of copper, lead, and zinc were not available, but it seemed inadvisable to delay the preparation of the report until they could be compiled. The principal areas containing these metals were outlined roughly, using data from "Zinc and Lead Deposits of Canada" (Alcock, 1930) and various local reports and papers, supplemented in some instances by personal knowledge and by discussions with certain geologists. Inevitably, however, persons familiar with particular areas will note errors and omissions. Even for the other metals, errors will probably be detected because data on some known occurrences were not available or because too great liberties were taken in 'roughing out' the areas. The information must, therefore, be regarded as more or less diagrammatic and not of the standard of ordinary geological maps.

Maps A and B exhibit patterns of various degrees of complexity. The simplest patterns, such as the existence of many occurrences in the Canadian Shield whereas few are known in the Interior Plains, are obvious. The more detailed patterns are fairly self-evident on the maps and need little description. They can, however, be interpreted in different ways. The writer's approach to this phase of the study was to prepare another map (Map C) on the same scale, outlining the geological subdivisions of the Canadian Shield and the Cordilleran region that have been suggested by various authors, or, in the many instances where more than one name has been advocated or where the boundaries are conflicting or undefined, using those that seem best for the time being. For the smaller subdivisions of the Cordilleran region, boundaries that are largely or entirely physiographic were used because geological subdivisions are not yet complete. Maps A and B were then compared with this map. If little correspondence had been noted, it would have been discarded and an attempt would have been made to generalize and describe the metallogenic patterns without reference to geological or tectonic subdivisions. There appeared, however, to be considerable, although far from complete, agreement. It was decided therefore to reproduce this map as Map C and to discuss one by one the subdivisions and the concordance or discordance of the metallogenic data with them. The distribution of occurrences is discussed only briefly. Consideration is given to the production of metals because one aspect of the study of metallogenic provinces is the distinction between productive and non-productive areas.

Acknowledgments

Information was obtained from many published reports, papers and maps, which are too numerous to acknowledge individually; many of the more significant ones are mentioned in the text. Particular use was made of papers by H.S. Bostock, J.E. Gill, A.W. Jolliffe, J.T. Wilson, and M.E. Wilson. The writer is grateful to the compilers of the metallogenic maps listed earlier. Helpful information was derived from discussions with H.S. Bostock and J.O. Wheeler regarding the Northern Cordillera, with G.B. Leech regarding the Rocky Mountain Trench, with J.A. Fraser and J.C. McGlynn regarding the Northwest Territories, with E.R.W. Neale regarding the Appalachian Region, and from a compilation of copper occurrences in Yukon Territory by E.D. Kindle and one of mineral occurrences in Newfoundland by W.D. McCartney.

SUMMARY OF DISTRIBUTION AND INTERPRETATION

GEOLOGICAL AND PHYSIOGRAPHIC DIVISIONS

The five main natural regions into which Canada is divided are both geological and physiographic, because the kinds of rocks and their geological histories have profound effects on the character of the land surfaces. Occupying about half the area of the country, the Canadian Shield is a region mainly of moderate relief, underlain by a complex assemblage of Precambrian rocks. The Shield is overlapped in many places by younger, flat or gently dipping sedimentary strata, forming the Interior Plains. The Appalachian region, in the eastern part of the country, is chiefly one of moderate relief, resulting from the long erosion of mountains formed in Palaeozoic times. The Cordilleran region, in the west, is chiefly one of high mountains and plateaux—the result of orogenies in Mesozoic and Tertiary times. The Innuitian region, in the northern part of the Arctic Archipelago, is a mountainous belt about which relatively little is known; it is not discussed in this paper, although it may prove to be an important metalliferous region.

Several broad generalizations can be made regarding the mineral deposits found so far in the four main regions, other than the Innuitian. Economically, the Shield is now Canada's greatest producer of metals; the Cordilleran region was the largest producer until about the beginning of the present century when the mines of the Sudbury, Cobalt, and Porcupine districts greatly augmented the production from the Shield. The Appalachian region has been, and is, an important source of metals, although not challenging the output from the two regions already mentioned. Parts of the Plains are large producers of coal, oil, natural gas, and non-metalliferous minerals, but the production of metals from the Plains has not been significant. The Shield and the Cordilleran and Appalachian regions each contain important producers of copper, iron, gold, silver, lead, and zinc. Production of nickel has been almost confined to the Shield, and uranium entirely so. Among the minor metals, arsenic, cadmium, calcium, cobalt, lithium, magnesium, manganese, molybdenum, metals of the platinum group, selenium, tellurium, titanium, and tungsten are or have been produced from the Shield, some as by-products of mining for other metals. Antimony, bismuth, cadmium, chromium, mercury, molybdenum, tin, and tungsten are or have been produced from the Cordilleran region, many as by-products. Antimony, chromite, and manganese have been produced from the Appalachian region.

There is thus much similarity between the metals produced in the three principal regions. The difference is mainly one of degree, except in the cases of nickel and placer gold; the latter is mainly derived from the Cordillera although an important amount was obtained from one area in the Appalachian region and some interest has been taken in placers in the Precambrian part of Ontario. The largest number of minor metals is produced from the Shield, but the Cordilleran region produces several of these and, in addition, a small amount of tin. Formerly the Cordilleran region produced an important quantity of mercury, whose virtual restriction to this region is to be expected because of the low-temperature origin of most mercury occurrences.

If occurrences in general, instead of productive deposits, are considered, even more similarities between the three main metalliferous regions are manifest. Each has large areas characterized by uranium, lode gold, iron, and copper; some of these areas overlap whereas others are separate. The Cordilleran region contains a very large lead-zinc area and the Appalachian a smaller one; the Shield also contains several such areas although they are still smaller. Areas containing nickel occurrences are most abundant in the Shield, but the Cordilleran region has several, and the Appalachian, one. Areas containing occurrences of minor metals are also much more widespread than are productive deposits of the respective minor metals. Areas known to contain several occurrences of lithium are confined to the Shield, although scattered occurrences have been found elsewhere. Both the Shield and the Cordilleran region contain areas of native-silver occurrences but most of the areas in the Cordillera are too small to show on the map or they consist of minor occurrences of supergene native silver in areas containing other, primary, silver minerals, whereas the Shield contains many occurrences of native silver that are considered entirely or mainly primary.

In discussing metallogenic provinces or subprovinces it is more desirable to deal with smaller regions than the fundamental ones mentioned above, and it seems useful to compare such smaller divisions to geological subdivisions of the same order. This, however, is difficult because for most parts of the country there is still much uncertainty regarding many of the geological subdivisions that are intermediate between the main regions such as the Shield, and the relatively small areas underlain by outcrops of a particular formation or intrusive body. The principal geological subdivisions of the Cordillera are well established. They correspond with physiographic divisions of the same order because the fairly young ages of the mountains permit much correspondence between physiographic and geological features. Smaller physiographic divisions show less correspondence with the geology, but were adopted because geological and tectonic subdivisions of these orders are far from being fully established.

As the Appalachian region is relatively small its geological subdivisions were not shown. Several authorities have contributed toward the dividing of the Shield into geological or tectonic areas but the subject is still uncertain. Names and boundaries are commonly conflicting or indefinite. Some students have suggested subdivisions based on kinds of rocks, some on their ages, and some have attempted to delineate regions based on the attitudes of strata or the prevailing directions of major folding and faulting. At present, important work is being done to compile more complete tectonic data and to relate this to age determinations on numerous samples, so that better defined and more widely accepted subdivisions of the Shield may be available within the next few years. Meanwhile, as the suggested classification of no single authority seems entirely suitable, parts of several systems were used, with a result that is not entirely uniform.

For the brief descriptions of geological subdivisions these usages were adopted:

> The largest divisions are termed regions; the main divisions of these, provinces; and smaller divisions are termed subprovinces.
>
> For brevity, the terms 'sedimentary' and 'volcanic' are used to embrace both unmetamorphosed and metamorphosed sedimentary or volcanic rocks.
>
> In discussing certain subprovinces named by Gill (1949, p. 65) the terms 'mountains', 'plain', and 'belted plain' are mentioned in the structural sense adopted by him, without reference to present relief. Thus 'mountains' refers to the eroded 'roots' of former mountains; 'plain' refers to a region underlain by flat-lying strata; and 'belted plain' refers to a region underlain by strata having a regional dip. Mountains and

plains are mentioned elsewhere in the physiographic sense, but the context will indicate which usage is meant.

In some instances linear patterns of occurrences are shown on Map B, or discussed; although these may not be, strictly, subprovinces, they seem pertinent.

Numbers in parentheses after the names of provinces or subprovinces refer to areas numbered on Map C.

CORDILLERAN REGION (1-3)

The Canadian Cordillera comprise a physiographically and geologically complex region, roughly 500 miles wide, extending from the islands along the Pacific coast to the Interior Plains, and from the 49th Parallel to the Alaska boundary. The region is composed of mountains, plateaux, and valleys generally trending northwesterly, that were formed by orogenic processes in Mesozoic and Tertiary times, and by subsequent erosion.

The Canadian Cordillera are divisible fundamentally into a western and an eastern Cordilleran 'province'. The division in British Columbia is made by the long and fairly regular Rocky Mountain Trench which, at least in those parts that have been studied closely, is due to erosion along various faults (Leech, 1959). The trench dies out near the British Columbia - Yukon boundary, beyond which the separation of the two main Cordilleran regions is less well defined. The Western Cordillera are on the site of the central part of a large eugeosyncline that extended from the vicinity of what is now California, to western Alaska. In this basin great thicknesses of sedimentary and volcanic strata accumulated intermittently, at least from late Precambrian times. There are some local evidences of early orogeny and metamorphism but these are largely obscured by the results of the great Nevadan orogeny. The latter appears to have begun in middle Jurassic time and to have included epochs of deformation that lasted well into Cretaceous time and that, in general, progressed eastward.

The mountain-building was accompanied by the emplacement of many large and small bodies of intrusive rocks, mainly granodiorite, granite, and related types, which are generally elongated or strung out northwesterly, parallel with the physiographic and formational trends. Ultrabasic intrusions are common in certain areas and although most are considered early phases of the Nevadan orogeny, some are probably older. The Nevadan mountains were eroded greatly during the Cretaceous; the resulting surface was uplifted during the Laramide disturbances; and the upland was dissected during later Tertiary time. Thus the present mountains of the Western

Cordillera, although commonly high and rugged, are second-stage mountains where concordant summit-levels and remnants of the dissected uplands can be seen, and where the intrusive bodies and their associated mineral deposits, once in the cores of the mountains, are now at or fairly close to the surface.

The Eastern Cordillera are on the site of a miogeosyncline that lay between the eugeosyncline and the stable interior of the continent. The strata deposited in it were mainly sedimentary and, at least as a general rule, they were folded later than those of the eugeosyncline—during the Laramide orogeny. This occurred mainly in early Tertiary time in the areas where the strata permit close dating, and presumably in other places as well. The mountains are in their first cycle of erosion; if many intrusive bodies and metalliferous deposits were formed in the cores of the mountain ranges, few have yet been exposed by erosion.

Western Cordillera

Physiographically, and to a large degree geologically, the Western Cordillera are divided into a coastal belt called the Western system, and a belt called the Interior system which lies between the Western system and the Eastern Cordillera.

The greater part of the Western system is formed by the Coast Mountains which extend almost from the 49th Parallel to the Yukon - Alaska boundary. The remainder is formed by the St. Elias Mountains; the Vancouver Island and Queen Charlotte Island Ranges which together are sometimes called the Insular Mountains; and, in the extreme south, the northern end of the Cascade Mountains which lie mainly in the United States. The predominant geological feature of the Western system is the Coast intrusions—a complex assemblage of batholiths and other bodies of different ages, ranging in composition from granite to gabbro. They include many roof-pendants of sedimentary or volcanic rocks, and there are also large areas of such rocks between intrusive bodies. The resistance to erosion of the intrusive rocks accounts largely for the high relief of the coastal belt.

