CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

Geological Maps of Canada: History and Evolution

The World, North America, and Canada
Quaternary Geology
Canada Offshore
Newfoundland
The St. Lawrence Lowlands - Appalachians
The Canadian Shield, Labrador
The Canadian Shield, Ontario - Quebec
The Canadian Arctic Archipelago
Interior Plains, Foothills, and Rocky Mountains

Compiled by W.C. Morgan

The Canadian Cordillera

Compiled by J.O. Wheeler

Natural Resources Canada
Ressources naturelles Canada
Canada

Introduction

The concept of having an exhibition of geological maps of Canada to mark the 150th anniversary of the Geological Survey of Canada was first suggested early in 1991 by Dr. W.C. Morgan, Chief Scientific Editor of the GSC. An ad hoc Geological Map Exhibit Committee was then formed to select, arrange, and describe the maps. This GSC Committee consists of Bill Morgan, Beverly Chen (Map Librarian), Evelyn Inglis (Editor), and Peter Corrigan and Louis Renaud (Cartographers). The map display has been assembled by Dana Kurfurst and Dave Everett of GSC Cartography. With the exception of maps that are still in print, it was decided to use coloured photocopies and photographic reproductions of material for the exhibit. Dr. J.O. Wheeler (GSC, Vancouver) selected the maps and compiled the text and captions for the panel on the Canadian Cordillera. Bill Morgan compiled the text and captions for the other panels. Due to limited space, only parts of some maps are displayed, and in some cases the original map scale has been changed.

Acknowledgments

Ed Dahl (Cartographic and Architectural Sector, National Archives of Canada, Ottawa) assisted greatly with this project chiefly by lending transparencies of maps and by enabling us to examine material held in the Archives. He also provided us with information on early cartographers. A National Archives of Canada transparency (NMC 132022) was used to reproduce Boué's map. A transparency of the Guettard map was obtained from the Library of Congress, Washington, D.C., U.S.A. The Library, University of British Columbia, supplied a transparency of Richardson's map of British North America. Burkhard Frebold kindly lent us his copy of Hans Frebold's "Geologie der Arktis".

Dr. Hank Williams (Memorial University, Newfoundland) provided suggestions for the text and captions of the panel on Newfoundland. Drs. Thom Frisch and Tim Tozer suggested maps for the panel on the Arctic Archipelago. Charlie Bruce and Roger MacQueen gave us ideas for the panel on the Interior Plains, Foothills, and Rocky Mountains. Gordon Fader, Ron MacNab, and Brian Sawyer provided maps for the panel on marine geology. Ideas for the Quaternary geology came from Vic Prest, Jean-Serge Vincent, Bob Fulton, and Helen Dumych. Discussions with Fred Chandler and Sandy Colvine helped us to select maps on the Precambrian Shield. Charlie Smith has supported and encouraged this project. The numerous others who assisted us with their ideas are thanked sincerely.

Morris Zaslow's magnificent 599 page book "Reading the Rocks: the story of the Geological Survey of Canada, 1842-1972" is an invaluable source of information.

THE WORLD, NORTH AMERICA, AND CANADA

The 8 items on this panel were selected to show the evolution of some interpretations of the geology of Canada at different times and different scales.

Guettard's "Mineralogical Map" of North America is the first geological map of the continent, and also of Canada and of the U.S.A. Produced in Paris in 1752, it was printed and released in 1756. The map is a remarkable achievement as Guettard never visited North America, but relied on information and samples sent by correspondents.

Ami Boué's "Geological Structure of the Globe" is reproduced here from an updated 1855 version of his 1845 one-sheet map, printed in Paris, that was the first to show the geology of the world.

Charles Lyell, the author of the classic "Principles of Geology" (3v., London, 1830-33), established a new era in geology by his work and influence. His hand-coloured map of eastern North America south of the Gulf of St. Lawrence, which appeared in volume 2 of "Travels in North America in the Years 1841-42", indicates the state of geological knowledge at that time, which coincided with the creation of the Geological Survey of Canada. Lyell (1845, v. 2, p. 103) notes that "The legislature of Canada have lately voted a sum of money for a geological survey of the province which has been placed under the direction of Mr. Logan, from whose labours we may soon expect an accurate map ...".

The two compilation maps of Canada by Richardson (1851) and Isbister (1855) are similar in the broad picture of the geology they present, but whereas Isbister's map has more detailed geology, Richardson's information is displayed on a magnificent topographical map.

Logan's famous map of Canada is at the same scale as the map compiled 20 years earlier by Lyell, but is more accurate and displays greater detail. Although Logan's 983 page "Geology of Canada" was published in 1863, the "Atlas of Maps and Sections" from which the geological map is taken was not issued until 1865.

A more detailed version of Douglas' National Atlas of Canada map (GSC Map 1250A, scale 1:5 000 000), released in 1969, has remained the official geological map of Canada until now. A new map to accompany the 9 volume Geology of Canada (DNAG) series is in preparation.

Six thematic tectonic maps by Williams et al. (1991) reflect current thinking, and are used by those authors to analyze the make-up of the entire North American continent.

Guettard's Mineralogical Map, Where the Nature of Terranes in Canada and Louisiana can be seen, 1752 (Paris, 1756), (scale about 1:19 800 000). Original in the Geography and Map Division, Library of Congress, Washington, D.C., U.S.A.

Guettard's map is one of the oldest geological maps in the world. There are 36 symbols shown and explained in the legend. The symbols on the map indicate locations of rocks, minerals, spring waters, fossils, petroleum, coal, silver, copper, and placer gold. Guettard was one of the first to show that rock sequences occur with some regularity. He mapped 3 linear geological zones parallel to the east coast of North America and, by suggesting these could be linked to counterparts he had mapped in Europe, became the first person to attempt intercontinental correlation. Guettard also recognized the importance of fossils in this correlation.

Boué's Geological Structure of the Globe, 1855 (scale about 1:31 680 000). Original in the Cartographic and Architectural Archives Division, National Archives of Canada, Ottawa (NMC 132022)

This magnificent map is reproduced from Plate I of A.K. Johnston's "Physical Atlas of Natural Phenomena". Six main map units are indicated by colour and number. The legend is an inverted stratigraphic column, with the oldest rocks at the top and the youngest strata (Alluvium) second from the base. Boué noted that the lakes in North America occur at the margin of his crystalline chain (Shield). Although the geology of the world was incompletely known at that time, Boué's synthesis is never-the-less a remarkable achievement.

Lyell's Geological Map of the United States, Canada etc., 1845 (scale about 1:7 920 000)

This compilation map, based on the published works of 26 authors as well as on Lyell's own travels, shows 20 rock units, identified by numbers and by letters. The geology of Upper and Lower Canada, and of the Maritime Provinces excluding Newfoundland, is shown. Although there is no mention of Precambrian (or Cambrian: Ordovician was not yet named or recognized), granite gneiss, metamorphic limestone, and trap rocks are identified as basement.

Richardson's Physical Geography and Geology of British North America, 1851 (scale about 1:14 570 000). Original in the Library, University of British Columbia, Vancouver

Richardson's map accompanies his 2 volume "Arctic Searching Expedition ..." describing the search for Sir John Franklin, his 2 ships and crew, last seen near Lancaster Sound in July 1845. Richardson accompanied Franklin in 1819-22 and 1825-27, and was thus familiar with the Arctic Ocean shores between the Mackenzie and Coppermine rivers. In summer 1848, when he was 60 years old, Richardson set out again to search that region for Franklin.

In his compilation map, metamorphic or primitive rocks are pink, fossiliferous Silurian and younger strata blue, and volcanoes red.

Isbister's Geological Sketch Map of the Northernmost Parts of America, 1855 (scale about 1:22 176 000)

Alexander Kennedy Isbister was born at the Hudson's Bay Company Post at Cumberland House in Rupert's Land (Saskatchewan), and educated at the universities of Aberdeen, Edinburgh (MA), and London (LLB). His map shows 7 coloured units, partly identified by age (e.g. Silurian), and partly by lithology (e.g. coal and lignites). The major trends of the Cordillera are indicated with several linear cores of crystalline rocks, such as the Coast Range. The Canadian Shield is clearly shown, wrapped around a Silurian-cored Hudson Bay, and extending north to Ellesmere Island in the east.

