Friends of GSC History, Series A - Historical Contributions, no. GSCHIS-A021
Title: History of the Geological Survey of Canada in the sedimentary basins of western and northern Canada, the proud heritage of the Geological Survey of Canada (Calgary)
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Released: 2015 06 01

History of the Geological Survey of Canada

in the

Sedimentary Basins of Western and Northern Canada

The Proud Heritage of the Geological Survey of Canada (Calgary)

Compiled by:

G. Grant Smith

[Completed: May 2015]

This report was prepared in order to document some of the significant accomplishments of the Geological Survey of Canada (GSC) in the sedimentary basins of western and northern Canada. The story of GSC's work in the region began in 1871 following expansion of the nation with entry into the confederation of Manitoba (1870) and British Columbia (1871).

In his publication on "Reading the Rocks", M. Zaslow documented the early years of the GSC from 1842 to 1972. The following report focuses mainly on the work of GSC in the western and northern sedimentary basins after 1950, following the discovery of oil at Leduc, south of Edmonton, and the advent of advanced fixed-wing and helicopter aircraft that facilitated mapping in remote and previously inaccessible regions of Canada – especially the Arctic.

A relatively comprehensive archive of documents on information summarized in this report has been established for those wishing to pursue further details.

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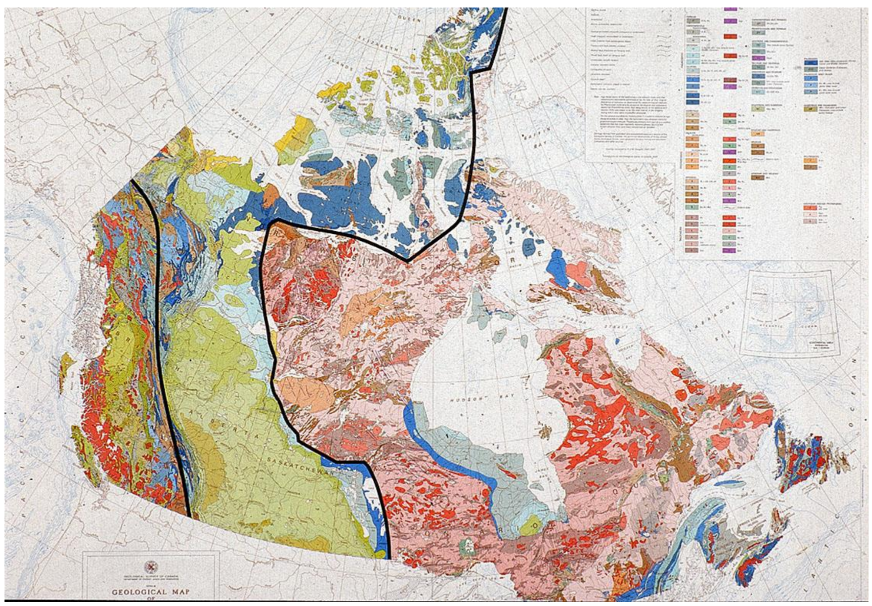
Region of Interest

The region of interest lies within a great wedge of sedimentary rocks that extends from the Canadian Shield to the Rocky Mountains and from the International Boundary to the Arctic Ocean.[1] It also includes the areas underlain by the sedimentary basins of Canada's Arctic Archipelago.

Most of the region falls within the domain of the Western Canada Sedimentary Basin (WCSB). This vast sedimentary basin underlies 1,400,000 square kilometres (540,000 sq mi) of western Canada, including southwestern Manitoba, southern Saskatchewan, Alberta, northeastern British Columbia and the southwest corner of the Northwest Territories. The massive wedge of sedimentary rock is about 6 kilometres (3.7 mi) thick under the Rocky Mountains, but thins to zero at its eastern margins. The WCSB contains one of the world's largest reserves of petroleum and natural gas and supplies much of the North American market, producing more than 16,000,000,000 cubic feet (450,000,000 m^3) per day of gas in 2000. It also has huge reserves of coal. Of the provinces and territories within the WCSB, Alberta has most of the oil and gas reserves and almost all of the oil sands.[2]



This report is intended to highlight some of the Geological Survey of Canada's most significant work in the region. The focus is on bedrock geology as the Quaternary or surficial geology of the region was often treated separately within the Geological Survey of Canada, and managed from Ottawa within the Terrain Sciences Division.

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[1] De Mille, George, 1969: Oil in Canada West, The Early Years, Northwest Printing and Lithographing Ltd, Calgary, 269 p.

[2] Wikipedia, February 2013, Western Canadian Sedimentary Basin http://en.wikipedia.org/wiki/Western_Canadian_Sedimentary_Basin

Acronyms

BMB	Beaufort-Mackenzie Basin
CBM	Coal-bed Methane
CGKN	Canadian Geoscience Knowledge Network
CGMS	Cooperative Geological Mapping Strategies
CSPG	Canadian Society of Petroleum Geologists
EMR	Department of Energy, Mines and Resources
ESS	Earth Sciences Sector
FAA	Financial Administration Act
FGP	Frontier Geoscience Program
GSC	Geological Survey of Canada
GOL	Government-On-Line Initiative
IPP	Industrial Partners Program
ISPG	Institute of Sedimentary and Petroleum Geology
MDA	Mineral Development Agreement
MERA	Minerals and Energy Resource Assessment
MITE	Metals in the Environment Program
MOU	Memorandum of Understanding
NATMAP	Nation Geoscience Mapping Program
NBI	Northern Basins Initiative
NEB	National Energy Board
NGSC	National Geological Surveys Committee
NRCan	Natural Resources Canada
NSERC	Natural Sciences and Engineering Research Council
NSTW	National Science and Technology Week
OERD	Office of Energy Research and Development
PERD	Panel on Energy Research and Development
PSEA	Public Service Employment Act (2005)
PSMA	Public Service Modernization Act (2005)
SDC	Standard Desktop Computing
SPA	Specified Purpose Account
SSHRC	Social Sciences and Humanities Research Council
TGI	Targeted Geoscience Initiative

Prologue

The Geological Survey of Canada (GSC), older than the country itself, has served Canada with distinction since 1842. It has helped shape the development of the nation and has established traditions of excellence in geoscience that are respected internationally. The GSC has played an important role in the exploration and development of Canada's North-West frontiers.

The first inhabitants of the North-West frontiers were Asians who migrated from Berengia starting about 28000 years ago. Our aboriginal natives of today came from these roots and formed our First Nations.

Radisson and Grosseillers were the first Europeans to venture west when they went on their fur trading expedition to Lake Superior in 1659. This led ultimately to the Hudson's Bay Company (HBC) receiving a charter in 1670 to trade in British North America. It was given Rupert's Land.

Between 1690 and 1692 Henry Kelsey journeyed west from York Factory seeking trade for the HBC.

Between 1734 and 1743 the La Verendryes explored westward to present-day Manitoba and Saskatchewan, and southward to the Black Hills.

Anthony Henday was the first non-aboriginal to see the Rocky Mountains when he wintered west of Red Deer in 1754.

In 1778 Peter Pond entered the Athabasca area and was the first non-aboriginal to see the outcrop of oil sands.

The map of North America changed several times during the second half of the 18th century. The most important change to the development of the North-West occurred in 1783 when the new United States of America was officially recognized. The boundary from the Atlantic coast to Lake of the Woods was established. Loyalists sought new homes in Canada. The two new colonies of New Brunswick and Upper Canada were created.

Montreal fur traders (referred to as the Nor'Westers or voyageurs) turned to the North-West from their previous traditional routes through Detroit and Michilimackinac. The Nor'Westers were in direct competition with the Hudson's Bay Company. They took their light-weight canoes (about 60 per year) well inland along the trans-Canada canoeways. The HBC traders maintained their posts near the shores of Hudson Bay and travelled inland with their heavier York boats along major waterways only.

In 1784 David Thompson began 20 years of mapping the western interior and mountains.

In 1787 Alexander Mackenzie began exploration in the Athabasca, Smoky and Peace rivers areas, and onto the Pacific Ocean. During the winter of 1792-93 he observed coal in the Peace River Canyon.

In 1792 Peter Fidler was the first HBC employee to pass through the Calgary area.

Much of the exploration of the North-West Territories to this point focussed on assessing fur trading possibilities with the Indians. It was driven mainly by commercial interests.