The Interior system comprises a diversified group of mountains and plateaux in which the kinds of rocks and the geological structures vary greatly. Much-folded sedimentary and volcanic strata range in age from Late Precambrian to Cretaceous, and are intruded by many bodies of acidic, intermediate, or ultrabasic rocks. Many of the plateaux are capped by flows of Tertiary basalt, some of which are extensive. These flows no doubt cover some mineral deposits. In general, they form negative prospecting areas, but two possibilities should be borne in mind; geophysical methods capable of detecting deposits through flows may become available, and some of the areas of flows shown on small-scale maps may contain 'windows' where erosion has revealed the underlying rocks.

The western Cordilleran region abounds in metal occurrences of many kinds. "Up to 1955 more than 90 per cent of the lead, more than half the zinc, nearly half the silver, and more than a sixth of the copper and gold produced in Canada came from the Cordilleran region. It also contributed all the mercury and tin, nearly all the tungsten and antimony, and most of the cadmium and bismuth, besides some iron and a few metals of minor economic significance" (Stockwell, 1957, p. 349). This production came almost entirely from the Western Cordillera.

This region as a whole probably represents a large metallogenic province. The concentrations of occurrences as indicated on Map A show that the most striking metallogenic feature is the wide distribution of gold; that there are several large areas where copper occurrences are numerous; that one large area in southern British Columbia predominates in lead and zinc but that several smaller areas are also characterized by those metals; and that many occurrences of nickel and cobalt have been found in southern British Columbia. Iron occurrences are also fairly numerous, particularly on Vancouver Island and in the southern interior. It is difficult to decide whether the region should be divided into two metallogenic provinces corresponding with the Western and Interior systems, because there are some metallogenic similarities and some differences, and because many deposits lie at or near the boundary between the two systems. They are discussed separately, partly because there are some differences.

Western System (1)

St. Elias Mountains (1A)

These high mountains in southwestern Yukon Territory, adjacent to the Alaska boundary, are formed mainly of Palaeozoic and Mesozoic strata intruded by acidic igneous rocks related to the Coast intrusions. The inaccessibility, height, and glaciers of most parts of the area have retarded prospecting but occurrences of several types have been found. Gold was found in many streams, and lead, silver, platinum, and native copper were detected in concentrates from some localities. Lodes containing nickel and copper have been found at two places in the northern part of the area, and float containing copper and molybdenum has been reported. The only concentrations of occurrences known are of gold, forming an extension of a gold area in the Coast Mountains to the east, and of copper, forming a belt along the northeastern side of the area, near Kluane Lake.

Coast and Insular Mountains (1B, 1C)

These areas are discussed together because both are characterized by bodies of the Coast intrusions and because they have many metallogenic similarities. A more or less continuous belt of the Coast intrusions extends northward along the mainland coast from the vicinity of Vancouver. Much of the belt is in the Alaska panhandle but there the eastern part lies in northwestern British Columbia. Still farther north, the belt crosses Yukon Territory immediately east of the St. Elias Mountains. In several publications this belt is called the 'Coast Range batholith' or 'composite batholith', but more detailed mapping in many parts of it in recent years has shown it is not as continuous as was supposed, so the phrase 'Coast intrusions' is now favoured.

The Coast and Insular Mountains form one of the main mineral areas of Canada, which contains several important producing or formerly producing camps. The principal deposits are massive copper or copper-gold deposits, gold-quartz veins, complex gold, silver, and base-metal deposits, and metasomatic iron deposits. Non-producing occurrences of these metals are widespread. Occurrences of molybdenite have been found in many places. Several occurrences of nickel and cobalt are known in the southern part of Vancouver Island. Tungsten, arsenic, antimony, chromium, titanium, vanadium, and germanium have been found in places. Known magnetite deposits contain little titanium, in contrast to deposits in the Grenville province of the Canadian Shield (G.A. Gross, personal communication).

Most deposits have been found along the eastern and western flanks of the belt of intrusions but the large number of roof-pendants and the complex arrangement of intrusive bodies indicate that this generalization should not be carried too far. The distribution of occurrences, and prospecting possibilities of the Coast mountains have been discussed by Bacon (1954), Bostock (1950), Campbell (1959), Riley (1956), and others.

Cascade Mountains (1D)

This relatively small area contains fairly numerous occurrences of gold, copper, lead, zinc, and nickel but these are in continuations of larger areas containing these metals in the Coast Mountains and the Interior system. Also, an area of chromite occurrences extends from the Coast Mountains, and one of tungsten occurrences extends from the Interior system. This area therefore does not appear to be distinct metallogenetically, at least on the basis of the criteria used in the present study.

Interior System (2)

The part of the Western Cordillera lying east of the Coast Mountains has been divided into many physiographic units—some are distinct geologically, whereas others are fairly closely related. Those that are large enough to be shown conveniently have been indicated on Map C and are mentioned briefly below. The information on those in Yukon Territory is mainly from Bostock (1950), supplemented by data from Aho (1958) and Christie (1960). The outlines of divisions in British Columbia are largely from a map by Bostock (1948). Information on the geology and mineral occurrences is from many sources.

Northern Area (2A)

The region called by Bostock the 'Northern Area' includes several ranges, plateau areas, and plains, in the Western Cordillera north of Ogilvie and Wernecke Mountains. It is one of the least-known parts of the Yukon but appears to contain few intrusive rocks except in the Old Crow Range. No accounts of mineral discoveries were found in the literature, but placer tin is reported to have been found along Eagle River (H.S. Bostock, personal communication).

Ogilvie Mountains (2B)

These mountains constitute a large area north of Yukon and Klondike Rivers, which has been relatively little prospected. It contains several granitic stocks around which occurrences of gold, silver, lead, and antimony have been found. Placer gold and gold-quartz veins have been found elsewhere. The only known concentration is the extension of an area of copper occurrences north of Keno Hill in the Klondike subdivision.

Klondike Area (2C)

This subdivision comprises the Klondike placer area and a large expanse of similar, unglaciated, rolling-plateau terrain between the Alaska boundary and Pelly River. It is underlain largely by metamorphic rocks of the Klondike group, and granitic intrusions. These rocks contain small lode-gold occurrences which provided gold for the placer deposits that characterize most of the area, including the rich placers of the Klondike camp. Some of these placers also contain small amounts of mercury, lead, tin, platinum, and tungsten. Silver, lead, antimony, and mercury have been found in veins. The only occurrences that appeared to be close enough together to be indicated on the maps are the widespread gold occurrences and the west end of what may be a belt of three tin occurrences—one in this area and two in the adjoining Mayo area.

Mayo Area (2D)

This area, like the Klondike, is mainly in Yukon Plateau and is largely underlain by rocks of the Yukon group, intruded in places by stocks of granodiorite. The separation from the Klondike area is rather arbitrary, and is based partly on the kinds of mineral deposits found. The area is noted mainly for large production from exceptionally high grade silver-lead veins at Galena Hill and Keno Hill. Important amounts of placer gold, although not comparable to the production of the Klondike, have been won from several streams, and a smaller quantity of placer tungsten has been mined. Placers also carry minor amounts of mercury, tin, bismuth, monazite, and hematite. Various lodes containing copper, zinc, gold, antimony, tin, and tungsten have been found. Bostock notes that tin was also revealed in a spectrographic analysis of granodiorite from the locality of the cassiterite-bearing vein. Only some of these discoveries are close enough to each other to be depicted on the maps. A large area of gold occurrences, mainly placers, extends eastward from the Klondike area. North of Keno Hill is a fairly large area of copper occurrences; this is only partly in Mayo area. A fairly large section in this vicinity is outlined as a tungsten area, and as already mentioned, a few tin occurrences may form a belt.

Selwyn Mountain Area (2E)

This large area lies astride the Yukon - Northwest Territories boundary for about 500 miles—between Peel Plateau to the north and Liard Plain to the south. It lies immediately southwest of the Eastern Cordillera and consists, from north to south, of the Wernecke, Hess, and Logan Mountains, and Hyland Plateau. The area is underlain mainly by folded Palaeozoic strata intruded by many relatively small granitic bodies. Few parts are readily accessible, so prospecting has been retarded. However, placer gold has been found in several streams, and lodes carrying lead, zinc, silver, copper, tin, tungsten, as well as hematitic iron-formation, have been reported. In 1960 considerable interest was aroused by tungsten discoveries near the head of Flat River, in both Yukon and Northwest Territories. The only other known concentration of occurrences that could be shown on the maps is the east end of the copper area already mentioned, which extends into the Wernecke Mountains near Bonnet Plume River.

Nisling River Area (2F)

The belt between the Coast Mountains and Dawson Range, whose relation to the Tagish belt is not well defined, is tentatively called the Nisling River area. The only known concentration of occurrences there is the south end of a belt of gold occurrences extending from Dawson Range.

Dawson Range Area (2G)

Dawson Range lies south of Yukon River, extending northwesterly from Carmacks. The mountains contain large bodies of granodiorite and related rocks, intruding mainly rocks of the Yukon group. Many mineral deposits of different kinds have been found. Small amounts of placer gold and tungsten, and lode gold, silver, and copper have been produced. Lead, zinc, and antimony have also been discovered. The information available permitted mapping only a gold area extending southward from the Klondike, and a copper area north of Carmacks.

Tagish Belt (2H)

This relatively low area east of the Coast Mountains contains the remainder of the Whitehorse copper belt, as well as numerous gold occurrences and a few of lead and zinc. The only occurrences of chromite in the Yukon, to which references were found, are a few at the east edge of the Coast Mountains and between Whitehorse and Tagish Lake.

Pelly Mountains (2I)

This area is underlain mainly by various late Precambrian and Palaeozoic strata cut by several intrusive bodies; the latter are along the projection of the Cassiar batholith to the south. The Livingstone camp in the western part of the area yielded important amounts of placer gold and is an extension of the gold area to the west. Gold has been found on streams in other parts of the area, but only occurrences near Frances Lake in the eastern part appeared sufficiently concentrated to be shown on Map A. A few lodes containing copper and gold have been reported.

Pelly Plateau (2J)

This area lies south of Mayo area and, mainly, north of Pelly River. It is underlain chiefly by Palaeozoic strata and a large body of granodiorite or rock of related composition. Lodes carrying gold, lead, and zinc have been found, but the area is as yet little prospected and no concentrations of occurrences that could be shown on the maps are known.

Liard Plain (2K)

A large part of the valley of Liard River, in the vicinity of Watson Lake, forms the Liard Plain, which is partly in Yukon and partly in British Columbia. It is mainly drift-covered and so far as known, it is lacking in mineral discoveries.

Stikine Plateau (2L)

This large area, mainly in northern British Columbia between the Coast and Cassiar Mountains, extends northward and merges with Yukon Plateau. The northern part is underlain mainly by Palaeozoic rocks cut by several intrusive bodies, and has been called the Atlin horst (Wheeler 1959, p. 24). South of this the strata are mainly Mesozoic, overlain in places by areas of Tertiary lava.

The Stikine Plateau includes, near Atlin, the Engineer mine, a former gold producer, the Ruffner mine, a former silver-lead producer, and several past or present placer-gold mines. This part contains a fairly large area of gold occurrences and smaller areas of copper and lead-zinc occurrences, all of which seem to form a continuation of the area of these occurrences near Whitehorse. A few occurrences of tungsten, nickel, uranium, and beryllium have also been found near Atlin. Farther south, in the vicinity of Telegraph Creek, is an area containing gold placers, some of which were productive. An area of gold placers near Dease Lake, many of which were producers, is mainly in the Cassiar Mountains but partly in the plateau.

Cassiar Mountains (2M)

The Cassiar Mountains form a large belt of highlands east of Stikine Plateau, mainly in British Columbia but extending into the Yukon. The northeastern part of the belt is flanked by the narrow Dease Plateau, which is too narrow to be shown conveniently on Map C; to the south the mountains extend to the Rocky Mountain Trench. The principal geological feature of the Cassiar Mountains is the long, northeasterly trending Cassiar batholith which, with several satellites, intrudes strata that are mainly Palaeozoic.