Logan's Geological Map of Canada, 1865 (scale 1:7 920 000)

This attractive map, compiled by Sir W.E. Logan, is a reduction to one fifth of a magnificent, detailed, larger map on a scale of 25 miles to 1 inch (1:1 584 000) that was engraved in Paris and hand-coloured. The various geological "formations" are represented by means of 30 coloured units and by letters and numerals. Although the term Precambrian is not used (neither Cambrian nor Ordovician appear), Laurentian and Huronian rocks are distinguished.

Douglas' Geology of Canada, 1971 (scale 1:15 000 000)

The subtle legend to this map uses colours and letters to indicate stratiform rocks by age: plutonic, igneous, and gneissic rocks by both age and lithology. Further subdivision makes use of 3 black-line patterns. Large undivided areas of the eastern Shield, shown as Archean granite gneiss (Agn) in northern Quebec, Labrador, and Baffin Island, were subdivided by helicopter reconnaissance mapping between 1967 and 1970. An inset map shows the geological provinces.

Williams, Hoffman, Lewry, Monger, and Rivers: Anatomy of North America, 1991 (scale about 1:90 000 000)

The six tectonic portrayals of North America, presented here in reduced format, are briefly discussed by the authors in their paper in Tectonophysics (1991, v. 187, p. 117-134). Themes used are: (Fig. 1) Tectonic elements; (Fig. 2) Time of last major deformation; (Fig. 3) Time of first major deformation; (Fig. 4) Miogeoclines and terranes; (Fig. 5) Sutures and terrane boundaries; and (Fig. 6) Time of accretion. These maps illustrate the vast increase in the geological knowledge of the continent since the time of Guettard.

QUATERNARY GEOLOGY

On 24 July 1837, Louis Agassiz, the young professor of zoology at the University of Neuchâtel in Switzerland, startled his audience of scientists with a presidential address on the Ice Age, instead of as expected on fossil fish, the subject of his world fame (Carozzi, 1984).

Agassiz's revolutionary glacial theory proposed that a vast continental ice sheet covered northern Europe, extending from the North Pole to the Mediterranean and Caspian seas. The ice sheet explained the occurrence of erratic boulders, blocks of exotic rock found far distant from their bedrock source. These boulders, accumulations of sand, gravel, and clay forming drift and moraines, and polished and striated rock surfaces, had previously been attributed to marine floods (the "Noachian deluge") or to transport by floating ice or icebergs. Agassiz's glacial theory met with considerable resistance from leading geologists of the day, and it took about 30 years for his theory to become accepted and established in Europe and North America (Carozzi, 1984).

In Canada, the first description of inland or continental glaciation was given by William Logan (1847) as a result of field work in 1845 in the Lake Timiskaming basin of northern Ontario. As Prest (1990) noted, it is remarkable that Logan's report of an ancient glacier went unnoticed by others involved in the glacial dispute, yet he recorded these observations in 1847, the year after Louis Agassiz arrived in the United States and became professor of geology and zoology at Harvard University, a position similar to that currently held by Stephen Jay Gould.

Various aspects of the Quaternary geology of Canada are displayed by the maps on this panel. The Quaternary is the geological time period in which we live, and is therefore the one about which we know most (Fulton, 1989). Although it is often referred to as the Ice Age or Glacial Age, there were in fact times when the climate was as warm or warmer than at present. These fluctuations in climate caused growth and decay of continental-scale ice sheets as many as eight times, and some experts believe that we are living in an interglacial period.

Bell's Superficial Deposits Between Lake Superior and Gaspé, 1865 (scale 1:7 920 000)

Although commonly attributed to Sir William Logan, because his is the only name on the map, as Director of the Geological Survey of Canada, this map was actually compiled by Robert Bell, professor of chemistry and natural history at Queen's University (1863-67). Bell first worked for the GSC as a 15 year old student assistant in 1856, joined the Survey full-time in 1867, and went on to become Acting Director (1901-06).

Logan's great volume the "Geology of Canada" (1863) contains an 81 page chapter on "Superficial Geology", and Bell's map was included in an "Atlas of Maps and Sections" (1865) intended to accompany that volume. The seven subdivisions (formations) indicated by colour on the *map are subdivided, just west of Ottawa, into Canada East and Canada West. The two formations east of Ottawa essentially indicate the extent of the maximum marine overlap in the Ottawa-St. Lawrence valley.*

Chamberlin's Map of North America During the Great Ice Age, 1913 (scale shown about 1:19 000 000)

North America during the Ice Age shows the area that was covered by ice (green), large terminal moraines (shaded), and the main directions of ice movement. In an earlier sketch map (Chamberlin and Salisbury, 1907) Chamberlin named three main centres of ice: the Labrador, Keewatin, and Cordilleran ice sheets.

The map displayed is a reduced copy of the original which was at a scale of 1 inch to 104 miles (1:6 589 440). It shows ice flowing outwards from the Richardson Mountains, extending westward over what is now recognized as unglaciated terrain in the Yukon. Ice is also shown east of Ellesmere Island, filling Nares Strait between Ellesmere Island and Greenland.

According to Prest (1990), although Chamberlin's maps are remarkably accurate, for some unknown reason they failed to receive the attention and acclaim they merited.

Johnston's Superficial Deposits and Soils, Ottawa, 1917 (scale 1:63 360) and Richard et al.: Surficial Materials and Terrain Features, Ottawa-Hull, 1977 (scale 1:125 000)

These 2 maps, at different scales, display the state of knowledge of the Quaternary geology of the Ottawa-Hull area based on field investigations in 1915 and in the 1970s.

Although glaciation in Canada started about 2 million years ago, only traces of the last event, the Wisconsinan, are found in this area. This glaciation was at a maximum 20 000 years ago, when Canada was covered by continental ice sheets that depressed the land surface. Once the ice melted, a branch of the Atlantic Ocean, called the Champlain Sea, flowed up the Ottawa-St. Lawrencc valley to a depth that would just have covered the tip of the flag pole on the Peace Tower of the Parliament Buildings. Leda Clay, which accumulated in this sea, is subject to landslides and mudflows, and such areas are shown in bright red on the Richard et al. map, particularly on higher ground north of the Ottawa River.

Dyke and Prest: Paleogeography of Northern North America, 18 000, 10 000, and 7000 Years Ago, 1987 (scale shown 1:25 000 000)

The 3 maps shown here, reduced to half their published scale, show the extent of the Laurentide Ice Sheet, the ice sheet which formed on the Canadian Shield, at different stages in its development and decline.

18 000 years ago. This map shows the ice sheet at its maximum extent with the location and direction of ice streams, such as the one flowing out of Hudson Strait. As the shoreline was about 100 metres below its present level, much of the Continental Shelf was dry land. Floating ice shelves occurred along some coasts.

10 000 years ago. At this stage in the retreat of the Laurentide Ice Sheet, its margin is bordered to a great extent by glacial lakes, the largest of which was glacial Lake Agassiz. The Champlain Sea occupied the St. Lawrence Valley, including the site of present-day Ottawa.

7000 years ago. Remnants of the ice sheet were restricted to Labrador, Baffin Island, Melville Peninsula, Southampton Island, and northern Ellesmere Island. The coastline was approaching its present-day shape, although Tyrrell Sea was higher and larger than present Hudson Bay, and much land farther north was submerged.

Klassen's Surficial Geology, Cypress Lake, Saskatchewan, 1991 (scale 1:250 000)

This attractive map is of an area which is typical of the glaciated southern Prairies, consisting of vast stretches of ground moraine interspersed with hummocky terrain. The Cypress Hills, in the west-central part of the area, form an upland of eroded Tertiary bedrock (shown in pink) that contrasts markedly with the surrounding morainic terrain. This upland stood as nunataks during the Pleistocene glaciations.

Glacial deposits, moraines dominantly formed of till, are shown in greens; lake and river deposits related to the ice sheet are shown in blues and orange-browns; Recent sediments, deposited chiefly by streams along valley bottoms and across lake plains, are shown in yellow, and Recent colluvium on valley sides and mantling steep slopes such as the Cypress Hills, is shown in dark brown.

The map also shows features indicative of ice flow direction, limits of the Wisconsinan glacier, and locations and details of radiocarbon-dated materials.