In 1841 much of what is now Canada was a vast, uncharted territory. Proclamation of the Act of Union officially united Upper and Lower Canada. The new colonial government of the united Canadas immediately passed a resolution to undertake a geological survey of the Province of Canada. On April 14, 1842, Montreal-born William Logan accepted an offer to direct the survey. This gave birth to the Geological Survey of Canada (GSC), Canada's first scientific agency and one of its oldest government organizations. In establishing the objectives of the Survey, Logan gave top priority to "*the discovery of economic minerals, especially coal*".[3]

In 1842, British North America included the colonies of Canada, New Brunswick, Nova Scotia, and Prince Edward Island. (Newfoundland achieved full colonial status in1855). The vast territory beyond these colonies was referred to as the North-West. The North-West Territories included Rupert's Land, which embraced the area drained by rivers flowing into the Hudson and James bays.

By the mid-19th century science was being transformed from the natural history tradition to a utilitarian ideology promoted by business and professional classes. Societal interests were becoming less local and more transcontinental.[4]

A new era for commerce and transportation was beginning to emerge in Canada. Fur trading was beginning to decline, and timber and wheat were becoming the major trading commodities. The colonies were heading toward responsible government.

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[3] Vodden, Christie, 1992: No Stone Unturned – The first 150 years of the Geological Survey of Canada; Energy, Mines and Resources Canada 1992, 52p.

[4] Zeller, Suzanne, 2009: Inventing Canada – Early Victorian Science and the Idea of a Transcontinental Nation; McGill-Queen's University Press 2009, p13-112.

By the end of 1844 Logan recognized that coal deposits that would be vital to economic development were absent from Canada. The large coal deposits in New Brunswick and Nova Scotia encouraged the united Canadas to enter into confederation with these colonies later in 1867.

1846: The International Boundary was established along the 49^{th} Parallel

1849: Vancouver Island was organized as a colony.

1850s: The beginning of real industrial growth and commercial development was being spurred by the building of railways.

In 1857 the British Parliament approved what became known as the Palliser Expedition to study and map the North-West Territories. It was to report on prospects for western settlement at about the time that the Hudson's Bay Company was asking to renew its licence. James Hector of the Palliser Expedition was the first to systematically record geological observations of the Interior Plains and Rocky Mountains.[5] He found coal along the Souris River in southeaster Saskatchewan and was the first to report the use of coal in the region in describing its use in the forges of Edmonton.[6]

Almost concurrent with the Palliser Expedition launched by the British Government, the Government of Upper Canada sponsored the Hind Expedition as it began to view westward expansion. Henry Hind examined and mapped the Cretaceous and Tertiary rocks of Manitoba and Saskatchewan during his expedition.

The Hudson's Bay Company licence was renewed in 1858 by the British Government after Palliser reported that much of the region was unsuitable (too arid) for agriculture.

1858: Coastal mainland to the watershed of the Rockies was made a separate colony (British Columbia).

Gold was discovered on the lower Fraser River in 1858. Tens of thousands of gold prospectors rushed to the region, especially from California. In their search for gold, they pushed up the Fraser Valley into the interior Thompson, Lillooet and southern Cariboo regions in 1860 and 1861.

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[5] Palliser Expedition *in* The Canadian Encyclopedia, Hurtig Publishers Ltd., 1985.

[6] Dowling, D.B., 1914: Coal fields of Manitoba, Saskatchewan, Alberta and eastern British Columbia; Geological Survey of Canada Memoir 53, 142p.

1860s: Reports of the Hind Expedition published in the early 1860s described the fertile Prairies at a time when available agricultural land in the Canadas was becoming scarce. Canadians began to consider westward expansion seriously.[7]

Gold production in the colony of British Columbia declined in the mid-1860s. Lumber and fishing became important export industries. Coal from the colony of Vancouver Island was being sold to San Francisco.

1866: The colonies of Vancouver Island and British Columbia were united.

1867: Canada, Nova Scotia, and New Brunswick were joined in Confederation. This greatly expanded GSC's territory.

1869: Canada acquired Rupert's Land from the Hudson's Bay Company and passed the Act for Temporary Government of Rupert's Land and The North-West Territory.

The Metis were not consulted and, under Louis Riel's leadership, resisted the transfer of Rupert's Land to Canada. Riel led a rebellion of Metis against Canadians in Manitoba (Red River Rebellion).

Later, after a similar rebellion in Saskatchewan, he was captured, tried and convicted of treason, and was finally hanged in Regina on August 1, 1885.

The Riel Rebellion emphasized the need for a railway to move troops to the North-West and to enforce sovereignty.

1870: Manitoba entered Confederation

1871: British Columbia entered Confederation

Following B.C.'s entry into Confederation in 1871, on the condition that a transcontinental railway link to the east be constructed by the federal government, Alfred R.C. Selwyn, the second Director of the GSC, immediately mounted an expedition to British Columbia. With his assistant James Richardson, Selwyn was commissioned

[7] Hind, Henry Youle, *Narrative of the Canadian Red River Exploring Expedition of 1857 and of the Assinniboine and Saskatchewan Expedition of 1858*; M.G. Hurtig Ltd., Edmonton, 1971

"to ascertain as much as possible respecting the general geological features and the useful minerals which may be found on and in proximity to the several lines which will be explored by the engineering parties, and on one or other which the future Pacific railroad will be located". [8]

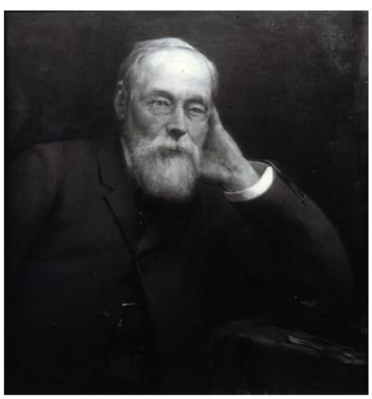
In addition to their geological observations, their attention was also to be directed to

"..... the nature of the soil, the vegetation, the quality and kind of timber, the distribution of plants and animals, the character of the climate, &c, &c,..."

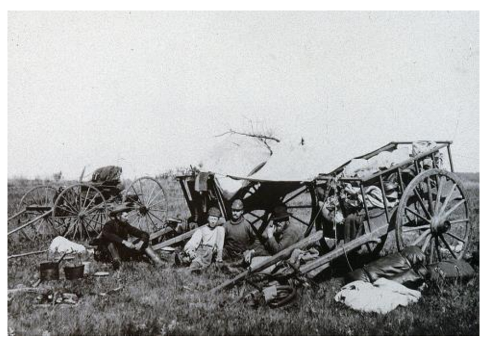
The geologists with the Survey were filled with optimism and excitement about the land they surveyed. In the report of his 1871 Preliminary Explorations in British Columbia, Selwyn noted:

"There can scarcely be a doubt in the mind of any one who has visited the country, that a bright and prosperous future is in store for the Alpine Province of the Great Dominion; only to be realized, however, when the iron road shall have brought her into closer communion with her elder sisters in the east." [9]

The Survey's activities in the 1870s and 1880s were directed to a great extent by factors that were important to the planning of transcontinental railway developments.



A.R.C. Selwyn



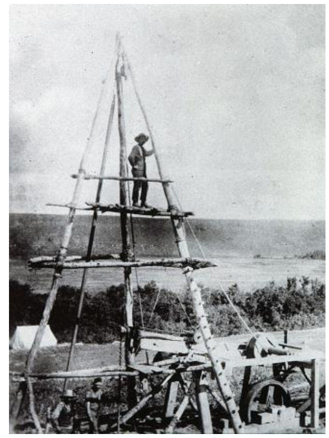
Selwyn's brigade of Red River carts
Stop for lunch
(1873)

[8] Selwyn, A.R.C., 1872: Geological Survey of Canada Reports of Exploration and Surveys 1871-72, Journal and Report of Preliminary Explorations in British Columbia, p. 17.

[9] Ibid: p. 72

George Mercer Dawson (Director, GSC 1895-1901) was the geologist for the International Boundary Commission (British American Boundary Survey) between 1873-1875. During this time, he laid the foundation for future geological surveys of coal deposits near the 49th parallel. In 1875, he produced the first comprehensive report pertaining to the geology and economic potential of the coal in the region.

G.M. Dawson



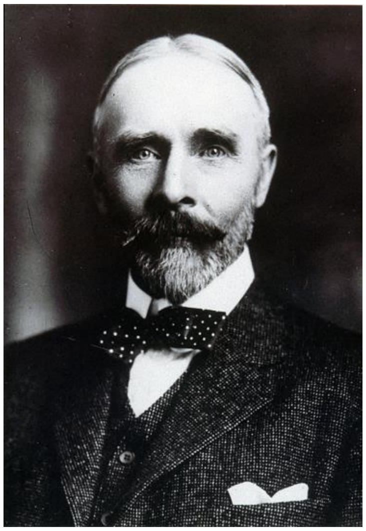
GSC drilling for coal
at Roche Percée, Saskatchewan
(1880)

J.B. Tyrrell, who discovered dinosaur remains and coal near Drumheller, Alberta, in 1884, explored the vast, virtually unknown region from Lake Winnipeg to Lake Athabasca to Hudson Bay (the “Barren Lands”), in 1893 and 1894. His observations and theories on Pleistocene glaciation in central Canada were major contributions to understanding the geology of Canada.