Lodes containing silver, gold, lead, zinc, tungsten, and tin have been found in the parts of these mountains crossed by the Alaska Highway, but the only occurrences that appeared to be sufficiently closely spaced to be indicated are a small group of tin discoveries. Farther south are the area of gold placers near Dease Lake, already mentioned, and another near McDame. The latter also includes about forty discoveries of lode gold.

Skeena Mountains (2N) and Hazelton Mountains (2P)

These mountains, which have several geological similarities, occupy a large area south of Stikine Plateau and east of the Coast Mountains. The Skeena Mountains are separated from the Coast Mountains by a narrow strip of the plateau and by the low-lying

Nass Basin, which are not shown on Map C. The Babine Range lying between the Hazelton Mountains and the Interior Plateau, immediately east of Hazelton and Smithers, is classed as the southern part of the Skeena Mountains.

The Skeena and Hazelton Mountains are formed chiefly of Mesozoic volcanic and sedimentary strata intruded in places by stocks of granite and related rocks, some of which are apparently Mesozoic whereas others are probably early Tertiary. In the northern part of this region an area of gold occurrences extends into Skeena Mountains from the Portland Canal district in the Coast Mountains. The Hazelton and Babine Mountains contain many mineral deposits that seem to form a complex subprovince which is also partly in the Coast Mountains and partly in the Interior Plateau in the vicinity of Babine and Francois Lakes. The relative nearness of this area to the Canadian National railway line and to roads was no doubt a factor in the number of mineral discoveries, but there seems now to have been sufficient prospecting in nearby areas to indicate that, in the area in question, metals are more abundant and more varied. It contains many relatively small, present or past producing mines, some of which were shippers of sorted ore whereas a smaller number are equipped with concentrators. Silver, copper, lead, zinc, gold, molybdenum, cobalt, and tungsten have been produced, in many instances from complex deposits that individually contain most of these metals. Certain occurrences also contain barium, nickel, manganese, uranium, or thorium. Some of the silver-copper-lead-zinc-gold occurrences are associated with stocks apparently of Tertiary age, and show evidence of deposition at low temperature and pressure. A feature of the area is that many other copper occurrences contain tetrahedrite instead of chalcopyrite.

Omineca Mountains (20)

These are the southward extension of the Cassiar Mountains, between upper Finlay River and Nation River. The mountains are formed largely of strata ranging in age from probable late Precambrian to Triassic, intruded by the Omineca batholith and smaller bodies of granite and related rocks.

Gold is the only metal that appears to have been found in sufficient quantities to show on Map A, but scattered lodes containing silver, lead, zinc, copper, cobalt, molybdenum, mercury, and niobium have been reported, and tin and platinum have been reported from placers. The occurrences of mercury are the northern part of a belt of such deposits, and those of tin and niobium may be related to other possible belts of deposits. (All of these belts are discussed later.)

Interior Plateaux (2Q)

This area extends southward for about 500 miles from the vicinity of Babine Lake to the 49th Parallel. In places it forms the entire terrain between the Coast and Rocky Mountains, and in others it is flanked by various mountains of the Interior system. Because of its large size the area is commonly divided into the Nechako Plateau in the north and the Fraser Plateau in the south; West Road River is regarded as the boundary between them. The upland surface, from about 3,500 to 6,000 feet above sea-level, is in places undulating and elsewhere very flat, particularly where formed of Tertiary lava. The surface is dissected by valleys, several of which are many miles long and up to 4,000 feet below the upland.

The Interior Plateaux are underlain by a complex pattern of rocks of various kinds and ages. These include a much-metamorphosed group, part of which is probably Precambrian; metamorphosed and unmetamorphosed volcanic and sedimentary rocks of Palaeozoic and Mesozoic ages; several large and small intrusive bodies ranging from granite to ultrabasic rocks; cappings of Tertiary lava, some of which are extensive; and smaller areas of Tertiary freshwater sediments.

The principal metal produced from the Interior Plateaux has been gold—from placers in many parts of the area, from large lode mines at Hedley at the south extremity of the area, and from smaller lodes at various places. High-grade silver-bearing veins are mined at Beaverdell. An important amount of mercury was produced from a deposit at Pinchi Lake in the northern part of the area, and lesser amounts came from other deposits there and farther south, near Kamloops. Rather small mines in different places produced copper, lead, zinc, or chromite.

Both placer and lode-gold occurrences are widespread in the Interior Plateaux, but are mainly in three areas: one in the north, which extends into Nechako Plateau from the Babine and Omineca Mountains; one in the Cariboo district, which extends into the Cariboo Mountains; and a large area in the southern part of Fraser Plateau, which extends into the mountains to the west and east. The latter area also contains many occurrences of copper, lead, zinc, and molybdenum, and several of nickel, cobalt, tungsten, iron, platinum, and chromium. Copper seems to be particularly concentrated in a belt extending southward from the vicinity of Ashcroft to the vicinity of Copper Mountain, which is in the Cascade Mountains. A belt of mercury occurrences about 120 miles long, which extends northward from near Fort St. James in Nechako Plateau to the Aiken Lake area in Omineca Mountains, is associated with a belt of faults known as the Pinchi fault zone

(Armstrong, 1946, pp. 13, 29). This belt is remarkably aligned with a shorter one near Kamloops, nearly 300 miles farther southeast. Other metals found in occurrences too scattered to show on the maps are arsenic, antimony, beryllium, manganese, strontium, thorium, and uranium.

Caribou Mountains (2R)

The Caribou Mountains are the northern ranges of a large group of mountains sometimes called the 'Columbia Mountains', which also include the Monashee, Selkirk, and Purcell Mountains. The Caribou Mountains are formed mainly of sedimentary strata ranging in age from Late Precambrian to Carboniferous, many of which are metamorphosed.

This area is principally one of gold occurrences; it contains the eastern and most-productive part of the well-known Caribou placer field, as well as important lode-gold mines. Virtually no other metals have been produced, other than the silver alloyed with the gold. Some quartz veins carry considerable tungsten, and various minor occurrences of lead, zinc, copper, arsenic, and bismuth are present.

Monashee (2S), Selkirk (2T), and Purcell (2U) Mountains

These areas are discussed together because they have many geological and metallogenic similarities. The Monashee Mountains merge gradually with the Interior Plateaux east of North Thompson River and Okanagan Valley; they are separated from the Caribou Mountains by the upper reaches of the North Thompson, and from the Selkirks by Arrow Lakes and the south-flowing part of Columbia River. The Purcells are separated from the Selkirks by the Purcell Trench, which is occupied by Kootenay Lake and Duncan River. The area is underlain by a complex assemblage of sedimentary and volcanic rocks and their metamorphic equivalents, ranging in age from late Precambrian to Jurassic. These are intruded by many stocks and batholiths of different ages, ranging in composition from granite to diorite; the largest is the Nelson batholith. These igneous rocks, together with their counterparts in the Cascades and the southern part of Fraser Plateau, appear in a general way to form an easterly extension of the Coast intrusions.

This area is and has been the largest producer of metals in the Canadian Cordillera. It contains so many past and present producing mines that only a few of the largest mines or camps can be mentioned. It includes the huge Sullivan lead-zinc-silver deposit at Kimberley, the former St. Eugene lead-zinc-silver mine south of Cranbrook, the high-grade silver-lead-zinc ores of the

Slocan camp near Kaslo, the former gold-copper mines at Rossland, the copper-gold deposits of the Phoenix area west of Rossland, and several gold mines south of Nelson. The largest producers of tungsten in Canada were south of Nelson; chromium was produced near Greenwood, west of Rossland; and molybdenum was obtained from the area south of Nelson. Antimony, bismuth, cadmium, indium, and tin are recovered as by-products from lead-zinc ores.

Most of the Monashee Mountains and virtually all of the Selkirks and Purcells are included in a large area of lead, zinc, and gold occurrences that extends eastward from the southern part of the Interior Plateaux; most of this area also includes copper occurrences; and many occurrences of uranium, nickel, cobalt, and iron have been found, particularly in the southern parts. The most important silver-lead-zinc deposits have been found in the eastern part of the region, analogously to the deposits at Mayo, Yukon Territory. Tungsten has been found in many places and tin in several; both metals seem to be sufficiently widespread to be indicated on Map B. The area of tin occurrences is more or less aligned with those at Finlay River and in Yukon Territory, but the distances separating these three areas are so great that it is doubtful whether the alignment has significance. A small area in the Purcells contains placers carrying niobium. Across the Rocky Mountain Trench from these is a deposit of niobium associated with alkaline rocks. A few occurrences of this kind have been found in the Caribou and Omineca Mountains at two localities shown on Map B. These are roughly aligned, but again the distances separating them make correlation doubtful. The area also contains numerous occurrences of molybdenum and scattered beryllium and platinum occurrences.

Eastern Cordillera (3)

Northern Ranges (3A)

In the Yukon and Northwest Territories, and in a small area in northernmost British Columbia, the Eastern Cordillera are represented by several mountain ranges, plateaux, and intervening plains. Near the Arctic coast are the British Mountains and the Arctic Plateau and Plain. Farther south are the Richardson Mountains, Peel Plateau, Mackenzie Mountains and Plains, Franklin Mountains, and, astride the boundary between the Yukon and British Columbia, the Liard Plateau. Most of these units are not well known, as geological studies have been mainly of the reconnaissance type and prospecting has been relatively slight because of inaccessibility and perhaps because the region, on the whole, has had rather an unfavourable reputation; this may have been too sweeping, as certain parts of the

Eastern Cordillera appear promising. A few granitic intrusions have been found in the British Mountains, near the Alaska-Yukon boundary, and some may be present in Richardson Mountains (Bostock, 1950, p. 20). As the distinction between the Eastern and Western Cordillera in the north has been based largely on the presence of intrusions, there is some doubt as to whether these mountains should not be classed with the Western Cordillera.

Placer gold occurs on Firth and Blow Rivers, which flow into the Arctic Ocean, and a little is reported to have been found on South Nahanni River. Tungsten is reported to have been found near the head of Blow River (Christie, 1960, p. 32). Copper is reported to have been found in a small intrusive body near Mount Goodenough in Richardson Mountains (Bostock, 1950, p. 20). Prospectors have stated that chalcopyrite can be panned in many places in an area in Mackenzie Mountains, as indicated roughly on Map A (H.S. Bostock, personal communication). A little uranium and thorium are associated with hotsprings in the Liard Plateau (S.S. Holland, personal communication).

Too little information is available to permit a satisfactory metallogenic analysis of this region. Present indications suggest that the northern parts contain, locally, extensions of conditions favourable for copper, tungsten, and gold, in adjoining parts of the Western Cordillera. The more southerly part of the Mackenzie Mountains appears to be less well metallized but the information is too incomplete to indicate that this part of the region may not yet prove to contain deposits.

Rocky Mountains (3B)

The Canadian Rocky Mountains and a belt of foothills between them and the Interior Plains constitute the Eastern Cordillera from the 49th Parallel to the vicinity of Liard River, a distance of about 900 miles. The only significant metal production has been from the vicinity of Field, B.C. and east of Cranbrook, B.C. The Monarch and Kicking Horse mines near Field formerly produced considerable silver, lead, and zinc. The high silver-content and the fact that small intrusive bodies have been found a few miles away suggest that these deposits are related to intrusive activity rather than to concentration from sedimentary rocks, but this has not been proved. An occurrence of niobium associated with alkaline intrusive rocks has also been reported from Moose Creek southeast of Yoho National Park (B.C. Dept. Mines, Ann. Rept. 1953, p. 78). Placer gold has been mined from streams flowing from the Rocky Mountains in the Fort Steel area east of Cranbrook, and lode occurrences carrying gold, silver, lead, zinc, and copper have been found in the same area. However, in this region neither the Rocky Mountain Trench nor any line parallel with it marks the boundary between distinctly Nevadan and Laramide orogenies

(Leech, 1959, p. 167), therefore it seems probable that this metallization is Nevadan. Iron deposits occur in the Rocky Mountains not far north of the 49th Parallel (Gross, 1959). In addition to the foregoing, a few scattered occurrences of sulphide minerals have been reported from various places in the Rockies. A little gold and platinum have been found on some streams flowing from these mountains in places other than in the Fort Steele area, but the nature of the occurrences is such that the metallic grains have been reconcentrated from glacial deposits not derived from the Rocky Mountains. Copper occurrences were reported recently from the vicinity of Toad River in the northern part of the Rocky Mountains.