Zarkhidze et al.: Circumpolar Map of Quaternary Deposits of the Arctic, 1991 (scale shown 1:12 000 000)

This circumpolar compilation map of the Arctic, the result of a Canada-U.S.S.R. project, shows Quaternary deposits north of 60°N latitude. The map is a circular, polar stereographic projection with legend, explanatory notes, and map credits in Russian, English, and French. The half of the map displayed here concentrates on Canada.

The map legend combines 12 units for the genesis of sediments indicated by colour and letter, with 7 ages indicated by number and intensity of colour. The map is also classified into 3 types of area: land, shelf, and ocean, with additional information for each type of area portrayed by means of letters, numbers, and symbols. The result is a most attractive map with a clear distinction between land and marine Quaternary deposits.

CANADA OFFSHORE

Although oceanographic institutions were founded earlier, modern marine geoscience in Canada really started with the establishment in 1972 of the Atlantic Geoscience Centre (AGC) at Dartmouth, Nova Scotia, and in 1977 with the Pacific Geoscience Centre (PGC) at Victoria, B.C.

A lot of public attention was attracted in the late 1950s by the Mohole Project, a plan to drill a deep hole in the ocean floor to sample rocks below the crust of the Earth. This plan was abandoned in 1965 because of the high cost.

Marine geologists and geophysicists have, however, been at the centre of a recent major revolution in understanding the Earth. To them goes credit for geomagnetism, magnetic reversals, magnetic striping, and the explanation of continental drift, plate tectonics, continental accretion, and exotic terranes.

The maps and cross-sections on this panel show the evolution of Canadian marine geoscience, from Dutch surveying in the late 1600s which depicted the first offshore marine moraines, to modern computer-generated magnetic anomaly maps that can be produced on request to meet client needs.

van Keulen's Newfoundland, New France, Canada, and Acadia, 1687 (scale 1:1 267 200)

This early map of southeastern Canada includes the offshore regions of Newfoundland and Nova Scotia. Many of the large sandy fishing banks are identified, including shoals and rock outcrops. Of particular interest is the linear shallow area on the inner Scotian Shelf off Nova Scotia. This feature is probably the first delineation of a large offshore moraine, now known as the Scotian Shelf Moraine Complex, mapped by marine geologists in the 1970s.

King's Scotian Shelf Surficial Geology, Halifax to Sable Island, 1970 (scale 1:300 000)

This is the first published map of the offshore sediments of Canada, produced for part of the Scotian Shelf off Nova Scotia, by Lewis H. King, a marine geologist with the Geological Survey of Canada. It was the first in the world to depict surficial marine sediments on a formational basis.Similar maps have now been produced for much of the Canadian offshore. The map shows the Scotian Shelf Moraine Complex, first delineated by van Keulen on his 1687 map. Five unconsolidated Quaternary formations are depicted here: Scotian Shelf drift (unit 4), Emerald silt (unit 3), Sambro sand (unit 6), La Have clay (unit 7), and Sable Island sand and gravel (unit 8). On the two cross-sections shown (E-F and G-H), three bedrock units are indicated: Cambrian to Devonian, Cretaceous, and Tertiary.

Davis, Currie, and Sawyer: Explorer Ridge and Northern Juan de Fuca Ridge, 1987 (scale about 1:769 230)

These graphically enhanced coloured maps of the seafloor off Western Canada, in which bathymetric relief is simulated by illuminating the contours from a western "light source", have been produced from 1:250 000 scale black-and-white maps (Davis et al., 1987 a, b).

The seafloor spreading centres of this active ridge system are characterized by lineated volcanic ridges and tiled normal fault blocks.

Chains of sea mounts constructed off the ridge axis occur parallel to the direction of plate motion. On flanks of the ridge the original volcanic and tectonic relief is buried by abyssal plain sediments.

The diagrammatic cross-section illustrates volcanic activity and crustal spreading along an active ridge axis.

Okulitch, Lopatin, and Jackson: Circumpolar Geological Map of the Arctic, 1989 (scale 1:6 000 000)

This, the first circumpolar compilation map of the Arctic, resulted from a joint Canada-U.S.S.R. project and shows the on-land and offshore bedrock geology north of 60°N latitude. The map is a circular, polar stereographic projection. Legend, explanatory notes, and map credits are in Russian, English, and French. Although the outline of Greenland is readily recognizable by its vast ice cap, it is difficult to distinguish coastlines elsewhere. The half of the map displayed here concentrates on Canada.

A main feature of the map is the fundamental difference between the continental and marine portions: the marine areas being underlain by younger strata with less complex geology.

The Arctic Ocean is divided into two basins by the Lomonosov Ridge which runs from the Lincoln Sea, north of Greenland, to the North Pole. The mid-Atlantic ridge can be seen north of Iceland.

Macnab, Verhoef, and Srivastava: Preliminary Magnetic Anomaly Maps of the North Atlantic and Arctic, 1991 (scale about 1:35 000 000)

The preliminary magnetic anomaly maps presented here illustrate, at a reduced scale, the type of automated products that will be produced when this Atlantic Geoscience Centre project is completed in 1993.

One aim of modern automated cartography is to produce what are termed "maps on demand" or "maps on request". The client will be able to purchase tailor-made maps as a hard-copy (or data on a disk) without the necessity of conventional production by a printing press.

The map of the North Atlantic (upper map) shows the typical magnetic striping and central North Atlantic spreading ridge that passes through central Iceland.

The magnetic anomaly map of the Arctic (lower map) has a typical magnetic striping pattern in the North Atlantic, north and east of Greenland.

NEWFOUNDLAND

In 1763 and 1764 Lieutenant James Cook of the Royal Navy charted the coasts of Newfoundland, Labrador, and the Gulf of St. Lawrence in the small ship Grenville, and by noting coal, gypsum, and iron on the west coast of Newfoundland probably made the first recorded observations on the geology of the island. Details of the stratigraphy of St. John's harbour were described in 1766 by Joseph Banks, a contemporary and acquaintance of Cook, and also a man of wealth and position, who endured the privations and dangers of sea travel in small ships in his pursuit of knowledge. The first serious attempt to understand the geology of interior Newfoundland, however, resulted from a remarkable expedition across the island, from east to west, in fall 1822, by W.E. Cormack, accompanied by one Micmac Indian. Cormack's observations were accurate, and among other things, he described a hilly ridge composed of rocks with all the attributes of what are now considered to be ophiolite.

The 3 maps in this display, those by Jukes, Murray, and Colman-Sadd et al., show stages in the evolution of deliberate attempts to map and understand the geology of the whole island.

The earliest map shown is by Joseph Bette Jukes who was offered the post of "Geological Surveyor of Newfoundland" in 1839, and spent the field seasons of 1839 and 1840 mapping the island. Jukes, who had studied under Adam Sedgwick at Cambridge, was dismissed in 1840, ending the first official survey of Newfoundland.

Alexander Murray, a Scot, was hired by W.E. Logan in 1843, one year after the Geological Survey of Canada was instituted by the Canadian Government with Logan as Director. Murray, a naval man, was a superb surveyor and had some geological experience under Henry Thomas De la Beche, who founded the Geological Survey of Great Britain in 1835. Logan and Murray then became the backbone of the GSC for some 20 years. On 18 May 1864, however, Murray, aged 54, left Montreal for Newfoundland to commence his new career, and for the next 20 years became, in effect, the Geological Survey of Newfoundland.

The latest geological map of Newfoundland, by Colman-Sadd, Hayes, and Knight, is patterned after earlier maps by Hank Williams that depict major tectonic divisions with rocks classified by age and formation within these divisions.

Perhaps David M. Baird (Geoscience Canada, v. 2, 1975, p. 218) in an article on early geological studies of Newfoundland, best states our progress in geological mapping of the Appalachians. "...how strange it is that the more we seem to find out in any area of investigation,..., the horizon is still there, always inviting us to go closer. We have more problems now than Jukes did. Where will the horizons be teasing us to approach in 25 or 50 or 100 years?...Will we be then as far away from where we stand now as our present position is from the world of Jukes and Murray?"