J.B. Tyrrell

Tyrrell’s party at Fort Edmonton
(1886)

R.G. McConnell, who assisted Dawson on many expeditions, conducted geological reconnaissance during the 1880s and 1890s north of the 60th Parallel and north of the Arctic Circle, and in the Athabasca and Peace River areas. He led a Survey drilling program at Athabasca, beginning in 1893, aimed at discovering liquid oil associated with the Athabasca oil sands.

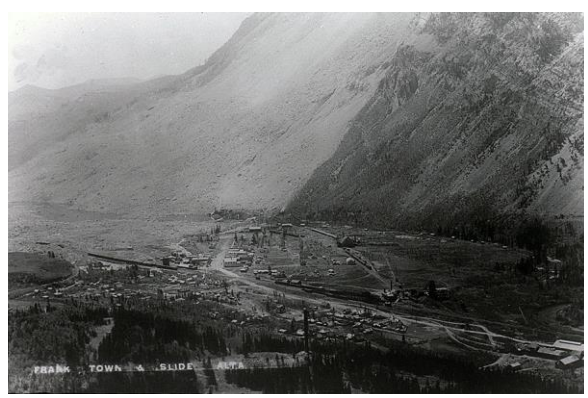


R.G. McConnell

Outcrop of bituminous sands
along the Athabasca River, Alberta

The discovery of rich deposits of gold in the Klondike, in 1896, sparked a frenzy of activity in the North-West. Thousands of prospectors rushed to the Klondike from all over the world in search of the precious yellow metal. The stampede reached its peak in 1897-98, and petered out almost as quickly as it had begun. Some of the luckier prospectors "struck it rich" and became millionaires almost overnight; many others died in attempting to reach the area. As a result of the gold rush, access to the Yukon was improved substantially.

Dawson City, Yukon
(1898)



Frank, Alberta
(1910)

In 1903, within days of the Frank Slide, McConnell and Reginald Brock (Director, GSC 1907-1914) were directed to investigate the causes of the destructive landslide from Turtle Mountain onto the town of Frank in southwest Alberta.

In 1903, D.B. Dowling, who had accompanied Tyrrell on some expeditions, was directed to thoroughly investigate coal-bearing formations in the Rocky Mountains of Alberta. He outlined and discovered major coalfields between the Bow and Yellowhead passes and became the nation's leading authority on its coal resources.

D.B. Dowling

Dowling's camp near Morley, Alberta
(1903)

In 1903-04 A.P. Low of the GSC commanded an Arctic expedition, using the steamship Neptune, to assert Canada's sovereignty over the Arctic Islands and coastal mainland. Information on the inhabitants, geology, weather, plants and animals was systematically recorded.

The pioneer geologists of the Geological Survey of Canada travelled by foot, boat, horseback and dogsled into the uncharted hinterland to record the geology, topography, flora and fauna. They identified the young nation's wealth of resources that would contribute to its increasing prosperity. They were outstanding scientists and woodsmen, often enduring the difficult conditions on the nation's frontier but enjoying the privilege of being among the first to behold its splendour.

In the 1930s the Survey began widespread use of the airplane in its field work. This greatly increased the pace of geological and topographical mapping and began a new era in the Survey's methods. Aeromagnetic mapping was added to the tools available for mineral exploration and the development of geoscientific theory.

The development of the Alaska Highway and Canol Road during the years of World War II greatly improved access to Canada's northern mainland. The development of airstrips associated with weather stations and North American defence installations in Canada's far north in the years immediately following the war (beginning of the Cold War), gave aircraft access to areas previously inaccessible. The advent of commercial helicopters after World War II allowed access to areas previously inaccessible by fixed-wing aircraft. By 1950, the Geological Survey of Canada began to consider seriously the geological mapping of Canada's far north.

In 1947 the discovery of oil south of Edmonton at Leduc marked the beginning of western Canada's oil boom. The demand by industry and government for geological information about this energy-rich region was unprecedented. In response, the Survey opened an office in Calgary in 1950, coinciding with the increased opportunities in Canada's far north.

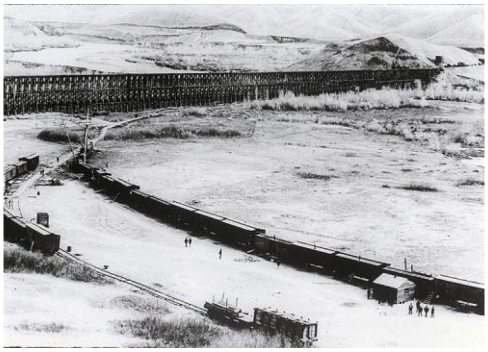
This office was replaced in 1967 with a facility designed expressly to meet its specialized research requirements, the Institute of Sedimentary and Petroleum Geology. It has become a key source of information on the geology, geophysics, geochemistry and resources of western and northern Canada.

During the past 300 years the North-West frontiers have been transformed from a largely uninhabited hinterland into a major industrial, agricultural and commercial region. The wealth of natural resources in the region contributes to a standard of living for all Canadians that is considered by many to be amongst the world's highest.

The Geological Survey of Canada has been and continues to be a major contributor to the commercial, industrial, and social development of the region. It provides knowledge necessary for its responsible development.

The Geological Survey of Canada has helped to push back the North-West frontiers, from the first planning of transcontinental railway routes, to the successful exploration for coal, petroleum and other geological resources. The frontiers today are in the remote regions of northern Canada and in the depths of the sedimentary basins.

New tools and scientific theories are available to help better understand the geology of areas investigated in the past.

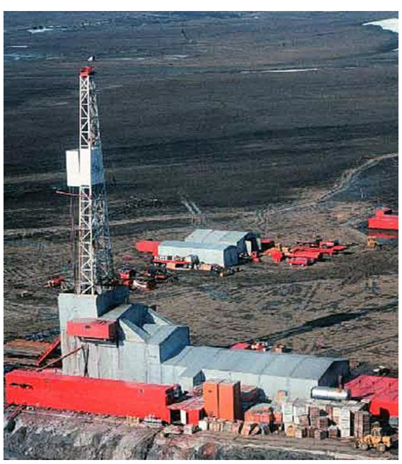


Transcontinental railway development
St Mary's River bridge, Alberta
Crows Nest Branch of C.P.R.
(1898)

Fuel for the railway
Canmore, Alberta
(1903)

Leduc #1 oil well, Alberta
(1947)

Coal-fired power plant, Alberta
(1992)



Petroleum exploration in northern Canada

Petroleum production, Alberta

Section 1 – Summary and Background

Introduction

The government of Canada's Department of Natural Resources (NRCan) and its predecessors focussed their activities on the economic development of the nation's energy and mineral resources. It used scientific data to formulate government policy and to promote the orderly, safe and environmentally acceptable extraction of those resources across the Canadian landmass and offshore areas.

The Geological Survey of Canada was the first scientific arm of the Government of Canada, dating from 1842. GSC has a proud heritage and long history of service to the government and people of Canada. The mission of the GSC is

> **to ensure the availability of comprehensive** geological, geophysical and geochemical knowledge technology and expertise
>
> **concerning the** Canadian landmass and offshore areas, mineral and energy resources, and conditions affecting land and seabed use
>
> **as required for** effective exploitation of mineral and energy resources, estimation of the resource base of Canada, land use planning, public safety and security, and formulation of policy.

GSC fulfills this mission by conducting regionally- and topically-based research and surveys, and making results of this work available for use in formulating government policy in the energy, minerals and environmental areas, and in promoting and encouraging the orderly, safe and environmentally acceptable development of the Canadian landmass and offshore areas and their resources.

The story of the Geological Survey of Canada is the stuff of legends, ranking in the history of this country alongside the fur trade and the building of the railways. It is a story full of colourful scientists and determined explorers, amazing adventures and great accomplishments. The staff of the GSC has made immense contributions to Canada's economic development, laying vital foundations for the mining, oil and gas industries.

And the story continues today. The GSC's traditions of accomplishment and useful service remain unique and indispensible. It is helping to build the economy of the nation and continues to make major contributions to the prosperity of Canadians.

The Early Years (1870-1950)

In 1870 Manitoba and the North-West Territories were added to the Dominion of Canada following the purchase of Rupert's Land from the Hudson's Bay Company. The immediate task became to develop the rich farmlands and coalfields of the prairie region. It fell to the Geological Survey of Canada to explore this vast new territory, greatly enlarging its area of operations.