Present information seems to indicate that the Rocky Mountains as a whole do not form a metallogenic province. A small silver-lead-zinc subprovince is suggested as lying near Field; it may be related to the much larger concentration of such occurrences in the southern part of the Western Cordillera, or it may indicate that lead-zinc occurrences of different origin are more widespread in the Rockies than is now apparent. A small subprovince characterized by alkaline intrusions, and niobium and perhaps other related metals, seems to lie in the same area and may be related to the possible belt of such occurrences already mentioned as lying in the adjacent part of the Western Cordillera. Occurrences in the Fort Steele area appear to be an extension of the metallized area in the nearby Western Cordillera. Although other parts of the Rockies do not appear to be particularly favourable for prospecting for metalliferous deposits, it would be a mistake to overlook them. The fact that the intrusions and occurrences near Field are in the part of the Rocky Mountains crossed by the Canadian Pacific railway suggests that accessibility may have been a factor in their discovery and that there may be other areas where intrusions and, perhaps, related mineral occurrences exist. Also, it is possible that deposits formed by concentration of metals dispersed in sedimentary rocks, unrelated to intrusions, may be found.

PLAINS (4, 10, 11)

Interior Plains (4)

Underlain by flat and gently dipping sedimentary rocks of Palaeozoic and younger ages, the Interior Plains are an important source of several non-metalliferous minerals and rocks, but few metalliferous occurrences have been found in them. The largest known occurrences are near Pine Point, at the south shore of Great Slave Lake. These are zinc-lead deposits in Devonian dolomite; large tonnages have been found and production may be begun soon. It is not yet certain whether the deposits were formed entirely by circulating meteoric waters or hydrothermally. The deposits are more or less on the projection of the zone of faulting that marks the boundary between the Slave and Churchill provinces of the Shield, and this fact has caused several students of the subject to consider that hydrothermal processes or some related activity connected with structures in the Precambrian basement offer the most plausible explanation. In the most recent publication on the subject Campbell (1957, p. 174) concluded: "Broad tectonic movements in the Pine Point area appear to have played an important part in developing a sedimentary environment particularly favourable for the deposition of lead and zinc, and may also have been instrumental in creating the structural conditions necessary for the flow of ore-bearing solutions. While the extensive recrystallization of the dolomite and the deposition of much of the ore are believed to be hydrothermal in origin, conclusive supporting evidence cannot be produced at this time. There is no doubt that some solution and re-deposition, and possibly primary deposition, of sulphides by meteoric waters have occurred."

A few unconfirmed reports of sulphide minerals, other than pyrite, in the Interior Plains, are scattered throughout the literature. The important deposits at Pine Point indicate that possibilities may exist elsewhere, for even if the origin of that deposit was hydrothermal, structural and other conditions necessary for concentration of metals were probably present in other parts of this large region. Outcrops are scarce, but clues may be obtained by study of samples from wells drilled for oil and gas, or by geophysical or geochemical investigations coupled with geological studies.

Interesting information on the nature of the Precambrian rocks underlying the region at depth have been compiled by Burwash (1957) from samples from wells drilled into the basement. A few occurrences of magnetite and chalcopyrite are listed.

Hudson Bay Lowland (10)

There are no known reports of metalliferous occurrences, other than iron, in the flat and gently dipping strata that form the extensive lowland south of Hudson Bay and east of James Bay. A few iron occurrences are shown on Map 1045A-M4, including one in a 'window' exposing Precambrian rocks.

St. Lawrence Lowland (11)

The St. Lawrence Lowland, underlain by gently dipping Palaeozoic sedimentary strata, is an important source of non-metalliferous mineral products but contains few metalliferous occurrences.

Deposits of zinc and lead in the Ottawa Valley, and an iron deposit at Marmora that is just beneath the overlap of Palaeozoic strata, are exceptions. There are also a few occurrences of sphalerite in the Bruce Peninsula. A little copper occurs near Madoc in fluorite-bearing veins of post-Ordovician age.

Alkaline intrusions forming the Monteregian Hills lie in a zone crossing the Lowlands near Montreal. They also occur in the adjoining part of the Appalachian region, and may cross into the Canadian Shield. These intrusions are post-Lower Devonian, and may be Triassic. One occurrence of niobium has been reported (Rowe, 1958, p. 97) from this belt, east of Montreal.

Anticosti Island and a strip of the mainland near Havre St. Pierre are continuations of the St. Lawrence Lowland, in which metalliferous occurrences are not known to occur.

CANADIAN SHIELD (5-9)

As already mentioned, there is fairly general agreement that the Canadian Shield is divisible into geological provinces and sub-provinces based on ages or kinds of rocks, or ages or directions of tectonics, or combinations of these. For many of the divisions, however, the boundaries and names are not yet thoroughly established. The literature is fairly extensive, and the subject is only touched upon here. Where names are conflicting or lacking, tentative ones have been chosen.

The mainland part of the Shield seems divisible into about five major parts or 'provinces'. The most northwesterly of these, bounded by the Arctic coast, has been called the 'Slave' province (5). Some authors place its southern boundary at a prominent fault or zone of faults near the south shore of Great Slave Lake, and others carry it to the vicinity of Lake Athabasca. The former seems preferable to the writer because of the prominence of the zone of faults mentioned. South of the Slave is a region commonly called the 'Churchill' province (6), bounded to the southeast by a line coinciding approximately with the Hudson Bay branch of the Canadian National railway, which marks a fairly definite change in the direction of tectonic trends. To the east of this line is a large, arc-shaped province generally called the 'Superior' province (7), although the names 'St. Lawrence' and 'Keewatin' have also been applied. It lies north of Lakes Superior and Huron and is generally regarded as extending at least as far as the Chibougamau region of Quebec. It seems probable that another province, which may be called the 'Ungava' province (8), lies north of the Superior, but if so the boundary is not yet apparent. South of the

Superior is a large geologically distinct area known for many years as the 'Grenville' (9), which is now regarded as extending to the southern part of the coast of Labrador.

Slave Province (5)

Coppermine (5B)

The northwestern part of the Canadian Shield is underlain by late Precambrian sedimentary and volcanic strata that generally are fairly flat lying as compared with late Precambrian strata immediately to the south, and that may be, at least in part, younger than them. Gill called this region the 'Coppermine Belted Plain'. Recent mapping has shown that these strata are not as extensive as was formerly believed, but that another area (5A) of these rocks lies south of Amundsen Gulf; this has not been named for the purposes of this report because no metal discoveries are known for it. The mineral occurrences found in the Coppermine subprovince as here defined are of three kinds: native copper in flakes, small sheets, and amygdules, which are common in basalt of the Coppermine River series; shear and fracture zones in the basalt, containing bornite, chalcocite, covellite, and chalcopyrite; and 'giant' quartz veins containing a little bornite, chalcopyrite, and chalcocite (Lord, 1951, pp. 47, 48). Nickel has been found in the southeastern part of the copper-bearing area.

Great Bear (5C)

Both Lord (1951, pp. 59-60) and Jolliffe (1952, pp. 141-147) recognized a metallogenic province or subprovince extending eastward from Great Bear Lake and southward in tapering fashion to the north arm of Great Slave Lake. This area corresponds to a geological subprovince characterized by folded strata and granitic intrusions that appear to be late Precambrian (Henderson, 1948, pp. 48-51; Lord, 1951, pp. 32-37). Gill termed two folded belts along the west and east sides of this area the 'Bear Mountains' and 'Snare Mountains'; it is not quite clear whether the 'Snare Mountains' were meant to include a belt of folded strata at the west side of the Yellowknife subprovince as defined by the present writer.

The Great Bear area is noted principally for uranium occurrences, including those of the Eldorado mine and the smaller Contact Lake and Rayrock mines, and hundreds of others that did not prove large or regular enough to mine. It is noteworthy that almost all these occurrences are pitchblende-bearing veins or related types such as lenses and stringer systems, and that pegmatitic or other types of primary uranium occurrences are virtually unknown. The deposits in the northern part of the area contain many other metals as well as uranium, and there are probably a few deposits that do not contain uranium. These other metals are iron, copper, cobalt, nickel, silver (both combined and native), bismuth, lead, zinc, manganese and molybdenite. Copper, silver, and cobalt were recovered as by-products of mining for uranium. The Great Bear area shows marked contrasts in its lack of native copper and in having in its northern part an uncommonly large variety of metals. These metals appear to be much less abundant in the southern part of the area, where uranium and iron in the form of hematite are the only conspicuous metals; although a little copper, lead, bismuth, and silver have been found in deposits in the Hottah Lake district and a little copper was reported from the Rayrock deposit.

Yellowknife (5D)

Jolliffe gave the name 'Yellowknife' to a geological division of the Shield lying east of the Great Bear division and north of Great Slave Lake. He did not define the eastern or northern boundaries; the writer has placed these tentatively, as shown on Map C, on the basis of recent information kindly supplied by J.A. Fraser and G.M. Wright. Their data indicates that the granitic rocks east of Clinton-Colden and Artillery Lakes are more gneissic than those typical of the Yellowknife subprovince. This boundary also agrees with the distribution of strata of the Yellowknife group as shown on Map 1055A (compiled recently by I.C. Brown). The Yellowknife subprovince is underlain by steeply folded sedimentary and volcanic strata, all considered to be early Precambrian, and by granitic rocks.

This subprovince is principally a gold area; gold and its alloyed silver are the only metals produced there at present. Jolliffe stated that more than a thousand gold-bearing veins had been found. Although most were discovered relatively near the town of Yellowknife, others are fairly well distributed throughout the division. Several copper and lead-zinc occurrences have also been found, particularly in the southeastern part of the division. Less than a dozen widely scattered uranium occurrences are known, as compared to hundreds in the Great Bear division and a substantial number in the East Arm division.

The southeastern part of the Yellowknife subprovince is noted for its abundance of pegmatites, quartz veins, and related deposits carrying beryllium, lithium, molybdenum, niobium, tantalum, tin, and tungsten. Known occurrences of these metals are so concentrated in the southeastern part of the area that it might be advisable to consider it a separate metallogenic division. The distribution of certain metals, particularly tungsten, lithium, and beryllium, shows a tendency to be offset from one another, at least so far as could be determined from the maps compiled for individual metals. This may to some extent be more apparent than real, due to personal factors in 'rounding out' areas of occurrences or to incomplete prospecting, but other factors point to variations in distribution. It is to be expected that tungsten-bearing quartz veins would be more abundant in places where pegmatites are less abundant. Also, Hutchinson (1955, p. 39) showed that the pegmatites in the Ross Lake section are zoned spatially around a granite mass—those containing beryllium are closer to the granite than those containing niobium and tantalum, and these in turn are closer than those containing lithium. If this relationship is applicable to other granitic bodies, it probably accounts for much of the spatial variation in distribution of minor metals. To outline and explain the distribution of minor metals in the southeastern part of the Yellowknife division would appear to offer an interesting and useful project for research.