Jukes' Newfoundland, 1843 (scale 1:950 400)

This same map, but not geologically coloured, accompanies a 2 volume book on Newfoundland, published in London in 1842. The map displayed shows 6 main coloured units, broken down into 20 sub-units in the legend, which provides no indication of the age of the rocks. Although the fossiliferous limestones and shales of the west coast are missing from his map, the other main elements of the geology of Newfoundland are depicted after a mere 2 seasons' fieldwork. Jukes' map also shows the track and geological observations made by Cormack in 1822 on his excursion across central Newfoundland, from Random Sound in the east to St. George's Bay in the west. Thirteen cross-sections accompany Jukes' map and 1843 Geological Survey of Newfoundland report.

Murray's Geological Map of Newfoundland, ca. 1873 (scale 1:1 800 000)

Alexander Murray's landmark map of Newfoundland was the first to pretty well delineate the major geological divisions of the entire island, and to subdivide the rocks by age. His map units are indicated by hand-colour, numbers, and letters, and in addition to stratiform rocks include trap, granite-syenite, and serpentine. The map is accompanied by 4 detailed cross-sections.

Colman-Sadd, Hayes, and Knight: Geology of the Island of Newfoundland, 1990 (scale 1:1 000 000)

The major tectonic divisions of Newfoundland, with rocks classified by age and formation within these divisions, are depicted on this map. The Humber, Dunnage, Gander, and Avalon tectonostratigraphic zones are shown. Subzones of the Dunnage Zone follow earlier divisions. The map legend (not shown) entails an elaborate accretionary history according to the suspect terrane analysis of the Newfoundland Appalachians.

THE ST. LAWRENCE LOWLANDS - APPALACHIANS

The 6 maps on this display illustrate some aspects of the evolution of knowledge on the geology of the region between the St. Lawrence Lowlands and the Appalachians of Nova Scotia.

Although the earliest account of Nova Scotian geology appears to be by Jackson and Alger in 1828, the real pioneer in the Maritimes was Abraham Gesner, a medic and amateur geologist. His "Remarks on the Geology and Mineralogy of Nova Scotia", with a geological map, was published in 1836. Gesner also undertook the first geological survey of New Brunswick, publishing 5 reports between 1839 and 1843. The interest he created in the economic potential of the mineral resources sparked a mining boom, where many investors lost money. Gesner then immigrated to the U.S.A., and about 1852 was the American inventor of the process of kerosene oil, thereby becoming one of those responsible for the birth of the petroleum refining industry.

In 1868 Sir William Logan extended the work of the Geological Survey to the Maritimes, and employed 6 new New Brunswick and Nova Scotian geologists to commence fieldwork that spring. One of those hired, as a junior full-time officer, was young Edward Hartley, who mapped the Pictou coalfield in Nova Scotia with Logan. Hartley then commenced mapping the coalfields at Springhill and on Cape Breton Island, but became ill and died at Pictou on 10th November 1870.

Based on his fieldwork and on a compilation of maps by other geologists, William Logan produced a magnificent and now rare "Geological Map of Canada", encompassing Lower and Upper Canada (now southern Quebec and southern Ontario) at a scale of 25 miles to 1 inch. The production of this map was the greatest work of Robert Barlow, an English cartographer and topographical draftsman, who came to Canada in 1855 aged 42 years. The map was engraved on steel in Paris, is hand-coloured, and is dated 1866. It was exhibited in 1867 at the Paris Exhibition, where it won a prize.

The geological map of the Montreal area by Frank D. Adams and Osmond E. LeRoy (1905) depicts several aspects of the St. Lawrence Lowlands, now interpreted as a failed rift valley. The flat-lying Paleozoic rocks NW of Logan's Line overlap Precambrian strata and are cut by alkaline intrusives. Adams, who studied at McGill, and then at Heidelberg (PhD, 1892) in petrography under Professor Rosenbusch, commenced working on the great anorthosite masses north of Montreal in 1885. Although Adams, with his pupil and assistant A.E. Barlow, produced a classic GSC map (Map 708) and report (GSC Memoir 6) in 1910 on "Geology of the Haliburton and Bancroft areas, Ontario", Adams is best known for his 1938 monumental book "The Birth and Development of the Geological Sciences".

The Canadian Society of Petroleum Geologists' "Phanerozoic Geology of Canada" illustrates lithological, structural, and stratigraphic relationships of sedimentary rocks formed since the beginning of the Cambrian Period. Two cross-sections are reproduced to show the geology of the area dealt with in this panel, and to indicate Logan's Line, a major fault, mapped by Logan, marking the NW limit of transported rocks (allochthons) of the Appalachian orogen.

Duncan Keppie's map of the northern Appalachians depicts terranes as 3 groups: in Newfoundland and both north and south of the Fredericton-Norumbega Fault. The terranes are named, and their ages, overstep sequences, main rock types, and environments are indicated.

Gesner's Geological Map of Nova Scotia, 1845 (scale 1:2 041 190)

This hand-coloured map by A. Gesner was modified to illustrate papers by Brown (1845) on Cape Breton and Dawson (1845) on Nova Scotia. Four units are shown: igneous rocks, metamorphic - Silurian, Old Red Sandstone - Gypsiferous series, and Carboniferous Coal Measures. There is more detail than on Gesner's 1836 map, which identified the main geological features and deposits of iron ore and coal.

Logan and Hartley: Pictou Coalfield, Nova Scotia, 1870, (scale 1:63 360)

This one inch to a mile map of the Pictou coalfield by Sir William Logan and Edward Hartley, based on fieldwork in 1868 and 1869, shows 4 coloured lithological units. Coal seams are indicated by black lines; faults by white lines. Names of the many different coal companies that were working the Productive Coal Measures at that time are shown on the map.

Three examples of Edward Hartley's meticulous field notes, used to construct the one inch map of the Pictou coalfield, are shown above the map. Indeed, young Hartley's notes and sketch maps are of such a high standard that they have been confused with the work of the master, Logan himself. The detailed observations had to be greatly generalized for the one inch to one mile map.

Hartley's coloured sketch map (top left) shows the New Glasgow conglomerate at Alma Mills on Middle River. The other sketch maps are of outcrops on East River south of New Glasgow (top right), and of the Coal Brook Branch in the General Mining Association area.

Logan's Geological Map of Canada, 1866 (1881) (scale: 1:1 584 000)

Copies of Logan's magnificent hand-coloured "Geological Map of Canada" at a scale of 25 miles to 1 inch were produced by Edward Stanford, London, England. The copy displayed here, however, is Sheet No. 2 of an "Illustrated Atlas of the Dominion of Canada" printed in 1881. The atlas map, which covers the area described on this panel of the exhibit, is colour printed, uses different colours, and employs a modified legend. Although Logan authorized the publication of his map in 1866, and several copies with that date are in circulation, it seems that it was not published until 1869. In that year Richard Cecil Selwyn took over as director of the Survey, which explains his authorization on the 1881 atlas copy.

Adams and LeRoy: Geological Map of the Island of Montreal and Vicinity, Province of Quebec, 1905 (scale 1:253 440)

This 4 miles to 1 inch map by Adams and LeRoy illustrates their report on artesian wells of the Island of Montreal. The legend shows 14 map units, by colour, letter, number, and age, ranging from Precambrian (Laurentian) to Devonian. Eruptive rocks are depicted by lithology, but not age. The map is accompanied by one NW-SE cross-section indicating overlap of flat-lying Phanerozoic rocks of the St. Lawrence Lowlands onto the Precambrian Shield. Cross-cutting relationships of intrusive alkaline rocks, such as nepheline syenite and essexite at Mount Royal, now considered rift-valley environment rocks, are shown on the cross-section.

The Canadian Society of Petroleum Geologists' Phanerozoic Geology of Canada, 1978 (scale 1:30 000 000)

This CSPG map sheet contains an index-location isopach map showing thicknesses of sedimentary rocks in Canada's Phanerozoic basins, and also cross-sections with their locations and a Phanerozoic Time Scale. Two cross-sections (of 12) are displayed to demonstrate aspects of the

St. Lawrence Lowlands - Appalachian geology and to indicate Logan's Line. The cross-sections are explained by a 12 age-colour key in conjunction with 12 lithological symbols.