The history of the GSC in studying the sedimentary basins of western and northern Canada is intertwined with the history of Canada's coal and petroleum industries. The GSC has conducted coal geoscience studies since its inception in 1842. Its early work focused on coal as an essential ingredient for industrial growth. Coal occurrences in the North-West were first reported in the 1780s from observations of float coal, burning coal beds and coal outcrops. The works of G.M. Dawson, D.B. Dowling and J.B. Tyrrell, among several others, are intimately tied to GSC's coal assessments in the North-West. Results from GSC's coal studies profoundly affected the planning of transcontinental railways and ancillary developments that were essential for Confederation.

The petroleum industry in Canada began in Ontario in 1858 when the first oil was recovered from a well dug by hand at Petrolia. In 1861 a GSC scientist named Sterry Hunt formulated the important theory that oil and gas accumulates in anticlines. Exploratory drilling in the Western Canada Sedimentary Basin started in the 1880s.

Early GSC explorers were disappointed by the lack of bedrock exposure in the Interior Plains. It was recognized that exploratory drilling would be required not only to aid the interpretation of the stratigraphic successions but also to assess the potential for coal, water, petroleum and other useful mineral resources. In his 1873 "Proposed Operations of the Geological Survey", Selwyn noted, with regard to "examination of the Fertile Belt" of the prairies:

> *"Where superficial deposits are so thick and wide-spread as they are in the region referred to, the knowledge gained from surface examination alone of the nature and character of the deeper seated strata is, at best, limited and, to a great extent conjectural, and unsatisfactory, whereas by the judicious employment of the diamond drill a number of highly important questions would be speedily and definitely determined. Amongst these may be mention of the formation of artesian wells, the existence of springs of petroleum and of brine and also deposits of rock salt and other valuable minerals, as well as the thickness and character of coal seams."*[10]

[10] Selwyn, Alfred R.C., 1874: Summary Report of Geological Investigations, Proposed Operations of the Geological Survey 1873, Part I, p. 11.

The earliest detailed geological investigations of coal measures in the Interior Plains began in the late 19th century by Dawson (1875, 1883), McConnell (1886) and Tyrrell (1887). Each recognized the vast coal potential in the region at that important time of planning and development of transcontinental railways. G.M Dawson was the geologist for the International Boundary Commission that deliberated between 1873 and 1875. He produced the first comprehensive report pertaining to the geology and economic potential of coal deposits near the 49th parallel. In referring to the Devonian beds exposed west of the Precambrian shield in Saskatchewan and Manitoba, he wrote *"…would if properly explored, be found to yield mineral oil as well as salt*."[11] In 1884 J.B. Tyrrell discovered one of the two richest beds of dinosaur bones in the world while exploring the Red Deer River valley in what is now central Alberta. A few days later he unearthed the biggest coal deposit in Canada, which was to become the economic foundation for Drumheller. D.B. Dowling published several reports in the early 1900's pertaining to the vast coal potential of the Interior Plains. In 1913 he published Canada's first national inventory of coal resources.

The GSC saw the potential of the Athabasca oil sands very early. Between 1882 and 1884 Robert Bell investigated the region of the Athabasca oil sands and was the first to attach a real commercial value to the occurrence. He had it sampled and analyzed, and recommended early development.

In the 1888 Report of the Select Committee of the Senate, "appointed to enquire into the resources of the Great Mackenzie Basin", it noted:

> "*The evidence submitted to your Committee points to the existence in the Athabasca and Mackenzie Valleys of the most extensive petroleum field in America, if not in the world. The uses of petroleum and consequently the demand for it by all nations are increasing at such a vast ratio, that it is probable that this great petroleum field will assume enormous value in the near future and will rank among the chief assets comprised in the Crown domain of the Dominion. For this reason your Committee would suggest that a tract of about 40,000 square miles be, for the present, reserved from sale and that as soon as possible its value be more accurately ascertained by exploration and practical tests…*"[12]

[11] Dawson, G.M., 1875: Report on the Geology and Resources of the Region in the Vicinity of the Forty-Ninth Parallel from the Lake of the Woods to the Rocky Mountains; British North American Boundary Commission, Montreal.

[12] 1888: Report of the Select Committee of the Senate, Appointed to Enquire into the Resources of the Great Mackenzie Basin, Session 1888, p. 14.

In 1890 R.G. McConnell carried out a geological reconnaissance survey of the Athabasca and Peace River areas and was impressed with the immense deposits of oil sands "exposed downstream from Fort McMurray for some 50 miles or more".[13] He stated:

> "*The commercial value of the tarsands themselves, as exposed at the surface, is at present uncertain, but the abundance of the material and the high percentage of bitumen that it contains, make it probable that it may, in the future, be profitably utilized for various purposes, when this region is reached by railways*."

In 1891 A.R.C Selwyn, the second Director of the Geological Survey of Canada, was the first geologist to examine oil seepages in the Cameron Creek area near Waterton Lake in the extreme southwest of the "yet unorganized North-West Territory" near its boundary with British Columbia. He reported:

> "*Cameron Falls brook is a rapid mountain stream, eight or ten yards wide. After following it up about a mile and a-half on the left bank, Mr. Fernie, my guide, remarked that we must be close to where the oil has been found. He had scarcely spoken when, while still in the saddle and on the trail eight or nine feet above the brook, I noticed a powerful odour of petroleum. Descending to the edge of the water and stirring the stones and gravel in the bed of the stream, considerable quantities of oil at once rose to the surface and floated away. Crossing to the right bank it was again seen coming out of the bank, some inches above the level of the stream. Here, skimming it off the surface of a shallow pool, a wine bottle full was soon collected. This can now be seen in the Geological Survey Museum*."[14]

The discovery of these oil seeps started a stampede of speculators to the area, staking claims from the Rocky Mountains out to the eastern prairies. This eventually lead to the drilling of western Canada's first commercial oil discovery in 1902.

In 1914 a GSC party under D.B. Dowling began studying the geology of Turner Valley when the big discovery from the Dingman well came in May. Within months of the Dingman discovery and in the midst of the wildest oil boom Calgary has ever seen, the GSC issued the first scientific report on the geology of Turner Valley.

[13] McConnell, R.G., 1893: Report on a Portion of the District of Athabasca; Geological Survey of Canada Annual Report, Vol. V, Pt. D.

[14] Selwyn, Alfred R.C., 1892: Summary Reports of the Operations of the Geological Survey for the Year 1891, Part A, p. 11.

The GSC did much of the geological groundwork for petroleum exploration throughout western and northern Canada. GSC scientists very often drew attention to regions where major discoveries followed: in the oil sands, the Peace River country, the Mackenzie Valley, and the Arctic Islands, in addition to countless other conventional petroleum producing areas in western Canada.

In 1928 G.S. Hume reported on "Oil and Gas in Western Canada"[15]. In 1925 annual oil production from Alberta surpassed that of Ontario, increasing from 1000 barrels in 1924 to 169,000 barrels in 1925. Hume worked through the 1930s and 1940s on correlating the Mesozoic and Paleozoic stratigraphic successions of the Plains with those of the Rocky Mountain foothills.

A large discovery of oil made in 1947 at Leduc, south of Edmonton, started a major oil industry in western Canada and ushered in the modern age of the petroleum industry in Canada. Coincidentally during the years immediately following World War II access to Canada's north improved with the development of longer-range fixed-wing aircraft, establishment of northern airstrips, and increasing use of helicopters. The GSC opened a small office in Calgary in 1950 to meet the needs of the growing petroleum industry for geological information.

The Geological Survey of Canada has conducted coal geoscience studies, to varying degrees, since its inception in 1842. Much of the GSC's early work focused on coal, an essential ingredient for industrial growth during the second half of the 19th century and early 20th century. The works of G.M Dawson, D.B. Dowling and J.B. Tyrrell, among several others, are intimately tied to GSC's coal tradition. Results from GSC's coal studies profoundly affected the planning of transcontinental railways and ancillary developments that were essential to Confederation. They have assisted the establishment of effective coal exploration strategies, and have stimulated new mine developments in support of the nation's industrial growth.

[15] Hume, G.S., 1928: Oil and Gas in Western Canada; Geological Survey of Canada, Economic Geology Series No. 5, 152p.

The Recent Era (1950-2012)

The Survey's recent activities in the Western Canada Sedimentary Basins can be traced back to a single event – the landmark oil strike that occurred in the Leduc field south of Edmonton in 1947. This was the turning point in Canadian petroleum exploration and development, and hundreds of oil and gas fields were discovered and developed over the next several decades. The oil boom created a burgeoning demand by government and industry for geological information on an unprecedented scale, and GSC responded by opening an office in Calgary in 1950. The facility expanded over the years to become, in 1967, the Institute of Sedimentary and Petroleum Geology (ISPG).