East Arm (5E)

Jolliffe applied the name 'East Arm' to a relatively small area embracing the islands and south shore of the East Arm of Great Slave Lake, where the strata are fairly gently folded and are mainly late Precambrian. The folds and several prominent faults strike slightly north of east. Gill named this geological division the 'Slave Lake Mountains'; the writer prefers Jolliffe's name because some readers may not realize that the word 'mountains' is used structurally, not physiographically, and because of the possibility of confusion with the larger 'Slave province'.

The metals found in the East Arm subprovince are similar in several respects to those of the Great Bear. Uranium occurrences are fairly abundant, but most of them contain minerals other than pitchblende (Lang, 1952, pp. 63-66); some radioactive occurrences contain more thorium than uranium. Several occurrences of copper, lead, zinc, iron, nickel, cobalt, gold, native silver, and tungsten have been reported. Certain occurrences of uranium, nickel, cobalt, copper, and iron, on the north shore of the arm or slightly inland, may be in either the Yellowknife or East Arm subprovinces. Most of the rocks along the north shore belong to the Yellowknife division, but the metals are those mainly characteristic of the East Arm division. The writer regards these occurrences as marking a metallogenic transition.

Bathurst Inlet (5F)

The islands and shores of Bathurst Inlet are composed of strata similar to those of the Coppermine subprovince, separated from it by older rocks that appear to be the northward part of the Yellowknife subprovince. This area is tentatively called 'Bathurst Inlet'. O'Neill (1924, pp. 61-71) reported that native copper was seen on almost every island in an area about 25 miles wide and 50 miles long containing more than 150 islands, and that copper sulphides were also found. Three occurrences of lead are reported to have been found at Galena Point and one at Detention Harbour (Lord, 1951, p. 154).

Churchill Province (6)

Taltson (6A)

The region extending approximately from the south shore of Great Slave Lake almost to Lake Athabasca is underlain mainly by granitic and gneissic rocks of which most appear to be early Precambrian but some may be late Precambrian. Near the centre of this region, in the vicinity of Nonacho and Taltson Lakes, is a large northeasterly trending belt of sedimentary and volcanic strata comprising the Nonacho group, which are considered late Precambrian and are intruded by younger granitic rocks. Jolliffe named this entire region the Taltson subprovince. Gill named the belt within it, which contains the Nonacho group, the 'Nonacho Mountains'. Because there appear to be metallogenic distinctions between the occurrences in this belt and those to the west of it, the name 'Nonacho' is here applied to the included belt, and 'Taltson' is used for the areas to its west and east. The northeastern boundary of the Taltson is left in abeyance. In the area west of the Nonacho subprovince several occurrences of copper and lead-zinc have been found, as well as scattered radioactive occurrences of pegmatitic or related types. No occurrences are known to have been found in the eastern part of the subprovince.

Nonacho (6B)

The area outlined on Map C as the Nonacho is slightly larger than that underlain by the main bodies of Nonacho strata. This is done to include outlying remnants of Nonacho strata and also areas of older rocks that appear to have been affected by the disturbances that folded the Nonacho group. Within the 'Nonacho' subprovince have been found occurrences of lead of different type from those of the 'Taltson' (J. C. McGlynn, personal communication). Copper and nickel have also been found, as well as radioactive occurrences of two kinds: pitchblende in veins or related deposits, and pegmatites or related deposits. The Nonacho is thus fairly similar metallogenically to the East Arm subprovince.

Thelon (6C)

A large area in the Thelon River region is underlain by flat-lying strata that apper to be late Precambrian, although it is conceivable that part or all might be Palaeozoic. Smaller areas of these rocks lie to the east. Gill named the larger area the 'Thelon Plain'; his boundaries were revised to agree with later information. The name 'Thelon' has been retained, but a smaller area which Gill named the 'Dubawnt Plain', has been omitted. No metal occurrences are known to have been found in the Thelon subprovince. It appears to be a negative area because of the young and undisturbed nature of the strata, but it is not impossible that occurrences might be found in these strata, or that 'windows' of older rocks may be present.

Northern Part of the District of Keewatin

Most of the region northeast and south of the Thelon subprovince, and north of the eastern part of what is here called the Athabasca-Rankin subprovince, appears to be underlain by older Precambrian rocks. These should contain metals in places but are as yet relatively unprospected. The name 'Back River' has been suggested for a geological subdivision embracing at least part of this region (Jacobs, et al., 1959, p. 323) but it is not clear whether it should be regarded as a separate province or as a subprovince of what is here termed the Churchill province.

Athabasca-Rankin (6D)

A belt of folded and faulted strata trending easterly and northeasterly occupies most of the region between Lake Athabasca and the south boundary of the District of Mackenzie. It is underlain mainly by an older, possibly early Precambrian assemblage of altered sedimentary strata and their granitized equivalents, constituting the Tazin group, which are intruded by granites and pegmatites. In places these rocks are overlain by younger, fairly unaltered sedimentary and volcanic strata termed the Athabasca series and regarded as late Precambrian by most authorities. The rocks of the Athabasca series have been folded more gently than those of the Tazin group, and they have been displaced by faulting. Gill suggested a geological subprovince called the 'Athabasca Mountains' for the main area of folded Athabasca strata, and another called the 'Tazin Mountains' for the adjacent area or areas. This separation was made on the basis of there being two periods of folding and faulting, the Tazin structures having a dominant trend of N60°E and the Athabasca N40°E. As the writer is not aware of sufficient metallogenic differences to separate these two areas for the purpose of the present discussion, the term Athabasca is used in a geographical rather than a tectonic sense for the entire belt north of Lake Athabasca and continuing northeastward between Black and Selwyn Lakes.

Still farther northeast, in the District of Keewatin, the belt continues in a general way. The writer has suggested the name

'Rankin' for this part because Rankin Inlet is the best known mining centre in it. The geology of this section has not been mapped or studied in as much detail as that of the Athabasca, but reconnaissance mapping (Lord, 1953) has indicated large areas of greenstones which appear to be early Precambrian, granitic intrusions, greywacke, and conglomerate classed as late Precambrian, and still younger quartzite and other sedimentary strata, some of which may be related to the Athabasca series.

The Athabasca belt contains a wide variety of metals, several of which seem to distinguish it metallogenically from regions to the north, west, and south. The first recorded interest in the mineral possibilities of the Lake Athabasca region concerned copper and nickel, and soon afterwards iron-formations in the area were tested, but none of these efforts yielded economic deposits. Later, gold deposits were found and mined for a few years at Goldfields. After 1944 the area became one of Canada's principal uranium fields, with several producing mines and several thousand known occurrences. The latter include both pitchblende and pegmatitic types, and some tendency for these to occur in separate parts of the belt can be detected; pegmatitic discoveries are most numerous on the flanks of areas of less-altered rocks that carry abundant pitchblende occurrences. Studies mainly related to uranium deposits have shown that vanadium, lead, and selenium minerals are fairly common, and minerals containing zinc, platinum, silver, cobalt, titanium, tin, and mercury have also been detected (S. C. Robinson, 1955, pp. 54-68). Several occurrences of molybdenum have been found.

The Rankin part of the belt probably has not been prospected as intensively as has the Athabasca region, although a few companies have carried out organized programs. Occurrences of several metals have been reported. Only gold occurrences, and a few nickel-copper-platinum occurrences at Rankin Inlet, have been reported from sites sufficiently near one another to permit outlining them on the maps; discoveries of other metals are, so far as the writer could determine, widely scattered. These include occurrences of nickel, copper, and silver; one of lead; and one of molybdenum. Nickel-copper deposits at Ferguson Lake, in gneisses a few miles north of the volcanic rocks, are regarded tentatively as belonging to the Rankin belt.

Athabasca Plain (6E)

A large area south of Lake Athabasca and Black Lake is mainly covered by overburden, but sufficient outcrops have been found to indicate that it is underlain mainly by sandstone that is flat lying or gently folded. A Cambrian age was originally suggested for these beds but recent investigators have considered them as late Precambrian

(Blake, 1956; Fahrig, in press). Gussow (1957) has reviewed the subject and concluded that the strata south of the lake are younger than those to the north, and that they may be Devonian. Gill applied the name 'Athabasca Plain' to the area; this has been retained, the word 'Plain' being required to distinguish the area from the more northerly Athabasca-Rankin subprovince.

The only metal occurrences known to have been found in this region are a few uranium occurrences of the supergene type that probably were derived from primary deposits in nearby older rocks. On the whole, the region is not considered as being favourable for prospecting, because outcrops are scarce and because the strata are poorly consolidated and only slightly fractured. Occurrences may nonetheless be found, either in the Athabasca rocks or in the basement rocks in places where the covering strata are absent or thin.

Southern Part of Churchill Province (6F)

The large segment of the Churchill province lying south of the Athabasca Plain and the Athabasca-Rankin subprovinces contains several northeasterly trending belts of folded sedimentary and volcanic strata of early Precambrian types, separated by large areas of granitic and gneissic rocks. So far as the writer is aware, no subprovincial names have been suggested for this part of the Shield, and it is not yet certain whether it should be regarded as a single geological subprovince or whether more than one will be recognized.

The southern part of the Churchill province is one of the leading metal-producing parts of Canada. It includes several copper-zinc mines near Flin Flon, copper-nickel mines near Lynn Lake, nickel mines near Thompson, and gold mines at several places. Minor occurrences of these, and several other metals, have been found in many places. The part lying in Saskatchewan, with the exception of the Flin Flon area, is noted mainly for its large number of uranium occurrences of pegmatitic and related types, although no pitchblende is known to have been found south of Lake Athabasca. This area also contains many occurrences of gold, copper, zinc, and nickel. Some of the copper-zinc deposits at and near Flin Flon also contain gold, silver, lead, cadmium, iron, and bismuth, as well as the non-metals tellurium and selenium. The Lynn Lake deposits contain minor amounts of cobalt, zinc, and gold; information on other metals of the Thompson deposits was not found. The area north and east of Flin Flon also contains many occurrences of gold, copper, zinc, lead, and nickel, and several occurrences of tungsten and of pegmatite carrying uranium.

Areas in which one or two metals seem to predominate can be recognized, but these overlap in such ways that they are difficult to define. They agree to a considerable extent, but not entirely, with the belts of sedimentary and volcanic strata. The most prominent are: the uranium area in Saskatchewan; two belts of nickel occurrences, one east of Reindeer Lake and one roughly between Flin Flon and Thompson; a large area of gold occurrences southwest and southeast of Reindeer Lake; and smaller areas of zinc and copper occurrences.

Superior Province (7)

The Superior province, as the term is used here, embodies a great variety of rocks of different ages; many are structurally complex and difficult to correlate. It includes the oldest known Precambrian rocks and several of the classical areas of Precambrian study. The definition of this province and its subdivision present many difficulties. M.E. Wilson (1939, p. 237) applied the name 'St. Lawrence province' to a large part of the Shield corresponding approximately to the Grenville together with what is here called the Superior Province. Gill, and J.T. Wilson (1949) used the name 'Superior' in the sense used in this paper, leaving its northeastern boundary undetermined. Jacobs (1959, p. 323) and others used the name 'Keewatin' for a large province corresponding more or less to the Superior. The writer prefers the term Superior because the Grenville seems too large and geologically distinct to be classed only as a subprovince, and because Keewatin may be confused with the administrative District of Keewatin.

M.E. Wilson divided his St. Lawrence province into three subprovinces: the 'Northwest' extending from Lake Winnipeg to a line trending northeasterly from the vicinity of Marathon, on the north shore of Lake Superior; the 'Timiskaming' extending eastward from the 'Northwest' to the 'Grenville'; and the 'Grenville'. The boundary between the Northwest and the Timiskaming subprovinces appears to have been chosen arbitrarily at the locality where the exposed part of the Shield is narrowest, and to be of geographical rather than geological significance.