Keppie's Terranes in the Northern Appalachians, 1982 (scale 1:5 000 000)

This modern terrane map of the Northern Appalachians subdivides terranes into 3 groups: those north of the Fredericton-Norumbega Fault; those south of the fault; and those in Newfoundland. The terranes are indicated by colours and letters, and the legend shows the main features of their geology and age. Overstep sequences are also indicated with the age of the unconformity at their base. The nature and ages of faults and ages of mélange terrane boundaries are shown. Isotopic intrusive ages of plutons are given in millions of years.

THE CANADIAN SHIELD, LABRADOR

This region is atypical of the common picture of the Precambrian Shield as a flat, low relief, lake-dotted terrain. Labrador is a mountainous, fiord-dissected, high grade gneissic region, like most of the rest of the eastern margin of the Canadian Shield, that stretches north through Baffin, Bylot, Devon, Coburg, and Ellesmere islands.

Although the earliest documented geological description of this area appears to have been made by 2 Moravian missionaries who travelled along the Labrador coast in 1813, the Ramah chert has been quarried for several thousands of years by both prehistoric Indian and Inuit cultures for the manufacture of stone tools.

The 5 maps displayed show changes in knowledge of the Aphebian supracrustal Ramah Group and contiguous terranes at the Nain-Churchill Structural Province boundary in the Torngat Mountains of northern Labrador. The maps become more detailed and of larger scale with time, and show that until Taylor's major helicopter-supported reconnaissance in 1967, almost all geological work was restricted to the coast.

Daly's Northeast Coast of Labrador, 1902 (scale 1:6 336 000)

Reginald Aldworth Daly's sketch map, based on fieldwork in 1900, shows the Ramah series (horizontal lines) and Mugford series (vertical lines), both of which he named and described. The Nain anorthosite is shown by solid black; strikes are heavy straight lines, or sinuous lines where the rocks are contorted. Little is shown of the geology inland.

Coleman's Nachvak Fiord, Labrador, 1921 (scale 1:253 440)

A.P. Coleman, Daly's mentor at the University of Toronto, undertook fieldwork in northern Labrador in 1915 and 1916. This map, from Coleman's GSC Memoir 124, shows the northern extent of an undivided Ramah series, and two subdivisions of older Precambrian rocks. The topographical map on which the bedrock is shown was surveyed and produced by Coleman in order to show his geology of the region.

Douglas' Geology of the Ramah Series in the Rowsell Harbour-Ramah Bay Area, Coast of Labrador, 1953 (scale 1:36 000)

This map (Fig. 9, GSC Paper 53-1), based on fieldwork in 1946 and 1947, was printed in 1953 and shows undivided sedimentary Ramah series with a lower volcanic horizon, a chert marker bed, and intrusive diabase sills that outline the folding illustrated in one of the accompanying cross-sections. The topographical base map was surveyed and constructed by the field party so that they could map and display the geology in detail and with precision on an accurate map.

Taylor's South Cape White Handkerchief-Hebron, 1977 (scale 1:250 000)

The advent of helicopter-supported fieldwork, detailed topographic maps, and air photographs enabled F.C. Taylor to produce this map that extends into the previously geologically unknown interior of northern Labrador. The known extent of the undivided Ramah Group, with its western thrust and faulted contact, is shown between Nachvak and Hebron fiords. Archean rocks east of the Ramah, cut by diabase dyke swarms, are distinguished from Proterozoic basement rocks to the west, which are chiefly granulite facies tectonites.

Morgan's Nachvak Fiord-Ramah Bay, 1979 (scale 1:50 000)

This map, based on fieldwork in 1971 and 1972, shows the northern part of the Ramah Group, divided into 7 newly named formations, and cut by numerous diabase sills with local ultramafic cores. Structural complexity in the Archean Nain Province to the east of the Ramah is indicated by mafic, ultramafic, and paragneiss marker horizons. Basement rocks west of the Ramah are interpreted as re-metamorphosed, transposed Archean that has been thrust eastwards over the Ramah.

THE CANADIAN SHIELD, ONTARIO-QUEBEC

Much of Ontario and Quebec is underlain by Precambrian bedrock forming a peneplained, gently undulating, dome-like surface, typical of the Canadian Shield. Of the 6 items on this panel, 4 maps were produced in 1991 and 1992, and show increasing use of digital technology in capturing field data and in geological cartography.

Andrew C. Lawson's classical map of Rainy Lake (1887) and companion report, released the following year, set new standards for Precambrian geologists and also for cartographers. Lawson, a Scot, who lived for almost 91 years, first worked for the Survey in 1882 as a summer assistant to Robert Bell, and in 1888 became the first GSC officer to hold a PhD in geology, now a mandatory requirement for Research Scientists. Two years later Lawson resigned and, after a brief spell as a consulting geologist in Vancouver, joined the staff of the University of California at Berkeley. In January 1931, he married Isabel, the 21 year old daughter of W.H. Collins, Director of the GSC. Apart from his geological achievements, Lawson is noted for fathering a son, their first child, shortly before his 88th birthday (Vaughan, 1970). Lawson started the Logan Club in 1887, a GSC club that still organizes keynote lectures in geology at the Survey.

William Henry Collins, an Ontarian, made Precambrian studies, particularly of the Huronian, his life's work, and undertook field work and research even when Director of the GSC (1920-36). Collins worked on the vast nickel deposit at Sudbury and mapped the Huronian west to Sault Ste. Marie. In the 1950s, when it was discovered that the basal conglomerate of a Huronian unit contained uranium, Collins' Blind River map sheet (Collins and Eskola, 1925) "....proved to be of critical importance in ... tracking, staking, and subsequent development of what became known as the $30-billion uranium field" (Joubin and Smyth, 1986, p. 208). In his studies, Collins collaborated with two other Precambrian experts, Pentti Eskola of Finland, in 1922, and, from 1919 until 1931, with Terence Thomas Quirke, an American Professor at the University of Illinois.

To commemorate the centennial of the founding of the Ontario Bureau of Mines, the Ontario Geological Survey (OGS) has published a series of landmark geoscience maps of Ontario, compiled at a scale of 1:1 000 000, using 7 map themes. Each map theme consists of 4 map sheets, and the entire series of maps accompanies a special 2 part volume entitled "Geology of Ontario" (Thurston et al., 1991). Parts of two of the bedrock map sheets are displayed here to illustrate some aspects of the geology of southern and east-central Ontario (Ontario Geological Survey, 1991a, b).

The northeast portion of a 1:1 000 000 scale GSC map of the Lake Superior-Sudbury area (Card et al., 1992) is exhibited to show an alternate method of portraying the bedrock geology of a part of the area covered by the OGS maps.

A thematic map produced by the Ministère de l'Énergie et des Ressources, Québec, has been selected to illustrate a method of portraying metalliferous deposits in an important mining district, located in the Abitibi greenstone belt of Superior Province. The map (Couture, 1991) shows the geology of the metalliferous deposits of Rouyn-Noranda and Val-d'Or at a scale of 1:250 000.

With the use of modern digital technology it is becoming increasingly possible to make what are termed "maps on request" or "maps on demand". Indeed, custom-made geophysical maps have been available for some time from the GSC. Open File 2495 (Percival and Card, 1992a) is, however, the first all digital coloured geological map released by the GSC, and its June 1992 production date demonstrates the Survey's ability to deliver the results of field work prior to the commencement of the next field season.

Lawson's Rainy Lake, Ontario, 1887 (scale 1:253 440)

In this 4 miles to 1 inch map, a result of 3 seasons' field work in Superior Province, Lawson divided the Archean rocks into Laurentian gneisses, Coutchiching metamorphosed sediments, and Keewatin lavas and sediments. His innovative depiction of the complex structure of the Rainy Lake area by means of compositional trend lines is remarkable, as it took place long before the advent of air photographs. Later work on the

Precambrian, such as the classical study by Adams and Barlow (1910) in the Haliburton and Bancroft areas, was modelled after that of Lawson. Indeed, his method of depicting structure is used for the Grenville on the 1992 Lake Superior-Sudbury map on this panel.

Collins, Eskola, and Quirke: Lake Panache-Collins Inlet, 1929 (scale shown 1:126 720)

The map is divided diagonally into two along a northeast-trending line, known as the Grenville Front.

The older rocks, in Southern Province to the northwest, shown in blues, mauve, and grey, are Huronian formations cut by diabase sills and dykes (orange-brown). Folding of the Huronian into anticlines and synclines is indicated on the map and cross-section.