In the early 1970's recurring energy crises brought about a revival of interest in coal as an energy option and the GSC responded by increasing the number of people engaged in coal studies at ISPG.

ISPG was created to interact with the newly developed University of Calgary and with industry. The Institute was housed in its own specially-designed building near the university. It was then, and remains today, one of the finest geoscience centres in the world.

Institute of Sedimentary and Petroleum Geology (1967)

As a Division of the GSC, ISPG was given responsibilities, through field and laboratory research, for describing the geology of western and northern sedimentary basins, from the 49th parallel to the Arctic Islands, and between the Canadian Shield and the Rocky Mountain Trench. These sedimentary basins occupy about one-third the area of the country's landmass and contain most of Canada's oil, natural gas and coal resources. Units of the Division are responsible for the appraisal of oil, natural gas and coal potential of the country.

In addition to its research responsibilities, the Institute was also commissioned with the responsibility for the custody of drilling cores, samples and other data resulting from exploration activities by industry in all provinces and territories of western Canada, and submitted as required to Federal administration in conformity to regulations. Facilities are provided for the public examination and study of such cores, samples and other data, with due consideration given to security requirements of industry and government.

Operations of the Institute of Sedimentary and Petroleum Geology were designed to coordinate with work carried out by industry, the universities, and the provincial surveys and research organizations in the western provinces. It was anticipated that the main benefactor would be the petroleum industry.

At the opening of the Institute the then Mines Minister Jean-Luc Pepin said "It is another investment in resource development by the Government of Canada…" He said that the institute in Calgary provides an "illustration of the Government of Canada's policy of decentralization of service."

The mission of ISPG has been:

> *To ensure the availability of comprehensive knowledge, technology and expertise on the geology, geophysics and resource potential of sedimentary basins of western and northern Canada, and to provide national resource estimates for oil, gas and coal*.

To carry out this mission, and to contribute to collaborative studies with, or to provide services to, other GSC divisions, other levels of government/other government agencies, ISPG has served as a national centre within GSC for:

- Current assessments of undiscovered oil and gas resources for all regions of Canada
- Studies related to Canada's coal resources
- Organic geochemical research and technology relevant to the origin, migration and accumulation of oil and gas
- Maintenance of a national repository of subsurface data and material derived from petroleum exploration in the region north of 60^{o}N
- Paleontological research and services

The main research activities of ISPG (later GSC-Calgary) in the sedimentary basins of western and northern Canada include:

- Stratigraphic, sedimentological, structural, geophysical and tectonic analyses
- Development of biochronological standards and paleoenvironmental interpretations to assist correlation and comprehension of the geology of the basins
- Organic and inorganic analytical studies pertaining to the origin, migration and pooling of hydrocarbons
- Studies of geological setting and distribution of oil and gas deposits
- Development and application of methods for estimating Canada's oil and gas resources
- Studies of geological setting, origin, distribution and properties of coal deposits

- Development and application of methods for estimating the size and distribution Canada's coal resources

In fiscal year 1967/68 the total scientific and professional staff establishment was 36, the technical staff establishment was 25, and administrative support was 14.

Organization

Over the years the scientific programs and staff have been organized mainly according to the following general units:

Regional Geology unit: To conduct geological investigations for determining the nature, origin, and depositional and deformational histories of Proterozoic and Phanerozoic sedimentary rocks of western and northern Canada, and for preparing detailed geological maps, and lithostratigraphic and sedimentological reports of the regions. Results provide the basis for the appraisal of the potentialities of these rocks, both as reservoirs for, and sources of oil and natural gas, and as hosts for other economic deposits including coal, potash, lead, zinc and copper.

Basic information is acquired from geological field work, drillholes and geophysical surveys that test the subsurface, potential-field surveys such as aeromag and gravity, and remote sensing, such as LANDSAT and RADARSAT.

Petroleum unit: To conduct programs on petroleum resource evaluations of the sedimentary basins in western and northern Canada, and to research the mode of origin and occurrence of the resources.

Research is directed toward

- identifying, investigating and defining geological factors responsible for specific oil and gas plays at all stratigraphic levels in sedimentary basins
- assisting the assessment of Canada's undiscovered oil and gas potential by providing new relevant geological data and new hydrocarbon discovery data
- identifying and refining concepts significant to understanding the occurrence of hydrocarbons and their primary and secondary recovery possibilities
- developing methodology for assessing petroleum resources
- understanding the origin, migration and accumulation of hydrocarbons in sedimentary basins
- contributing data and interpretations on the nature of hydrocarbons; character, distribution, quality and maturity level of petroleum source

facies; and on other matters relevant to hydrocarbon assessment studies of sedimentary basins in Canada
- understanding rock-water interactions and diagenesis affecting reservoir quality

Coal unit: To establish a basic understanding of the coal measures of Canada, to evaluate Canada's coal resource potential, and to develop and maintain a coal resource inventory of Canada's coal deposits in collaboration with the provinces.

Research is directed toward

- understanding the stratigraphy, sedimentology and structures of important coal-bearing sequences
- determining the compositional attributes of coals
- determining regional distributions and patterns of organic maturity to interpret evolutionary histories of sedimentary basins and their hydrocarbon potential
- developing methodologies for collecting, synthesizing, analysing and managing geoscience data in support of coal resource evaluation and effective resource management

Paleontology unit: To conduct scientific studies in paleontology and biostratigraphy in support of exploration for, and assessment of, the non-renewable resources of western and northern Canada. These studies ensure precise and consistent biostratigraphic correlation in support of basin modeling.

Research is directed toward

- the application and refinement of biostratigraphic zonation for use in basin analysis and tectonostratigraphy
- examining and calibrating various characteristics of fossils that indicate the relative age of strata, defoemation intrusion, etc., and reflect paleotemperatures
- comparing fossil communities with modern analogues to interpret paleoenvironments and to develop paleoecological models
- developing models of paleobiogeography for sedimentary basins, ancient oceans and the globe

Electronic Data Processing unit: To provide the computer-based infrastructure (hardware and software) and expertise required for the Division's work in petroleum and coal resource assessments, geochemistry and laboratory analyses, regional mapping and interpretation, paleontology, petroleum geology, curation, library, publications production (cartography and document composition) and administration.

Geological Information unit: To communicate the results of the scientific program to government, industry and other users through the production of scientific publications (editing, cartography, photography, etc.) and the provision of information distribution services (library and bookstore).

Sample Collections unit: To develop and maintain collections of geological materials primarily for scientific research. Collections are gathered through field collection, drill core and cuttings sampling, and donation. They comprise fossil, rock and mineral specimens, thin and polished sections of rock and fossil materials, photographs and other associated documentation.

Administration unit: To provide financial, procurement, central registry, stationery/ supplies, general office services, and building facilities operation and maintenance services.

Funding

The main sources of funding for ISPG's work have been:

- A-base
- Frontier Geoscience Program (FGP, 1983-1993)
- Office of Energy Research and Development (OERD)
- Mineral Development Agreements (MDA) between the Federal government and the provinces
- Industrial Partners Program (IPP)
- Private sector funding through Specified Purposes Accounts (SPAs)

Results

Significant advances have been made in areas such as:

- Lithostratigraphy
- Biostratigraphy - paleogeography
- Seismic-stratigraphy and sedimentological
- Facies relationships and depositional sequences
- Geological mapping – new concepts
- Structural geology and tectonic analyses
- Radiometric dating
- Petrophysical analyses (stress)
- Petrographic analyses
- Organic maturation and burial history

- Heat flows
- Fluid flows – porosities and permeabilities
- Basin origin and evolution
- Understanding of orogens
- Basin modeling techniques
- Geochemistry – properties
- Trace element distributions and mobilities
- Biomarker geochemistry
- Source rock evaluations
- Oil-source correlations and petroleum systems
- Petroleum migration
- Diagenesis
- Fluid-rock interaction models
- Resource assessment methodology

Impact

The major impact of ISPG's research, publications and resident expertise to date lies within two important areas:

- The provision of regional or site specific geological, geophysical and geochemical data that can be used by petroleum, coal and mineral exploration companies and consultants to enhance, modify, increase or even abandon (in certain areas) their exploration programs, in addition to increasing their level of understanding of a particular area, feature or process;

- The provision of geological, geophysical and geochemical data essential for government decisions regarding the regulation of exploration industry activity, the understanding and abatement of natural hazards, and the protection of the environment.

In 1995 the Institute's name was changed to Geological Survey of Canada – Calgary (GSC-Calgary).