Gill did not subdivide the greater part of his Superior province, but separated two folded belts, three belted plains, and one plain. These are: the 'Cuyuna Mountains' in the part of the province lying in the United States; the 'Penokean Mountains', a folded belt extending into Canada from the United States and which involves the Bruce and Cobalt series; the 'Port Arthur Belted Plain', formed of Late Precambrian strata near Port Arthur and Lake Nipigon; the 'Cobalt Plain' formed of Late Precambrian strata in the area between Sudbury and Lake Timiskaming (a smaller area of these rocks lies near Noranda, Quebec); and the 'Mistassini Belted Plain', an area of Late Precambrian strata near Lake Mistassini.

The writer has used Gill's subdivisions and has also indicated the 'Timiskaming' because the name is well established despite doubt as to its western and northeastern limits. The 'Timiskaming' is, however, to some extent a geographical subdivision, including the 'Penokean', 'Cobalt', and 'Mistassini' structural units as well as much apparently older Precambrian terrain. It seems probable that the latter, and similar terrain east of Lake Winnipeg and north of Lake Superior, will be subdivided in the future. Meanwhile, for the following discussion, it is desirable to use geographical designations to indicate certain areas. All geographical names used do not appear on the maps accompanying this paper, but are indicated in Map 1045A and other general maps.

The Superior province is the greatest metal-producing part of Canada. It contains the nickel-copper-gold mines of Sudbury, the copper-zinc-gold and the gold mines of northwestern Quebec, the gold mines of the Porcupine and Kirkland Lake areas, the uranium mines of the Blind River area, the Steep Rock and Michipicoten iron mines, and many smaller producers or former producers. There are also countless occurrences of various metals, some of which show fairly distinct patterns whereas others are scattered or overlapping. Information on many occurrences was obtained from the Mineral Map of Ontario (No. 1957A). The main features of the distribution are outlined below.

Northwestern Part of Superior Province

The part of the Shield lying north and east of the northern part of Lake Winnipeg contains many easterly trending belts of folded volcanic and sedimentary rocks classed as early Precambrian, and intervening areas of granites and gneisses. The known mineral occurrences are principally of iron-formation and gold; most of the latter are in the Gods Lake, Island Lake, Sachigo Lake, and Favourable Lake areas. Several scattered occurrences of nickel and copper have been found, indicating that this part of the Superior province bears some resemblance to the southern part of the Churchill.

Winnipeg River

An area in southeastern Manitoba near Winnipeg River, and neighbouring parts of Ontario near Werner Lake, may constitute a separate metallogenic subprovince because, in addition to gold occurrences, many other metals, at least in small quantities, are present. These include beryllium, caesium, chromium, cobalt, copper, germanium, lead, lithium, molybdenum, nickel, niobium, platinum, tin, titanium, tungsten, pegmatitic uranium and thorium, and zinc. Wright and Stockwell (1932, pp. 49-143) have described many of these occurrences. The unusual diversity of occurrences may be due at least in part to the fact that the area contains rocks that have yielded the oldest age determinations so far obtained from Canadian sources, suggesting that it has not only had a very long, but perhaps also a particularly varied, geological history. Stockwell (1948, pp. 306-314) has shown that some of the metals occur in separate parts of the area, and under different structural conditions. The area seems to offer unusual opportunity for additional metallogenic studies.

Red Lake and Lake of the Woods

In the westernmost part of Ontario the Shield contains several large easterly trending belts of folded volcanic and sedimentary strata that correspond fairly well with the distribution of mineral occurrences, of which the most prominent are gold deposits in the Red Lake and Kenora areas. There are also belts of iron-formation and of occurrences of copper and nickel, and scattered pegmatitic (and related) types of uranium and thorium occurrences. As all these metals have also been found in the Winnipeg River area the distinction between it and the area under discussion is as yet uncertain.

Steep Rock

The area between Lake of the Woods and the 'Port Arthur Belted Plain' contains various rocks of early Precambrian types, as well as strata such as those of the Steep Rock group, that may be early late Precambrian. The area is best known for the large Steep Rock iron deposits; it also contains other iron deposits, several occurrences of gold and nickel, and some of platinum, copper, lead, zinc, uranium, molybdenum, titanium, and lithium.

Port Arthur (7A)

The 'Port Arthur Belted Plain' is underlain by late Precambrian, fairly flat lying, sedimentary and volcanic rocks and diabase sills. These rest on older rocks, and, because the boundary of the area has been generalized in places, it is not in all cases certain whether metal occurrences are in the older or the younger rocks. The most notable metallogenic features of the area appear to be the large number of occurrences of native silver, and the presence of pitchblende. The area thus has some similarities with the Great Bear and East Arm subprovinces, although only one of the native silver occurrences is regarded as primary (Tanton, 1931, p. 91). Several lithium deposits have been found near the southeast corner of Lake Nipigon. Occurrences of copper, zinc, lead, nickel, chromium, molybdenum, platinum, and gold have been reported from the area, but few gold occurrences appear to have been found in the younger strata. Tanton (1931, p. 90) lists cobalt, arsenic, antimony, bismuth, and mercury as metals present in small amounts.

Lake Nipigon to Michipicoten

This area is discussed separately—partly for convenience and partly because it differs somewhat from the Michipicoten area proper. The region east of Lake Nipigon contains large areas of granitic rocks and several belts of early Precambrian sedimentary and volcanic rocks. The latter contain several producing or formerly producing gold mines, and copper-zinc-silver mines at Manitouwadge. There are also numerous occurrences of iron-formation, gold, copper, zinc, molybdenum, niobium, and pegmatitic or related occurrences of uranium and thorium.

Michipicoten

Extending northeasterly from Michipicoten is a fairly large area of folded volcanic and sedimentary strata of early Precambrian type. It contains large producing and formerly producing iron mines and smaller gold mines, as well as occurrences of those metals, and of nickel, molybdenum, and niobium.

Penokean (7B)

A belt extending easterly from the vicinity of Sault Ste. Marie contains rocks of both early and late Precambrian types; the latter include the classic examples of the 'Huronian' sediments noted by Logan and later geologists. The Huronian was considered to consist of two unconformable series—the older is the 'Bruce' and the younger the 'Cobalt'. The Bruce rests with great unconformity on the ancient basement complex of gneisses and volcanic and sedimentary rocks. Both the Bruce and the Cobalt strata have been folded, representing the remnants of what Gill termed the 'Penokean Mountains'. In the eastern part of the belt, near Sudbury, certain strata were considered equivalent to the Bruce, and others were regarded as younger than the Cobalt; recent investigations have suggested that the 'Bruce' strata near Sudbury are early Precambrian (Thomson, 1948).

The Penokean belt contains large nickel-copper-gold mines near Sudbury, which also produce the platinum group of metals, silver, cobalt, iron, sulphur, tellurium, and selenium. It also contains the Blind River uranium ores which yield thorium as well. Occurrences of uranium, thorium, copper, nickel, and gold are widespread, and some containing iron, lead, zinc, molybdenum, and tin are known. Most of the minor uranium occurrences are of the Blind River type, but in the Sault Ste. Marie area many stringers and other kinds of deposits carry pitchblende.

Cobalt Plain (7C)

A fairly large area in the vicinity of the Cobalt silver camp is underlain by flat or gently dipping sediments of the Cobalt series, and diabase sills. The area contains many past-producing silver-cobalt mines and some that are still in production. Occurrences of native silver, cobalt, nickel, arsenic, and antimony are common, and gold, copper, lead, zinc, bismuth, chromium, and uranium have also been reported.

Mistassini (7D)

The Mistassini area contains a fairly large belt of strata that are now regarded as late Precambrian although some geologists have considered some or all to be Palaeozoic. They contain bands of iron-formation, some being tested actively. A few occurrences containing lead, zinc, and silver have also been reported.

Timiskaming (Unsubdivided Part) (7E)

As mentioned previously M.E. Wilson (1939, pp. 238, 252-260) applied the name 'Timiskaming subprovince' to a large part of the Shield extending from the Grenville on the southeast to the Palaeozoic overlap in the vicinity of James Bay, and from the northeastern shores of Lake Superior to the neighbourhood of Lake Mistassini. This term has not been universally accepted; the writer uses it for this report to describe the parts not otherwise separated.

The older rocks of the Timiskaming subprovince contain several of the largest gold, copper, and zinc mines in Canada and many smaller producers or former producers of these metals. Silver, lead, molybdenum, lithium, iron, bismuth, and tungsten are or have been produced as well. Gold is mined from two distinct classes of deposits: gold-quartz veins and other deposits in which gold and silver are the only principal constituents of value; and massive or disseminated deposits of copper or zinc which carry important amounts of gold and silver. The district also contains innumerable occurrences of gold and most of the other metals just mentioned, as well as several occurrences of nickel, cobalt, chromium, beryllium, uranium, thorium, niobium, platinum, and tin.

Although gold is widespread, most of the gold-silver ore-bodies and minor occurrences are concentrated in two easterly trending belts that were pointed out by Knight (1924). The northern belt includes the Porcupine area in Ontario and the Duparquet area in Quebec. The southern belt includes the Kirkland Lake - Larder Lake areas in Ontario as well as many deposits between Chapleau and Kirkland Lake, and a large number of mines in Quebec, including those of the Noranda, Malartic, Val d'Or, and Pascalis areas.

Copper and copper-zinc occurrences also are widespread, but they likewise tend to occur in easterly trending belts. The largest extends roughly from near Chapleau and Timmins in Ontario to Val d'Or in Quebec. A smaller one extends north of the Canadian National railway, from the vicinity of Normetal, Quebec, to the area immediately northwest of Senneterre, Quebec. A third lies in the Mattagami area, about 100 miles north of Senneterre. Farther northeast are numerous occurrences in the Opemiska and Chibougamau areas. It may be significant to note that the more important copper deposits in some of these belts, and in the Penokean belt, lie in the eastern parts of the belts, near the Grenville 'front'. This is illustrated by the fact that the orebodies of Sudbury, Noranda, Bourlamaque, Opemiska, and Chibougamau are fairly close to the boundary of the Grenville province. Conceivably they might be related in some way to the zone of faulting that marks part of the Grenville boundary, or to the Grenville mountain-building.

Ungava Province (8)

Present geological knowledge does not indicate whether the Superior province extends throughout the part of the Shield lying east of Hudson and James Bays. It is convenient tentatively to consider the region between these bays and the Atlantic Ocean as a separate province. The name Ungava was used in this sense by M. E. Wilson, and with somewhat the same scope by Gill. The area is divisible into several subprovinces by separating areas where strata of late Precambrian types are preserved.

Belcher Islands and Richmond Gulf (8A)

Belcher Islands and the coast and islands at and near Richmond Gulf are underlain by strata of late Precambrian type, which are much folded at Belcher Islands and gently dipping at and near Richmond Gulf. The northern boundary was left indefinite because it is not clear whether certain occurrences of strata on islands and scattered along the coast near Povungnituk and elsewhere are more closely related to the Belcher or Cape Smith belts.

Iron-formation has long been known to be present at Belcher Islands and near Richmond Gulf. A copper occurrence was recently reported to have been found on one of the Belcher Islands. At and near Richmond Gulf, occurrences of lead and zinc have been found, are reported to carry a little copper, cadmium, silver, and gold.

Western Ungava (8B)

The large region between Hudson Bay and the Labrador Trough and north and south of the Cape Smith belt is tentatively regarded as the 'Western Ungava subprovince'. It has received relatively little geological investigation or prospecting. Bands of iron-formation lie in the vicinities of Great Whale and Fort George Rivers. No other mineral occurrences sufficiently closely spaced for indication on Maps A or B are known to have been found, but a few scattered occurrences of molybdenite, gold, and lithium have been reported. The region contains several greenstone belts and other rocks, in which additional occurrences of these or other metals will probably be found when more prospecting has been done. For the present, however, no attempt can be made to suggest the metallogenic character of the region.

Cape Smith - Wakeham Bay (8C)

A belt of late Precambrian strata extends easterly across the northern part of Ungava Peninsula from Cape Smith in Hudson Bay to Wakeham Bay in Hudson Strait. It contains sedimentary, volcanic, and intrusive rocks analogous to those of the Labrador Trough, which may also be related to the strata at Belcher Islands and Richmond Gulf.