Rocks to the southeast in Grenville Province, mainly shown in orange (unit 4a), were considered by Quirke and Collins (1930) in their classical GSC memoir, to have been derived from the Huronian by granitization. This process was thus responsible for the "Disappearance of the Huronian" across the Grenville Front, a view endorsed by present-day experts (Frarey, 1985).

Ontario Geological Survey's Bedrock Geology of Ontario, 1991 (scale 1:1 000 000)

Although the extensive legend and explanatory notes that accompany these bedrock geology maps of Ontario is not shown here, the figure taken from "Geology of Ontario" (Fig. 1.6 from Thurston et al., 1991) illustrates the main subdivisions of the Superior, Southern, and Grenville provinces.

A noteworthy feature of this map is the world-famous Sudbury intrusion, the elliptical norite-granophyre lopolith located northwest of the town of Sudbury. This intrusion has been a leading producer of nickel, copper, cobalt, and platinum-group elements. The Sudbury Structure is widely considered to be a meteorite impact structure (astrobleme).

Card, Sanford, and Davidson: Geology, Lake Superior-Sudbury, Ontario, 1992 (scale 1:1 000 000)

This map should be compared with the OGS Bedrock map of Ontario to illustrate how, by the selection of different colours, line weights, and more or less detail, different aspects of the geology are emphasized. Although *the GSC's use of trend lines accentuates the complex folding in the Central Gneiss Belt of the Grenville Province, the use of solid black lines for faults tends to be overbearing, whereas the naming of faults, such as the west-trending Murray Fault parallel to the north shore of Lake Huron, named after Alexander Murray who worked there in the 1850s and 1860s, is informative. Dyke swarms of different ages are depicted on the OGS maps, but are absent from the GSC Sheet 1, showing geology.*

Couture's Geological Map of the Metalliferous Deposits of Rouyn-Noranda and Val-d'Or, Quebec, 1991 (scale 1:250 000)

The general geology of these mining districts is portrayed by a simplified lithological map, using 14 numbered and coloured units, which are chiefly Archean. Important faults and tectonic zones outline a characteristic lozenge-shaped pattern. Metalliferous deposits in the area are divided into 4 types: base metals (Cu-Zn and Cu-Ni), gold (Au), and high-technology metals (Li, Be, Mo, Bi). Deposits that have been developed are identified on the map by symbols, letters, and numbers, and are tabulated with their name, duration of production, tonnage produced, and quantity of metal recovered.

Percival and Card's Vizien Greenstone Belt, Quebec, 1992 (scale 1:50 000)

This map portrays the bedrock geology of the Archean Vizien greenstone belt of northeastern Superior Province, in Ungava Peninsula, Quebec. Field work on this greenstone belt, an important exploration target with potential for gold and massive sulphide mineralization, was undertaken in 1991. The coloured map was produced from digital files on a 400 dpi electrostatic plotter.

THE CANADIAN ARCTIC ARCHIPELAGO

Early geological maps of the Arctic Archipelago reflect the history of exploration and discovery of new lands, possibly more spectacularly so than with any other part of Canada. Six maps are selected to illustrate this discovery and evolution.

Although early exploration followed the quest for a "Northwest Passage" to the Pacific Ocean, the impetus for exploration in the archipelago really took place during the search for Sir John Franklin's expedition, which had sailed into Lancaster Sound in 1845 and was never seen again.

During a 20 year period, numerous expeditions searched for Franklin, contributed greatly to advances in geographical knowledge, and made many geological discoveries.

Haughton, an Irish divine, who was appointed Professor of Geology at the University of Dublin (1851-81) reported on observations made by M'Clintock who, later in 1859, found remains of Franklin's expedition on, and near, King William Island. Haughton, whose map seems to be the first regional synthesis of the Arctic, also graduated in medicine in 1862, was opposed to the doctrine of evolution, and concluded that the entire duration of geological time, based on stratified rocks, was about 200 million years.

George Mercer Dawson, born in Pictou, Nova Scotia, in 1849, was Director of the Geological Survey of Canada between 1895 and 1901. His 1886 compilation map of the northern part of the Dominion of Canada, east of the Rocky Mountains, depicts the very generalized state of knowledge at that time. It shows, however, that since Haughton's 1856 map, most exploration had been aimed at the North Pole, and consequently channelled along Nares Strait, between Ellesmere Island and Greenland, as illustrated on his map.

In 1880 Great Britain transferred its claims to sovereignty over the North American Arctic to Canada, and consequently Canada took measures to assert her claims over these new territories. The appointment of A.P. Low (Director of the GSC, 1906-07) to command the voyage of the D.G.S. Neptune expedition to Hudson Bay and the Arctic islands was a recognition of the Survey's rôle over the years in helping to expand Canada's sovereignty over her dominion. During the Neptune voyage, Low declared Canada's sovereignty over the Arctic at several points, and also established permanent stations, occupied by Northwest Mounted Police.

Hans Frebold, an internationally renowned paleontologist who later worked at the GSC, published volume 1 of his proposed 2-volume "Geologie der Arktis" in 1945 in Berlin. Volume 1 dealt with North America and Greenland, and the Geological Map of the Canadian Arctic, shown here, is reproduced from the book. Printed by the Berlin company Borntraeger, the book was never sold or distributed, and it appears that the entire stock was destroyed during the war. Dr. Frebold's library, owned by Burkhard Frebold, seems to have the only copy in the west.

Yves Fortier, Director of the GSC (1964-73), did much work in the Arctic, culminating in 1955 with his management of Operation Franklin, an ambitious airborne reconnaissance survey that utilized 2 long-range Sikorsky S-55 helicopters. His 28 person party accomplished the reconnaissance mapping of about 100 000 square miles (2 590 000 km^2) of land in a 200 000 square mile (5 180 000 km^2) zone within a single field season, and laid the foundations for future aircraft-supported geological work in Canada.

Indeed "Operation Franklin" was responsible for the creation of the "Polar Continental Shelf Project" in April 1958. This project has an international reputation because of its continuing logistical support of scientific work in the Canadian Arctic.

Andy Okulitch's magnificent geological map of the Canadian Arctic Archipelago shows state-of-the-science knowledge of this region by means of a complex legend involving coloured and letter-identified map units. The map is Figure 2 in "Geology of the Innuitian Orogen and Arctic Platform of Canada and Greenland" (volume No. 3 of the Geology of Canada series) and is also available separately as GSC Map 1715A.

Haughton's Geological Discoveries in the Arctic Sea, 1856 (scale about 1:4 500 000). Original in the Library, University of Toronto

The Reverend Samuel Haughton's compilation map centres on the Northwest Passage. Observations made by Sir Leopold M'Clintock on journeys in search of Franklin, and the knowledge of geology and geography up to 1854 are shown. At this time little was known of the Queen Elizabeth Islands north of the Parry Islands and Jones Sound.

A geological legend is given in the accompanying text. 1) Silurian strata, limestone - brown; 2) Coal-bearing sandstones, and lower Carboniferous - yellow; 3) Carboniferous limestone - blue; 4) Liassic beds - vermilion; 5) Granitic and gneissoid rocks - pink, and 6) Beds of coal - black lines.

Dawson's GSC Map 255 of the Northern Part of the Dominion of Canada East of the Rocky Mountains, 1886 (scale about 1:12 000 000)

In geological maps the legend is typically portrayed as a vertical, stratigraphic column. Here, however, in Dawson's map, the legend, showing 9 units ranging from Miocene to Archean, is located at the foot of the map, the units being displayed horizontally, and increasing in age from left to right.

At this time most of the Queen Elizabeth Islands were unknown, and the coastlines and islands, particularly in Foxe Basin and Hudson Bay are incorrectly shown.

A red superprint shows locations of other geological features, including economic mineral deposits, particularly coal.

Low's Geological Map of the Northeastern Part of the Dominion of Canada, 1905 (scale 1:3 168 000)

Low's attractive map illustrates and accompanies his report (1906) on the "Cruise of the D.G.S. Neptune to Hudson Bay and the Arctic Islands" in 1903-1904. The geology of the coastline is coloured according to 8 subdivisions, but the interior of the islands and mainland is left undefined. The map shows the track of the ship, the D.G.S. Neptune, in 1903 and 1904.