Dowling’s party near Jasper, Alberta (1907)

Operation Franklin, Arctic Canada (1955)

GSC field camp, Victoria Island, NWT (2010)

Section 2 – Timeline of Significant Events

1719: Henry Kelsey was the first man to record the presence of oil in western Canada. In 1719, a Cree Indian gave him a lump of oil saturated sand from the cliffs along the Athabasca River.

1778: Peter Pond was the first European to reach the river and examine the oil sands.

1788: The second trader-explorer to describe the bituminous deposits along the Athabasca River was Alexander Mackenzie. He noted

> *"Some bituminous fountains into which a pole of twenty feet long may be inserted without the least resistance. The bitumen is in a fluid state, and when mixed with gum or a resinous substance collected from the spruce fir, serves to gum the canoes"*[16]

1823: Dr. John Richardson (surgeon and naturalist who also accompanied John Franklin on Arctic expeditions) recorded the presence of black pitch or bitumen at La vieux fort de la Riviere Rouge, in limestone fissures at La Butte on the Slave River, and elsewhere on the Mackenzie River.

1857-1858: Hind expeditions

1857-1860: Palliser Expedition (with Dr. James Hector)

(During the decade immediately preceding Confederation the Canadian oil industry was born. The high cost of whale oil as a luminant, about $2.50 per gallon, prompted the search for a cheaper substitute.)

1867: Confederation of Canada

1870: Canada acquired Rupert's Land from the Hudson's Bay Company

1871: A. Selwyn mounted an expedition to investigate the geology and mineral resources along the proposed railway routes in western Canada.

1873: A. Selwyn made "a preliminary examination of that portion of the North West Territories of the Dominion extending westward from Fort Garry to Rocky Mountain House on the upper North Saskatchewan River.

[16] Mackenzie, Alexander: Voyage from Montreal on the River St. Lawrence through the Continent of North America to the Frozen and Pacific Oceans in the years 1789 and 1793. Published 1801.

1873-1875: G.M Dawson was the geologist for the International Boundary Commission (British American Boundary Survey); produced the first comprehensive report pertaining to the geology and economic potential of coal deposits near the 49th parallel. In referring to the Devonian beds exposed west of the Precambrian shield in Saskatchewan and Manitoba, he wrote "…would if properly explored, be found to yield mineral oil as well as salt."[17]

1875: In September 1875 the North-West Mounted Police erected a stockade log fort (Fort Calgary) at the junction of the Bow and Elbow rivers. The Canadian Pacific Railway arrived in 1883 bringing a steady stream of settlers.

1880: The Geological Survey contracted for a number of drill holes on the southern prairies to investigate the extent of the lignite deposits exposed on the Souris River.

1882-1884: Robert Bell investigated the region of the Athabasca oil sands and was the first to attach a real commercial value to the occurrence. He had it sampled and analyzed, and recommended early development.[18]

1883: J.B. Tyrrell discovered coal and dinosaur remains near Drumheller

1888: Report of the Select Committee of the Senate appointed to enquire into the resources of the Great Mackenzie Basin noted:

> *"The evidence submitted to your Committee points to the existence in the Athabasca and Mackenzie Valleys of the most extensive petroleum field in America, if not in the world. The uses of petroleum and consequently the demand for it by all nations are increasing at such a vast ratio, that it is probable that this great petroleum field will assume enormous value in the near future and will rank among the chief assets comprised in the Crown domain of the Dominion. For this reason your Committee would suggest that a tract of about 40,000 square miles be, for the present, reserved from sale and that as soon as possible its value be more accurately ascertained by exploration and practical tests…"*

1890: R.G. McConnell carried out a geological reconnaissance survey of the Athabasca and Peace River areas and was noted the immense deposits of oil

[17] Dawson, G.M., 1875: Report on the Geology and Resources of the Region in the Vicinity of the Forty-Ninth Parallel from the Lake of the Woods to the Rocky Mountains, British North American Boundary Commission, Montreal.

[18] Bell, Robert, 1881, 1883, 1884: Report on Part of the Basin of the Athabasca River – NWT, GSC Annual Reports for 1881, 1883, 1884.

sand exposed downstream from Fort McMurray for some 50 miles or more.[19] He stated

> *"The commercial value of the tarsands themselves, as exposed at the surface, is at present uncertain, but the abundance of the material and the high percentage of bitumen that it contains, make it probable that it may, in the future, be profitably utilized for various purposes, when this region is reached by railways."*

1891: A.R.C Selwyn, the second Director of the Geological Survey of Canada, was the first geologist to examine oil seepages in the Cameron Creek area near Waterton Lake in the extreme southwest of the "yet unorganized North-West Territory" near its boundary with British Columbia. He reported

> *"Cameron Falls brook is a rapid mountain stream, eight or ten yards wide. After following it up about a mile and a-half on the left bank, Mr. Fernie, my guide, remarked that we must be close to where the oil has been found. He had scarcely spoken when, while still in the saddle and on the trail eight or nine feet above the brook, I noticed a powerful odour of petroleum. Descending to the edge of the water and stirring the stones and gravel in the bed of the stream, considerable quantities of oil at once rose to the surface and floated away. Crossing to the right bank it was again seen coming out of the bank, some inches above the level of the stream. Here, skimming it off the surface of a shallow pool, a wine bottle full was soon collected. This can now be seen in the Geological Survey Museum."*[20]

The discovery of these oil seeps started a stampede of speculators to the area, staking claims from the Rock Mountains out to the eastern prairies. This eventually lead to the drilling of western Canada's first commercial oil discovery in 1902.[21]

1893: R.G. McConnell led a GSC drilling program at Athabasca aimed at discovering liquid oil associated with the Athabasca oil sands.

1902: Lineham No. 1 well at Cameron Creek, near Waterton Lake, in southwest Alberta, made western Canada's first commercial oil discovery.

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[19] McConnell, R.G., 1893: Report on a Portion of the District of Athabasca, Geological Survey of Canada Annual Report, Vol. V, Pt. D.

[20] Selwyn, Alfred R.C., 1892: Summary Reports of the Operations of the Geological Survey for the Year 1891, Part A, p. 11.

[21] Smith, Thomas, 2010: Western Canada's First Oil Discovery: in GEOExPro, Issue 4, Volume 7, 2010.

1903: McConnell and R. Brock were directed to investigate the cause of the destructive landslide from Turtle Mountain onto the town of Frank in southwest Alberta.

1903: D.B. Dowling was directed to thoroughly investigate coal-bearing formations in the Rocky Mountains of Alberta. He discovered and outlined major coalfields between the Bow and Yellowhead passes and became the nation's leading authority on its coal resources.

1909: Dowling issued a comprehensive study, "The Coal Fields of Manitoba, Saskatchewan, Alberta and Eastern British Columbia", which included the first estimates of coal reserves and grades.

Brock reported on the probability of both oil and gas being found in quantity in the Cretaceous rocks of southwestern Alberta.

1913: Small pocket of oil was found in the Cretaceous Belly River formation.

1913: A branch office of the Department of Mines was opened in Alberta, where S.E. Slipper had remained over the winter of 1913-14 to keep in touch with the current oil boom southwest of Calgary, advise drillers, and collect stratigraphic data and drill samples. The office was in Calgary but moved to Edmonton when drilling proceeded into northern Alberta. After Slipper resigned in 1917 the office was unmanned until the spring of 1919 when J.S. Stewart was put in charge.[22]

1913: The authoritative knowledge of D.B. Dowling on the geology of the southern Western Canada Sedimentary Basin was demonstrated at the International Geological Congress in 1913 in Toronto, which featured coal resources.

1914: The Dingman well at Turner Valley discovered a good supply of oil and gas in what Dowling believed was the Cretaceous Dakota sandstone. Discoveries intensified the work of the GSC; S.E. Slipper and J.S. Stewart worked out the stratigraphy of the foothills south and west of Calgary.

1917: Dowling reported on "the possibility of there being potash salts in the rocks underlying the plains".[23]

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[22] Zaslow Morris, 1975: Reading the Rocks: The story of the Geological Survey of Canada 1842-1972, The Macmillan Company of Canada Limited, Toronto, 599 p., p.314

[23] Dowling, D.B., 1918: Geological Survey of Canada Summary Report, 1917, Part C, p. 4c

1919: Dowling reported on "the popular impression that oil in the Lower Cretaceous is underlain by great reservoirs of oil in the Devonian…"[24] He also noted:

> *"In the early history of the plains little value was attached to the presence of gas unless it was so situated that it could be piped to centres of large population to be used as fuel to replace coal; but the importance of these gas reserves and, therefore, of the areas in which they may be found is now constantly increasing…"*[25]

1920: The Normal Wells oil field was discovered when the Northwest Company (Imperial Oil Company) No.1 well was drilled on the east side of the Mackenzie River and produced about 100 barrels per day. Oil seepages from the Devonian rocks of this area had been known for a century.[26]

1928: G.S. Hume reported on "Oil and Gas in Western Canada"[27]. In 1925 annual oil production from Alberta surpassed that of Ontario, increasing from 1000 barrels in 1924 to 169,000 barrels in 1925

G.S. Hume worked on correlating the Mesozoic and Paleozoic stratigraphic successions of the Plains with those of the Rocky Mountain foothills through the 1930s and 1940s.