Occurrences of a little copper, nickel, and gold were found near Cape Smith several years ago. More recently, nickel, copper, zinc and lead have been found at other places in the belt. The belt is reported to contain ferruginous rocks (Bergeron, 1957, p. 6). No references to the presence of cobalt or platinum were encountered, although these metals might be expected to accompany nickel and copper. The presence of an easterly trending belt of late Precambrian strata, coupled with the presence of nickel and copper, suggests that uranium in the form of pitchblende might occur.

Some of the occurrences indicated on Map A lie north of the belt as shown on the Geological Map of Canada (1045A); more recent mapping by Bergeron showed the limit of the belt to be farther north.

Labrador Trough (8D)

A northwesterly trending belt of folded late Precambrian strata, about 600 miles long and up to about 60 miles wide, is commonly called the Labrador Trough. These strata consist of a thick succession of sedimentary and volcanic rocks, including abundant iron-formation resembling that of the iron ranges in the Lake Superior region of the United States rather than the 'Keewatin' type prevalent in many parts of the Canadian Shield. The strata in the trough, particularly in the northern part, are intruded by basic igneous rocks and at least one body of granite. At the west side of the belt the strata rest unconformably on older gneissic rocks. The eastern boundary is in places marked by zones of sheared rocks that probably represent a major fault, but there is some evidence that the granitized rocks lying to the east are altered equivalents of strata within the trough (Harrison, 1957, p. 40).

The Labrador Trough contains some of the world's largest deposits of iron ore—formed from iron-formation by natural processes of concentration. Many of the deposits also contain important quantities of manganese. Many occurrences of sulphide minerals have been found, particularly in the central and northern parts of the trough. These include several occurrences of copper, nickel, zinc, and lead, east of Lake Attikamagen, which also carry a little gold and silver, some occurrences of copper in the Griffis Lake area, and a zinc occurrence near Otelnuc Lake. Bergeron (1957, p. 22) states that a belt averaging about 10 miles wide, containing abundant sulphide minerals, mainly pyrite and pyrrhotite, extends for more than 120 miles between Fort McKenzie and Leaf River; and that copper, lead, zinc, nickel cobalt, and a little gold and silver have been found here and there.

Northern Labrador (8E)

This name is used tentatively for the region north of the Seal Lake belt and east of the Labrador Trough. Published geological information deals mainly with reconnaissance studies carried out along the coast; additional information on the geology and on mineral discoveries is probably known to holders of concessions, but is not yet available. The region is underlain in part by gneissic rocks and anorthositic intrusions. These resemble rocks of the Grenville region, but most authorities now consider, from the limited data available, that the Grenville boundary coincides with the south boundary of the Seal Lake belt (see Robinson, W.G., 1956, p. 16). At least some of the metamorphic strata in northern Labrador are more intensely altered equivalents of strata in the Labrador Trough (Harrison, 1957, p. 40). Available data indicate that the general structural trends are northwesterly—approximately parallel with the Trough and the coast.

Titanium, occurring in ilmenite in anorthosite, has been reported from a few localities. A few occurrences of molybdenum, chromium, copper, and lead have also been reported. These occurrences are too few and too scattered to permit generalization on the metallogenic nature of the region.

Seal Lake (8F)

A belt underlain largely by strata of late Precambrian type which may be related to those of the Labrador Trough extends from near Michikamau Lake to the coast of Labrador near Makkovik. This is sometimes referred to as the 'Seal Lake' belt—the name used in this discussion. The area is reported to also contain rocks that may be related to those of the Grenville region to the south. Because at least faulting, if not folding, is reported to continue in a northeasterly direction as far as the coast, the area has tentatively been projected that far. During the last few years the area has been prospected intensively by companies holding concessions, with the result that many occurrences of copper, including native copper, have been found. Numerous occurrences of uranium have also been discovered, both in the form of pitchblende-bearing veins and related deposits and occurrences of the general pegmatitic class. Occurrences of niobium, molybdenum, thorium, lead, and zinc have also been reported.

Grenville Province (9)

The Grenville is the most firmly established division of the Canadian Shield. Most Canadian geologists now recognize it although some call it a subprovince. It includes the southernmost part of the Shield in Canada, extending northeastward from Georgian Bay of Lake Huron. It is bounded to the south by Palaeozoic strata that underlie the St. Lawrence Lowland.

A narrow belt of Precambrian rocks crosses the St. Lawrence River east of Kingston and widens in the State of New York to form the Adirondack region. Near Georgian Bay the Grenville is flanked to the north by the classic Huronian strata; farther east it is flanked by various volcanic and sedimentary rocks in the region between Lakes Timiskaming and Mistassini. In places the northern boundary, often called the 'Grenville front', is marked by faults and shear zones, forming the 'Huron-Mistassini lineament'. Evidence has also been presented by several geologists suggesting that at least in places strata can be traced across the 'front' and that the boundary is a gradational one based on different grades of metamorphism. South of Noranda and northeast of Senneterre the position of the boundary is not yet closely defined. Farther eastward the region has not been studied so intensively as in Ontario and western Quebec, but earlier workers such as M.E. Wilson (1939, p. 262) considered that the province probably continues north of the Gulf of St. Lawrence as far as the southern coast of Labrador. The presence of Grenville-like rocks in northern Labrador apparently caused Coleman (1921, p. 21) to believe that the Grenville might extend into that region. Recent studies, however, such as those of W.G. Robinson (1956, pp. 14-21) and Gastil and Knowles (1960, pp. 1243-1254), have helped to confirm Wilson's view and have indicated that the eastern part of the 'front' is approximately as depicted on Map C.

The geology of the Grenville province is complex and diversified, presenting fundamental problems that have been summarized recently (Thomson, 1956). The series and other rocks probably related to it are characterized by abundant crystalline limestone and impure limy strata, and by large areas of sedimentary gneisses in various stages of granitization. The gneisses include a characteristic sillimanite-garnet gneiss apparently derived from shale. The rocks were intruded by numerous igneous bodies varying in size and composition, including, particularly in the eastern part of the province, many stocks and batholiths of anorthosite. Many of these intrusions are surrounded by belts of contact-metamorphic rocks of different kinds and grades. The complex structures, the interruption of strata by areas of intrusive and granitized rocks, and the metamorphism, combine to hinder the interpretation of ages and correlation of strata.

For many years most geologists considered the Grenville rocks to be early Precambrian. Later, Collins and Quirke (1930, pp. 3, 102) suggested that they are granitized equivalents of the Huronian. More recently, J.T. Wilson (1949, p. 235) and others have suggested that the Grenville orogeny occurred about 1,000 million years ago and that the erosion of the 'Grenville mountains' provided the Huronian sediments. This conclusion was based largely on age determinations on minerals from pegmatites, and although such ages can probably be regarded as dating an orogeny in a general way, it seems probable also that, in a region as large as the Grenville, orogenies took place at different times and that some of the strata or their altered equivalents could be early Precambrian.

Apparently there are no published reports of attempts to divide the Grenville province into regional subdivisions. To do so, some of the more obvious areas to consider may be those where anorthosite is abundant, an area at Hamilton Inlet containing strata mapped as late Proterozoic, and outliers of Palaeozoic strata in the Ottawa, Saguenay, and Manicouagan Valleys. Such attempts have not been indicated on Map C because, with the exception of an association of titanium with certain bodies of anorthosite, the metallogenic data available is not segregated into such subdivisions.

The Grenville province contains a fairly large number of producing or past-producing mines of various kinds, but as most of these are relatively small, the Grenville has not been as important in the production of metals as the Superior province. The first production of iron in Canada, in 1800, was from a magnetite deposit at Furnace Falls in Lees county, Ontario, and the first production of gold in Ontario was from a discovery made in 1866 near Madoc. Several small iron and gold mines were operated after these discoveries. Iron mines of moderate size are presently operated at Bristol, Quebec, and Marmora, Ontario. The latter, which is slightly south of the general boundary of the Shield, was found by an aeromagnetic survey at a place where the Precambrian is covered by about 125 feet of Palaeozoic strata. A large iron-titanium deposit consisting of segregations of ilmenite in anorthosite is mined north of Havre St. Pierre, Quebec, and smaller deposits of this kind near Baie St. Paul have been worked in the past. Large iron deposits related to those of the Labrador Trough are being prepared for production near Wabush Lake, north of Seven Islands.

A small amount of lead was produced many years ago in Hastings county, Ontario. More recently, substantial production of zinc and lead, with some gold and silver, was derived from the Calumet and Kingdon mines near the Ontario-Quebec boundary; the Calumet is still producing. Substantial production of zinc and lead, with some gold and silver, was derived from the Tetreault mine 50 miles west of Quebec City. Some of the zinc-lead occurrences near the boundary between Grenville rocks and overlying Palaeozoic strata are post-Ordovician in age. It is possible that some other deposits that lie entirely within the Grenville are also of post-Precambrian age.

The first discoveries of uranium in Canada were made in the Grenville province years ago. During the last few years recent discoveries in the Bancroft area of Ontario became important producers, although not as large as those of the Blind River and Beaverlodge areas.

Deposits of molybdenite in syenite and contact-metasomatic rocks were formerly mined in and near the Ottawa Valley.

Magnesium metal and refractory compounds are produced from deposits of dolomite, dolomitic magnesite, and brucite in the Grenville of Ontario and Quebec. As dolomitic rocks are fairly abundant in several parts of Canada the concentration of production in the Grenville appears to be for reasons of accessibility or specifications, rather than a metallogenic indication. So far as is known, however, occurrences of brucite are confined to the Grenville.

Occurrences of various metals are abundant in the part of the Grenville lying between Georgian Bay and the Saguenay district. From there to the coast of Labrador the known occurrences are mainly of iron and titanium, together with several of molybdenum and one of beryllium. This is no doubt partly due to the greater accessibility and more thorough prospecting of the southwestern part of the Grenville, but there appear to be metallogenic differences as well. In the Grenville of Ontario and southwestern Quebec the most numerous occurrences are of iron and uranium. Magnetite and titaniferous magnetite, commonly carrying a little vanadium, are present in many magmatic segregations and contact-metasomatic or pyrometasomatic deposits, mainly associated with gabbroic rocks (Rose, 1958). Small amounts of uranium and thorium are common in dykes of granite, syenite, and pegmatite, and in pyrometasomatic deposits. It seems significant that no substantiated occurrences of pitchblende or other evidence of typical hydrothermal uranium mineralization has been found in the Grenville, and that most Canadian occurrences of complex uranium minerals such as uranothorite, euxenite, and pyrochlore are in the Grenville (Lang, 1958, pp. 297-300). Molybdenite occurs in many pyrometasomatic and other deposits. Galena, sphalerite, and chalcopyrite are fairly abundant, but there has been no substantial production of copper from the Grenville province. Occurrences of nickel and cobalt are fairly common, but no records of production of these metals were found.

The Grenville of Ontario and a nearby part of Quebec contains fairly numerous occurrences of niobium-bearing pyrochlore and other minerals, in pegmatites and related deposits. In addition, L. B. Morley (personal communication to R. B. Rowe) and Rowe (1958, p. 27) pointed out that several deposits associated with alkaline-rock complexes lie along what appears to be a curving zone extending from the Monteregian Hills to Heron Bay, Lake Superior. Most of these are in the Grenville, but the belt appears to continue into the Superior region to the northwest, and into the St. Lawrence Lowland to the south. It is not yet clear whether an occurrence of this kind near Bancroft, Ontario represents a branch from the general zone, or a widening of the zone, or whether its position is merely fortuitous. The relationship of occurrences of this kind with Monteregian intrusions suggests that some or all of the mineralization of this kind may be related to a tectonic belt of Devonian or later age crossing this part of the Shield. Most of the niobium occurrences found so far in the Grenville carry little tantalum, and few occurrences of tantalum itself have been reported.