It should be noted that Low's map shows the Sverdrup Islands, discovered by the Norwegian Otto Sverdrup (1904) and his companions who spent 4 winters in the harbours of southern Ellesmere Island between 1898 and 1902 and conducted extensive explorations.

Frebold's Geological Sketch Map of the Canadian Arctic Archipelago and Bordering Areas, 1945 (scale 1:7 500 000). Original held by Burkhard Frebold

This black and white compilation map, which is one-of-a-kind, as Hans Frebold's book was destroyed and consequently never distributed, shows a compilation of knowledge of the Canadian Arctic up until 1944. Eleven stratigraphic units are indicated by patterns, and with few exceptions, the geography of most of the Arctic is complete.

Fortier's General Geology, Geological Regions, Main Structural Features, and Location of Columnar Sections, of the Arctic Archipelago, District of Franklin, 1963 (scale 1:2 027 520)

This map (Fig. 2 of Fortier et al., 1963, GSC Memoir 320) shows the principal geological subdivisions of the Queen Elizabeth Islands. The geographical exploration of the area is complete, but the geological exploration is only commencing at this time. Although 6 A-series geological maps accompanied this memoir, the geology was never-the-less only known on a reconnaissance scale.

Okulitch's Geology of the Canadian Arctic Archipelago, Northwest Territories and North Greenland, 1991 (scale 1:2 000 000)

This magnificent map, only part of which is shown here, accompanies Hans Trettin's Geology of the "Innuitian Orogen and Arctic Platform of Canada and Greenland", which is volume No. 3 of the GSC Geology of Canada series.

The map appearing as Figure 2 in that volume and also available separately as GSC Map 1715A, displays the state-of-the-science knowledge of the Innuitian Province.

The complexity of detail should be compared with the earlier maps of the Arctic Archipelago. The map has, in addition, been produced to a large extent by means of modern digital cartographic techniques.

INTERIOR PLAINS, FOOTHILLS, AND ROCKY MOUNTAINS

Although the 5 items on this panel show sedimentary basins, the emphasis here is on basins in those parts of Canada - the Interior Plains, Foothills, and Rocky Mountains - that are our chief sources of petroleum and natural gas.

Geological exploration of this region took place several decades after work had commenced in Eastern Canada by Provincial (at that time termed colonial) surveys and by the GSC. It must be emphasized, however, that this part of Western Canada was initially explored by several outstanding geologists of international repute, such as George Mercer Dawson (Director of the GSC, 1895-1901) and Reginald Aldworth Daly (Professor of Geology at Massachusetts Institute of Technology, 1908-1912, and at Harvard, 1912-1942). Between 1901 and 1913 Daly worked on a permanent and then on a temporary basis for the GSC. Both men were meticulous observers, and the acid test of their expertise is how remarkably well their geological maps and cross-sections have stood the test of time.

Dawson's detailed map of part of the Cascade Coal Basin in the Rocky Mountains shows coal-bearing strata and coal seams along the Bow River Valley, which was the route followed by the Canadian Pacific Railway. Much of the early exploration in Canada was in fact directed at the search for coal, the fuel required by industry at that time, and an essential commodity for efficient trans-continental rail routes.

Daly's work in this region is also quite exceptional. Between 1901 and 1906, inclusive, he carried out fieldwork across the Cordillera of North America, west from the Rocky Mountains to the Coast Range. This work, as a member of the International Boundary Commission, involved mapping the geology of a 5-10 mile (8-16 km) wide belt that straddled the Forty-ninth Parallel, the boundary between Canada and the U.S.A. Daly produced 17 maps at a scale of 1:62 500, each accompanied by a cross-section, that covered his 400 mile (740 km) long transect, and so in effect, he mapped about 2500 square miles (6475 km^2) in detail - a remarkable achievement.

Donaldson B. Dowling, who was hired in 1885 by Alfred Richard Cecil Selwyn, Director of the GSC (1869-1895), was not a geologist, but a civil engineer. Dowling's appointment followed Selwyn's plan to hire topographers to work in the field, and prepare the topographic base maps, so that the geologists were free to concentrate on their main task - mapping and studying the geology.

The Canadian Society of Petroleum Geologists' map and cross-sections showing the Phanerozoic Geology of Canada are not accompanied by marginal notes, but clearly depict the depositional thicknesses, lithologies, and structures of the sedimentary basins. Due to size constraints, only 7 of the original 12 cross-sections are shown here, and these are limited to the Western and Arctic basins.

R.A. Price's map of the Flathead area (GSC Map 1154A) accompanies GSC Memoir 336 and is based on his doctoral dissertation, presented at Princeton University, U.S.A. His mentor, R.J.W. (Bob) Douglas of the GSC, had worked extensively on the stratigraphy and structure of the

Rocky Mountains, and produced many classic GSC reports. Ray Price became the 16th Director/Director General of the GSC (1982-87) and went on to become Assistant Deputy Minister of the Survey (1987-88).

Dawson's Geological Map of Part of the Cascade Coal Basin, Rocky Mountains, 1886 (scale 1:95 040)

This GSC map (224) shows a section of the geology that extends southeast from Banff, Alberta, along the Bow River area. A two mile (3.2 km) wide strip of Cretaceous coal-bearing Kootanie Group rocks is flanked by undifferentiated Carboniferous and Devonian Limestone Series. The contact between the Cretaceous and Paleozoic is drift-covered, and is not mapped as being faulted. Dips and strikes of strata are indicated on the map, and the extent of folding and one fault are shown on the cross-sections. Coal seams are delineated in black on the cross-sections, one of which also shows their thicknesses.

Daly's Geology of the Forty-ninth Parallel, Sheet No. 5, Moyie Range, 1912 (scale 1:62 500)

Sheet No. 5 (GSC Map 78A) covers the western Purcell Range, and is one of 17 map sheets, at the same detailed scale, that accompany Reginald Aldworth Daly's 857 page classical account of the Geology of the North American Cordillera at the Forty-ninth Parallel (GSC Memoir 38). The map covers a five mile (8 km) wide strip centred on the Canada-U.S.A. boundary. Cambrian massive quartzites and meta-argillites are divided into 3 formations cut by abnormal intrusive hornblende gabbros - the Moyie sills - that contain no pyroxene. The superb cross-section depicts Daly's interpretation of the structure of the region, an interpretation that holds essentially true to this day. One of the foremost geoscientists of the early- to mid-1900s, Daly wrote several textbooks on structural geology and igneous rocks. Many important scientific reports also resulted from his work on the Cordilleran transect of the International Boundary Commission.

Dowling's Geological Map of the Cascade Coal Basin, Alberta (Sheet IV, Wind Mountain), 1907 (scale 1:63 360)

Although Dowling started his career with the GSC as an engineer, he became an outstanding geologist. With the construction of new railway lines in the west, the Survey directed its attention to the coalfields in the Plains and Rocky Mountains, and in 1903 Dowling started a detailed *investigation of coal-bearing strata in Alberta, which led him to become the expert on coal resources in Canada. This attractive map of Wind Mountain shows detailed stratigraphy, and demonstrates the structure of the area by means of 2 cross-sections, along the northern and southern margins of the map-sheet. Coal seams are denoted by black lines in the Cretaceous Kootanie Coal Measures. No strikes, dips, or map-unit designators are on the map, but important faults are indicated, and the legend shows advances in stratigraphy since Dawson's 1886 map.*

The Canadian Society of Petroleum Geologists' Phanerozoic Geology of Canada, 1978 (scale 1:30 000 000)

This map-sheet, number 5 of the CSPG, on Phanerozoic geology, contains an index-location map, 12 cross-sections (only 7 shown here), and a Phanerozoic Time Scale. The index isopach map indicates thicknesses of sedimentary rocks filling Canada's Phanerozoic sedimentary basins, and also locations of cross-sections. The map is at 1:30 000 000 scale: the cross-sections have a horizontal scale of 1 cm = 37.5 km, with a vertical scale of 1 cm = 1.5 km. Lithological, structural (folding, faulting, block-faulting), and stratigraphic relationships are portrayed in the cross-sections, which utilize a 12 age-colour key in conjunction with 12 lithological symbols.