1947: A large discovery of oil was made at Leduc, south of Edmonton, which started a major oil industry in western Canada. Although rocks from the Devonian Period had not proven to be oil-bearers, this major discovery in the Devonian rocks ushered in the modern age of the petroleum industry in Canada.

1950: The GSC opened a small office in Calgary to meet the needs of the growing petroleum industry for geological information.

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[24] Dowling, D.B, 1919: Geological Survey of Canada Summary Report, 1919, Part C, p. 22c.

[25] Dowling, D.B., Slipper, S.E., and McLearn, F.H., 1919: Investigations in the Gas and Oil fields of Alberta, Saskatchewan, and Manitoba, Geological Survey of Canada Memoir 116, p. 1.

[26] Camsell, Charles, and Malcolm, Wyatt, 1921: The Mackenzie River Basin, Geological Survey of Canada, Memoir 108, Canada Department of Mines, p.112-113.

[27] Hume, G.S., 1928: Oil and Gas in Western Canada, Geological Survey of Canada, Economic Geology Series No. 5, 152p.

1955: Operation Franklin ” …in 1955 marked the arrival of the machine age in the Geological Survey field work in the Arctic Islands”. “… two relatively large helicopters, the Sikorsky S-55s, were used in the islands to transport geological teams to widely scattered localities”.[28]

1957: Operation Mackenzie: “*In 1957, the Geological Survey of Canada embarked on a helicopter-assisted geological reconnaissance of 100,000 square miles of southwestern District of Mackenzie in order to provide basic geological information for general distribution and to assess the oil and gas possibilities”.*[29]

1961: Operation Porcupine was initiated as one of a series of operations for reconnaissance mapping of vast regions of Canada. The area encompassed was that part of Yukon Territory and Northwest Territories north of latitude 65^{O}N and west of longitude 132^{O}W (80,000 sq. mi.)

1967: The GSC’s Institute of Sedimentary and Petroleum Geology was established in Calgary as a natural outgrowth of the regional office of the GSC that was set up in Calgary in 1950.

Institute of Sedimentary and Petroleum Geology (2000)

[28] Christie, R.L., and Kerr, J.WM., 1980: Geological Exploration of the Canadian Arctic Islands, paper presented for a Symposium “A Century of Canada’s Arctic Islands 1880-1980”, held by the Royal Society of Canada, p.187-202.

[29] Douglas, R.J.W., Helicopter Operations of the Geological Survey of Canada– Light Helicopter Reconnaissance in Interior Plains and Mountains, Bulletin 54, Chapter IV

The Institute of Sedimentary and Petroleum (ISPG)

1967: H.R. Belyea (Senior Research Scientist, ISPG) and D.J. McLaren (Director, ISPG) jointly chaired the "International Symposium on the Devonian Systems", the Canadian Centennial Project of the Alberta Society of Petroleum Geologists.

1971: The Department of Energy, Mines and Resources began an inventory of Canada's undiscovered conventional oil and gas resources. The first estimates (by the Petroleum Subdivision of ISPG) were published in 1973 in "An Energy Policy for Canada".

1971: The Oil and Gas Pools Map of Western Canada, depicting oil and gas pools by geological position as well as geographical location, was completed and published.

1971: A study leading to preliminary estimates of the measured coal reserves of western Canada was completed.

1972: A joint Federal-Provincial program to evaluate the coal resources of Saskatchewan was started with the guidance and support of ISPG.

1973: "**An Energy Policy for Canada**" was published by the Federal Department of Energy, Mines and Resources[30]. Grave concerns were expressed regarding the availability and costs of future energy supplies in the face of increased demands. In addressing Canada's energy resources it was recognized that "the greatest gap in our knowledge of the resource base relates to the petroleum potential of the frontier areas".

"**1973 Oil Crisis**" started in October 1973, when members of the Organization of Arab Petroleum Exporting Countries (OAPEC consisting of Arab members of OPEC, plus Egypt, Syria and Tunisia) proclaimed an oil embargo. This was in response to the U.S. decision to re-supply the Israeli military during the Yom Kippur War.

The first detailed assessment of Canada's petroleum resources on a probabilistic basis was completed. The assessment team, coordinated by ISPG's Petroleum Subdivision, comprised members from Indian Affairs and Northern Development, Resource Management and Conservation Branch, Atlantic Geoscience Centre, and ISPG.

1977: Publication of the national oil and gas resource estimates (EMR publication "Oil and Natural Gas Resources of Canada, 1976"; Report EG77-1), which for

[30] Energy, Mines and Resources Canada, 1973: An Energy Policy for Canada – Phase 1, Volume 1, Analysis, 286 p.

the first time, explained the details of ISPG's methods and provided the first comprehensive published set of probability distributions by area for the country.

1977: Justice Thomas Berger gave his report to the federal government respecting the social, economic and environmental implications of a gas pipeline up the Mackenzie Valley. He recommended that the pipeline be postponed until the settlement of land claims.

1978: "Coal resources of southern Saskatchewan: a model for evaluation methodology" was published – resulting from the joint program of the Geological Survey of Canada, Saskatchewan Department of Mineral Resources, and Saskatchewan Research Council, which began in 1972.

1978-1982: A period of high turnover of scientific and support staff, and difficulty in recruiting staff as a result of intense competition for highly qualified personnel from the petroleum and coal industries in Calgary and vicinity.

1980: ISPG's Petroleum Resource Appraisal Secretariat was formed for the preparation of estimates of Canada's oil and gas resources, including the provision and testing of methodology. The results of their work was communicated to a Petroleum Resource Appraisal Panel (convened every 4-6 weeks), chaired by the Senior Assistant Deputy Minister (ADM) Energy, and consisting of ADMs in Energy, Science and Technology, plus representatives from Indian and Northern Affairs and the National Energy Board.

1982: GCS's first publication on west coast offshore petroleum potential.

1983: Presented a major new assessment (November 1983), "Petroleum Resources of the Mackenzie Delta – Beaufort Sea" to the Department's Petroleum Resource Appraisal Panel.

1983: Presented a major new assessment (December 1983), "Petroleum Resources of the Scotian Shelf" to the Department's Petroleum Resource Appraisal Panel.

1984: Publication of "Oil and Natural Gas Resources of Canada – 1983", superceding the 1976 estimates published in 1977. This was the first of a series of "***blue books***" to be published over the following 35 years.

Completed documentation and installation of PRIMES, a linked multiprogram computer software system for petroleum resource assessment usage.

1984: Introduction of the Frontier Geoscience Program with the general objective to ascertain the geological history and development of all frontier sedimentary basins in Canada[31]. Specifically:

- To understand the deeper geological controls on the development of the sedimentary basins in the frontier regions
- To outline the internal geology and evolution of the basins
- To elucidate the processes governing the generation, accumulation and preservation of hydrocarbons
- To identify and analyse natural hazards and constraints to development
- To provide essential supporting research, development , analyses and syntheses
- To supply data and support to the data base containing information necessary to appraise the nature and distribution of potential hydrocarbons within a basin

1984: Canada/USSR Arctic Science Exchange Agreement (Arctic agreement on geology and resources) was negotiated for a period of three years. An important theme was the comparison of the geological evolution of the Arctic regions of both countries.

1985: Plans for a multidisciplinary Peace River Arch Project were finalised. A major crustal seismic refraction survey, one of the most ambitious programs of its kind ever undertaken in Canada, was completed in the Peace River Arch area of northwestern Alberta and northeastern British Columbia. Information on the relationship between the Peace River Arch, and basement and crustal structures, and crustal and mantle densities help constrain geodynamic models of the mechanical and thermal evolution of the Arch and similar structures in the Western Canada and other sedimentary basins.

1985: GSC became a member of the International Ocean Drilling Program.

1986: "Geological Survey of Canada Forum on Activities in Oil and Gas" (February 11-12, 1986, Calgary Convention Centre).