Occurrences of beryl in pegmatites and related rocks are fairly plentiful in the Haliburton-Bancroft area of Ontario and, in Quebec, in the area north of Ottawa and Montreal and in the vicinity of Saguenay River.

Occurrences of rare earths, and of zirconium, appear to be more abundant in the Grenville than in other parts of Canada. However, as most of these are associated with occurrences of uranium or thorium in pegmatites and related rocks, this distribution may not be factual, but only the result of intensive prospecting with Geiger counters, or of the concentration of detailed studies of pegmatitic and related deposits in the southeastern part of the Grenville province.

Two occurrences of tin have been reported from the vicinity of the Ottawa Valley.

Many differences, either quantitative or qualitative, are apparent between metal occurrences in the Grenville and those in the Timiskaming division. (The latter term is used to include the areas separated as 'Penokean' and 'Cobalt Plain'.) The most marked differences are the large gold, copper, zinc, cobalt, silver, nickel, and uranium orebodies of the Timiskaming, as opposed to smaller producers of gold, zinc, and uranium in the Grenville; and the prevalence of pegmatitic and metasomatic deposits of various metals in the Grenville—characteristic of high-temperature and deep-seated mineralization.

APPALACHIAN REGION (12)

The Canadian Appalachian region is the northern continuation of the more extensive Appalachian Mountain system of the United States. It is mainly a gently sloping upland dissected by valleys to form plateaux, hills, and low mountain ranges; there are also several lowlands in places where the underlying rocks are weak.

Most of the region is underlain by folded and faulted Palaeozoic sedimentary and volcanic strata and Palaeozoic intrusions; the latter include both granitic and ultrabasic types. The northwestern boundary of the region is a long, arcuate fault or zone of faults extending from Lake Champlain at least as far as the Gulf of St. Lawrence. East and south of this line the strata have been folded and faulted by successive periods of orogeny, along axes that strike northeasterly. Thus strata of different kinds and ages, and belts of intrusive rocks, form northeasterly trending bands or lineaments. Three principal periods of orogeny—called the Taconic, the Acadian, and the Appalachian—have been recognized. The Taconic occurred at the close of the Ordovician, the Acadian during the Devonian, and the Appalachian at the close of the Palaeozoic. The Taconic disturbances were fairly widespread; the Acadian were more so, affecting areas that were previously affected by the Taconic and some that were not; but the Appalachian orogeny, which was a major feature in parts of the United States, was of minor and local importance in the Canadian part of the region. The region has not been subdivided on Map C because it is relatively small.

The Canadian Appalachian region contains occurrences of many different metals, including deposits that yield or formerly yielded important amounts of several metals. Most of the occurrences are related to the Devonian intrusions or orogeny, but others are older or younger. Lodes of iron, copper, lead, and zinc near St. John, N.B. may be Precambrian (Alcock, 1948, p. 57). Certain occurrences of magnetite and hematite in New Brunswick may be related to the Taconic orogeny (Alcock, 1948, p. 58). Some occurrences of copper in New Brunswick and of copper, lead, and zinc in Nova Scotia appear to be related to the Appalachian orogeny, and Triassic diabase in Nova Scotia contains native copper (Alcock, 1948, pp. 62-63).

The largest production of metals in the region has consisted of iron from the Wabana deposit in eastern Newfoundland; copper and other metals from mines in the Eastern Townships, Gaspé, northern New Brunswick, and various places in Newfoundland; and gold from many small deposits formerly worked in southeastern Nova Scotia and from placers in the Chaudiere area south of Quebec City. If small occurrences are considered, iron is widespread in the region. Copper occurrences are also fairly widely distributed but are concentrated in three areas: (1) a northeasterly trending belt in the Eastern Townships, in central Gaspé, and in the Bathurst area of New Brunswick; (2) in the part of Nova Scotia lying south of Northumberland Strait and in Cape Breton Island; and (3) in central and northern Newfoundland. Gold occurs in most of these copper areas and extends beyond them in the Eastern Townships, northern New Brunswick, and Newfoundland. Gold occurrences are concentrated in parts of southeastern Nova Scotia that are underlain by the Meguma series.

The largest zinc and lead deposits found are in the Buchans area of Newfoundland and the Bathurst area of New Brunswick. Many occurrences of zinc and lead have also been found in the Eastern Townships, including a few in the part of the St. Lawrence Lowland adjacent to the Appalachian region, and in northern Nova Scotia. A few uranium occurrences of the pitchblende variety have been found in the Chaleur Bay region, both in Quebec and in New Brunswick. Uranium occurrences of several other kinds have been found in other parts of New Brunswick and in Nova Scotia; one definite occurrence and a few uncertain ones have been reported from Newfoundland. Many of the ultrabasic rocks in the serpentine belt of the Eastern Townships contain small amounts of nickel, and a few occurrences in this belt contain larger quantities; cobalt is not mentioned in descriptions. Several other occurrences, some of nickel and some of nickel and cobalt, are scattered in New Brunswick, Nova Scotia, and Newfoundland. Useful information about Newfoundland occurrences is contained in a set of mineral maps issued by the Newfoundland Department of Mines and Resources.

The region contains occurrences of many of the minor metals. Perhaps the most outstanding characteristic in this regard is the large number of manganese occurrences of various geological types fairly well distributed across the region, including the Magdalen Islands. Molybdenum occurrences of several types are also fairly widely distributed. Chromium occurrences are common in the belt of ultrabasic rocks and serpentine in the Eastern Townships, and associated with ultrabasic rocks in several parts of Newfoundland. Several occurrences of tungsten have been found in that part of Nova Scotia extending about 60 miles northeasterly and southwesterly from Halifax, corresponding more or less with the concentration of gold occurrences there. Tungsten occurrences are also scattered in other places in Nova Scotia, New Brunswick, and Newfoundland. Five occurrences of tin are distributed in a strikingly linear pattern in New Brunswick, parallel with the contact between Ordovician and Pennsylvanian strata. The belt extends from the vicinity of St. Stephen to that of Bathurst and comprises occurrences of different geological types, including minor tin in one of the base-metal deposits near Bathurst. The belt includes one occurrence in the Pennsylvanian strata, suggesting that all the tin mineralization may have been late in the geological history of the region; on the other hand, mineralization may have taken place at different times. Several occurrences of antimony are scattered through the Eastern Townships, New Brunswick, Nova Scotia, and Newfoundland. Titanium and vanadium are reported from several widely spaced occurrences of magnetite in Newfoundland. A few occurrences of beryllium are known in various parts of Nova Scotia, New Brunswick, and Newfoundland. Platinum has been reported from a few places.

All the political provinces except Prince Edward Island contain many metal occurrences, but Prince Edward Island is a lowland containing few rock exposures or metal discoveries. Elsewhere the occurrences are distributed in such a way that few metallogenic subprovinces or belts can be suggested at present, except that many concentrations of occurrences follow the general northeasterly pattern of formations and intrusions. The most notable deficiencies (metallogenically rather than economically) among the minor metals, at least so far as discoveries to date are concerned, appear to be that references to only two occurrences of niobium, one of lithium, and none of mercury or native silver were found.

It is possible that the Eastern Townships, Gaspé, and northern New Brunswick may constitute a metallogenic province or subprovince, parts of which are characterized by deposits of copper, zinc, and lead, and lesser amount of other metals, whereas other parts are characterized by ultrabasic rocks with associated chromite and nickel. Other subprovinces may be represented by the copper area in north-central Newfoundland, the mixed base-metal deposits of the Buchans area, the Wabana iron deposits of eastern Newfoundland, the concentration of zinc and lead occurrences in northeastern Nova Scotia, and by the gold-quartz deposits of the Meguma series in Nova Scotia; but in the present state of knowledge it has been considered impracticable to delimit these or to relate them to geological subregions.

CONCLUSIONS

The foregoing discussion and the accompanying maps are only a 'reconnaissance' of the subject. The outlining of areas of occurrences is imperfect and in places crude, but is all that could be attempted in the time available. The data depend on the degree of prospecting in various parts of the country, and in some instances on the extent to which discoveries were reported and the thoroughness with which the literature was searched; these are however believed to have been sufficiently complete in most places to foreshadow actual conditions. If results of this kind are to be useful in planning prospecting they must necessarily be based on incomplete information. Additional discoveries, analyses, and special studies can be expected to augment the information and to bring the patterns into better focus.

Maps A and B contain data that can be interpreted in different ways, and may be useful to persons who make their own interpretations; the following are however the principal conclusions reached by the writer.

The three main metalliferous regions—the Canadian Shield, Western Cordillera, and Appalachian region—are considerably alike with regard to the presence of metals; the differences are chiefly in size of deposits. Of the major metals, nickel and uranium are the only ones not mined significantly in all three regions. Iron and gold are more widespread than other major metals, but uranium, copper, lead, zinc, and nickel are fairly abundant. A tabulation of minor metals showed that, although all are not mined in all three regions and some are not mined anywhere in Canada, most are found in at least small amounts in all three regions. Many of those for which data were not found are probably present but have either not been sought by analyses or not reported in the literature consulted.

The distribution of occurrences within the main regions seems to corroborate the concept that metallogenic provinces and sub-provinces may or may not correspond to geological provinces and sub-provinces. In the northwestern part of the Shield additional finds corroborate the metallogenic subprovinces suggested by Jolliffe and their relation to the geological subprovinces outlined by him. For the rest of the Shield and for the Cordillera there is correspondence to geological subprovinces in some instances and lack of it in others. In some districts there is marked agreement between metalliferous belts and belts of certain kinds of rocks, or of faulting, for areas smaller than most subprovinces as designated in this study.

The Shield appears to contain four main kinds of areas; some of these have been classed as geological subprovinces whereas others are, at least for the present, regarded as parts of subprovinces. One kind is composed largely of granitic and gneissic rocks which may be largely barren or may contain pegmatitic and related classes of deposits, but which contain few deposits of gold or sulphide minerals unless they have been subjected to younger faulting or intrusive activity. A second type consists of belts or areas of folded sedimentary or volcanic rocks of early Precambrian type. These commonly contain gold and sulphide deposits. A third type consists of belts or areas containing folded sedimentary or volcanic rocks of early late-Precambrian type. Some belts of this kind contain very important sulphide deposits, hematitic iron deposits, and uranium deposits; some contain producing gold deposits, but on the whole, gold does not seem to be as prevalent in rocks of this kind as in the belts of early Precambrian type. The fourth kind consists of areas of flat-lying or gently dipping sedimentary or volcanic strata, some of which contain important deposits of native copper, native silver, cobalt, or other metals.

The accumulated evidence seems to indicate that in many places the presence or lack of metals can be explained by orogenic history and the amount of subsequent erosion. The relative lack of metalliferous occurrences in the plains and lowlands is a superficial feature, for the Shield continues beneath them. It appears probable, however, that factors other than geological history account in part for the distribution. For example, original differences in the metal content of the crust seem the most plausible explanations for the metallized areas that cross well defined geological provinces or subprovinces; for the large concentrations of metals in the Sudbury, Porcupine, and other great camps; and for the association of niobium and tantalum in the Yellowknife subprovince in contrast to other regions containing niobium occurrences where little tantalum is known. A point that may be significant when considering the original distribution of metals in the crust is that metals have been shifted laterally to some extent during geological time by transport in solution or as mineral or rock particles, and this process would probably tend to disperse metals in some instances and to concentrate them in others.

The writer considers that special studies might be directed both to detailed work in selected areas and also, from time to time, to assembling data on a country-wide scale to form maps for individual metals as well as for composite maps. It would be desirable to attempt, at least for selected areas, studies that include data on the following: metals occurring in small or 'geochemical' amounts; the distribution of various classes of deposits such as veins, replacements, etc.; kinds of related rocks; and mineral or elemental associations, to learn the extent to which titanium, vanadium, selenium, tellurium, etc. are characteristic of deposits of iron, copper, gold, etc. in some areas and not in others.

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