Price's Geology, Flathead (Upper Flathead-East Half), British Columbia-Alberta, 1965 (scale 1:50 000)

This superb map is accompanied by 5 cross-sections, only 3 of which are shown here. The map has an attractive legend using 27 pastel colours, identified only by numbers, to indicate rock type and age. One unit, a Lower Cretaceous trachyte-syenite is indicated by a letter, "A". In many ways, the Flathead map bears a remarkable resemblance in overall style to maps produced by Dowling, almost 60 years earlier, in its use of pastel-colours, overall design, and cross-sections, and so should be compared to his map of the Cascade Coal Basin, also displayed here. Only a glance at Flathead is required, however, to illustrate the quantum-leap in the knowledge of stratigraphy and structure that has taken place since Dowling's time. A dominant feature of Flathead is the number of faults and thrusts. When Ray Price mapped this area, he recognized 2 distinct groups of structures: an older group, dominated by thrust faults, and a younger group, dominated by gravity faults.

THE CANADIAN CORDILLERA

The Canadian Cordillera is a mountainous region of 1.6 million km^2 of great geological complexity. Geological exploration by the GSC began in 1871 after the entry of British Columbia into Confederation. Geological traverses commenced along the main waterways and routes of travel with the journeys of Alfred R.C. Selwyn (1824-1902, GSC Director, 1869-1895) and James Richardson (1810-1883). These "route" surveys, which featured epic journeys by G.M. Dawson (1849-1901, GSC Director 1895-1901) and R.G. McConnell (1857-1942, Deputy Minister of Mines, 1914-1920) lasted until about 1910. During this period GSC officers made their own topographic maps and also collected a wealth of other information on geography, natural history, and the language and culture of the native people. In 1913, at the end of this period of rapid geological exploration, GSC provided the essential outline of Cordilleran geology shown on Map 91A.

From 1910 until the early 1950s GSC undertook more detailed geological mapping of mineral districts as well as systematic quadrangle surveys at a scale of 1 inch to 4 miles. Base maps were provided by the GSC's Topographical Division until the 1940s after which that division became an independent branch known as the Topographical Survey. The regional geological coverage increased slowly because of more detailed studies and the slow methods of transportation, using packhorses, canoes, and backpacking. By the end of this period about one quarter of the Cordillera had been mapped at 1 inch to 4 miles (GSC maps 1002A, 1048A, and 932A, 2nd edition).

Geological mapping was greatly accelerated in the late 1950s by the use of helicopters. Its precision was also greatly enhanced by air photographs and by better base maps. This resulted in the virtual completion of 1:250 000 scale reconnaissance geological mapping of the Cordillera by the late 1970s. Since then revision mapping and new stratigraphic studies, coupled with the use of conodonts and radiolaria, have permitted more refined subdivision and more extensive correlation of stratified units. Every geological system from the Lower Proterozoic through the Cenozoic is represented in the Cordillera. Radiometric dating of igneous and metamorphic rocks has now identified at least 25 magmatic episodes as well as several ages of metamorphic complexes. Faults of all types are abundant. Offshore geophysical and geological surveys have extended our knowledge of the geology beneath the adjacent seas off Mackenzie Delta and the Pacific Coast.

The current state of knowledge is best shown on the Tectonic Assemblage Map of the Canadian Cordillera (GSC Map 1712A) which follows the style of the 1981 first edition pioneered by H.W. Tipper, G.J. Woodsworth, and H. Gabrielse (GSC Map 1505A). Tectonic assemblages represent distinctive successions of stratified rocks comprising one or more formations, mainly bounded by unconformities or faults, deposited in specific tectonic environments during particular intervals of time. Plutonic suites are defined by age and subdivided by composition and other attributes.

Two areas, one in the northern Cordillera and one in the south, have been selected to show the progressive increase in geological coverage and understanding of the Canadian Cordillera. The parts of maps selected have been adjusted to similar scales to enable comparisons to be drawn.

GSC Map 411, 1884 (scale 1:2 851 200)

This was the first geological map of the Canadian Cordillera displaying the state of knowledge up to 1882, in the middle of the geological exploration phase. No Precambrian strata are shown except for probable Archean metamorphics in the Shuswap. Most stratified rocks are Paleozoic but include Triassic rocks. Granitic rocks are widespread in the Coast Range and occur locally to the east. Tertiary volcanics are extensive in the Interior Plateau where shield volcanoes are identified just south of latitude 53°N. Only on Vancouver Island was the geology misrepresented. The island is actually composed mainly of volcanic and granitic rocks, whereas crystalline schists are generally restricted to southernmost Vancouver Island.

Dawson's GSC Map 783, 1902 (scale shown 1:6 336 000)

G.M. Dawson completed this map compilation just before his death on March 2, 1901. The map represents the state of knowledge near the end of the geological exploration phase whereby the geology of the Canadian Cordillera is shown by 8 map units. High grade metamorphic rocks (unit A) are distributed much as today, although Dawson regarded them as Archean. "Coast granite" was separated from other granitic plutons because it contained metasediments and metavolcanics of probable Paleozoic age.

Young's GSC Map 91A, 1913 (scale 1:6 336 000)

Map 91A differs from earlier maps. The high grade metamorphic rocks (unit A) of the Shuswap are designated as undivided Precambrian because the rocks of the surrounding region were considered Late Precambrian or Cambrian. Schists in western Yukon are shown as chiefly Paleozoic and Precambrian. Late Paleozoic stratified rocks are shown along and west of Fraser River, and those of Triassic age are displayed east of lower Fraser River. Much more detailed geology is also shown along the Yukon-Alaska boundary.

Little's 1962 GSC Map 932A (2nd edition) - North Half and Bostock's 1957 GSC Map 1048A - South Half (scale shown 1:2 000 000)

These 2 maps represent the state of knowledge at the beginning of the helicopter reconnaissance phase of geological mapping. Although systematic mapping at 1 inch to 4 miles had delineated most of the geology in west-central Yukon, large gaps remained in eastern Yukon where geological knowledge resulted only from surveys along the main waterways and the Canol Road completed in 1944.

Little's 1962 GSC Map 932A (2nd edition) - South Half and GSC Map 1002A, 1951 - South Half (scale shown 1:2 000 000)

These maps represent the geological knowledge near the start of the helicopter reconnaissance. It was a product of 1 inch to 1 mile mapping in the Foothills and Front Ranges of the Rocky Mountains, and systematic 1 inch to 4 miles reconnaissance mapping in SE British Columbia. Stratified rocks were subdivided into geological systems. Most granitic plutons were considered to be Jurassic and/or Cretaceous, whereas some were known to be Tertiary. The porphyry copper-bearing Guichon batholith (unit 2) was the first pluton of Early Jurassic age to be dated in southern B.C. The Shuswap metamorphic terrane was considered to be Precambrian or later. Faults were shown for the first time on regional compilations.

Wheeler and McFeely's Tectonic Assemblage Map of the Canadian Cordillera (North), 1991 (scale 1:2 000 000)

The north part of GSC Map 1712A was mapped after 1957 and turned out to be a key region for revealing the nature of the tectonic evolution of the Canadian Cordillera. The map shows the leading edge of the largely volcanic terranes (assemblages DTs, MTc, TL, JI, and Ts) thrust, in part, onto the outer part of the ancestral North American continental margin (EDR, BEG, BEH, and UPw) and, in part, onto the pericratonic Kootenay Terrane (PTNK) sandwiched between the continental margin and the allochthonous terranes. These terranes and the outer continental margin (EDRC) were later displaced several hundred kilometres NW along dextral transcurrent faults such as Tintina and related faults.

Wheeler and McFeely's Tectonic Assemblage Map of the Canadian Cordillera (Southeast), 1991 (scale 1:2 000 000)

The SE part of GSC Map 1712A shows part of the largely volcanic allochthonous terranes (assemblages DTs, MTc, and TJN) and their subvolcanic plutons (EJgG) which are host to large porphyry copper deposits. The terranes are thrust, in part, onto the outer margin of the North American craton (mPpW, uPW, PEG, and EDR) and, in part, onto the pericratonic Kootenay Terrane (PPEK) sandwiched between the craton margin and the allochthonous terranes. The map also shows the characteristic imbricate style of the Foreland Thrust and Fold Belt in the Rocky Mountains, and metamorphic core complexes, some of which comprise Early Proterozoic gneisses (IPM, EPMO) but are bounded by Tertiary listric normal faults.

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