1986: Presentation to the House of Commons Standing Committee on Energy, Mines and Resources in which the GSC approach to petroleum resource

[31] 1987: Frontier Geoscience Program, Annual Report 1986-87, Geological Survey of Canada, Energy, Mines and Resources Canada, 121 p.

evaluation was described along with the petroleum resource potential of various regions of Canada.

1986: GSC/ISPG-hosted Western Canada Coal Geoscience Forum (November 17-19, Highlander Hotel, Calgary). This provided an opportunity for the exchange of recently acquired geoscientific information relevant to the exploration, development and utilization of western Canadian coals, and to promote the transfer of GSC-developed coal geoscience technologies to attendees from federal and provincial government agencies, coal companies, consulting firms and universities.

1987: Presentation to the Senate Standing Committee on Energy and Natural Resources regarding its examination of the production and use of coal in Canada. A presentation was given on the distribution and character of coals in Canada and GSC's approach to assessing the nation's inventory of coal resources.

1987: Decade of North American Geology:

> The volume "Sedimentary Cover of the Craton in Canada" was completed with the exception of the chapter on Petroleum Geology. This volume is part of the Geological Survey of Canada series on the Geology of Canada and is also part of the series by the Geological Society of America on "The Geology of North America". The volume deals with three tectonic-stratigraphic provinces and their basins: Interior Platform, Hudson Platform, and St. Lawrence Platform.
>
> The volume "Inuitian Orogen and Arctic Platform of Canada and Greenland" was submitted to the series editor.

1987: Start of a new project on the nature and origin of the Peace River Arch, in collaboration with personnel of the Alberta Geological Survey.

1987: A new gas-chromatograph-mass spectrometer allowed ground breaking work on oil-oil and oil-source correlations in the Williston Basin.

1987: Canada/USSR Arctic Science Exchange Agreement was extended for another two years.

1987: Petroleum resource estimates were prepared for three disputed boundary areas: Canada-Alaska, and Canada-U.S. boundaries in Dixon Entrance and Juan de Fuca Strait.

1988: "A standardized coal resource/reserve reporting system for Canada" was completed in collaboration with The Coal Association of Canada. These standards help to maximize the consistency of resource and reserve quantity estimates for coal deposits in Canada, to provide a reliable, objective framework for public and commercial planning.

1988: Cabinet decided that FGP funding should become a permanent part of the Survey's research responsibilities.

1988: GSC report "Conventional Oil Resources of Western Canada (Light and Medium)", was released in April 1988 (GSC Paper 87-26).

1988: GSC report on "Petroleum Resources of the Mackenzie Delta-Beaufort Sea" was released in the fall of 1988.

1989: "Forum '89 – Geological Survey of Canada – Oil and Gas Activities in Canada" (February 27-28, 1989, Calgary Convention Centre)

1989: "Coal Resources of Canada" (GSC Paper 89-4) was published providing a comprehensive summary of information pertaining to the distribution, geological setting, estimated quantities and characteristics of coals in Canada. Acclaimed by the coal industry as "the finest, most complete assessment of this resource ever available in Canada".

1989: The National Advisory Board on Science and Technology's (*Prime Minister Mulroney*, Chairman) began a review of federal intramural science and technology activities. It commissioned a Committee on Federal Science and Technology Expenditures (*Senator Pierre Lortie*, Chairman) to lead the review and report on its findings and recommendations. The committee requested the Natural Sciences and Engineering Research Council of Canada (NSERC) to administer a peer review of ISPG. They reported on the importance and high quality of work carried out at ISPG in the context of well-managed programs.

1989: "Western Canada Sedimentary Basin – A Case History", a textbook edited by B.D. Rickets (GSC/ISPG) was published by the Canadian Society of Petroleum Geologists. Comprising contributions mainly from GSC geoscientists, this publication addresses methods of basin analysis, emphasizing the processes of basin formation and sediment infill.

1989: "Coal deposits of the Rocky Mountain Front Ranges and Foothills of the southern Canadian Cordillera" was presented to the 28th International Geological Congress, Washington, D.C., July 9-19, 1989.

1989: GSC started to focus more attention on environmentally related research, especially studies linked to one of the most ambitious international initiatives ever undertaken – Global Change.

1989: Canada/USSR Arctic Science Exchange Agreement was extended for another two years. Collaboration under this program resulted in the production of an important circumpolar geological map of the Arctic.

1989: ISPG contributed to the construction of maps showing the distribution and magnitude of stress in Canadian sedimentary basins (Canadian stress map for the Decade of North American Geology, and World Stress Map for the International Union of Geodesy and Geophysics). The topic was of considerable growing interest for the Western Canada Basin particularly as related to the design and implementation of suitable enhanced petroleum recovery techniques.

1989: Analysis of the Beaufort-Mackenzie Basin was completed and the data were ready for assessing oil and gas resources.

1990: New initiatives in the field of continental drilling were developed including proposals for scientific drilling of 1) Cretaceous-Tertiary boundary in Manitoba, Saskatchewan and Alberta, and 2) Neogene sediments in the Old Crow Basin. Results contribute significantly to paleoclimatic and paleogeographic modeling of the regions.

1990: A 1:6 million scale Circum-Arctic geological map was published as part of the Canada/USSR Scientific and Technological Arctic Exchange Agreement.

1990: Organic geochemists at ISPG prepared several site reports of the Ocean Drilling Programme that documented the shipboard analytical results of the quantity, type and level of thermal maturity of organic matter in samples taken at the Wombat Plateau and Exmouth Plateau (northwest shelf of Australia).

1990: A new interpretation of the early Paleozoic tectonic framework of the western Northwest Territories and the Yukon Territory prompted a re-evaluation of factors that led to the occurrence of several large shale-hosted Pb-Zn mineral deposits – the Vulcan, Jason and Howard's Pass prospects.

1990: A new era began of "cooperation, collaboration, joint ventures and cost sharing" as a starting point for new research projects.

1990: A national geoscience mapping program (NATMAP) began. This new initiative was a cooperative, multidisciplinary program to improve the quality, relevance and completeness of bedrock and surficial geological maps and database coverage.

1990: Most of the results of the collaborative (GSC-Alberta Geological Survey) Peace River Arch Project were published as a special issue of the Bulletin of Canadian Petroleum Geology, in December 1990.

1990: A new technique for assessing thermal maturity using foraminifera was developed.

1990: Phase one of the GSC-Petroleum Industry Aeromagnetic Survey was completed for central Alberta. Industry funding was provided by Amoco Canada, Canadian Hunter, Esso, Mobil, PanCanadian, Petro-Canada, Amerada, and Cameco. ISPG provided funding from the Western Canada Initiative funds.

1991: Publication on "Tertiary Fossil Forests in the Geodetic Hills, Axel Heiberg Island, Arctic Archipelago" reported on a multidisciplinary study to better understand the Canadian Arctic's surprising tropical past as recorded in its fossil forests. The existence of tropical forests so close to the North Pole 45 million years ago clearly indicates the great degree to which global climate change has varied naturally over time.

1991: The Industrial Partners Program (IPP) was initiated, which enabled the application of our skills to a company's specific problems.

1991: A volume of the "Geology of Canada" series was released: "Geology of the Innuition Orogen and Arctic Platform of Canada and Greenland".

1991: A study of the Devono-Carboniferous Bakken Formation in the Williston Basin was completed, with important implications to assessing the petroleum resource potential.

1991: A major synthesis of the Cretaceous-Tertiary boundary event in western Canada was completed, describing the relationship of highly detailed palynology to the extinction event.

1991: A fact finding tour was conducted of coalbed methane (CBM) exploitation in the San Juan Basin, Colorado and New Mexico. Subsequently, a presentation to the Department's Executive Committee noted that methane contained in coalbed reservoirs is a potentially large source of natural gas in Canada. Also, although the Department of Energy, Mines and Resources had very limited capability to evaluate the nation's CBM possibilities, GSC had begun a modest effort to identify the most attractive targets for CBM exploration that could be used to conduct production tests.

1991: The applicability of GC-MS-MS was demonstrated for the detailed characterization of heavy oil stratification within a reservoir. This will be used to monitor production during a steam flood operation. The work was carried out in support of a consortium involving Petro-Canada, Esso and AOSTRA.

1991: Trace element studies of coals showed the effects of depositional environment, coal rank, provenance and sedimentation rates on the distribution of these elements. The presence of these elements has environmental implications during the production and use of the coals.

1992: GSC's 150th and ISPG's 25th anniversaries. A few of the Calgary-based commemorations included: CSPG commemorative calendar, Canadian Coal and Coalbed Methane Forum, GSC Oil and Gas Forum '92, Glenbow Museum exhibit, University of Calgary floral display, unveiling Tyrrell bust at the Royal Tyrrell Museum of Paleontology, Earthly Riddles Exhibit at the Calgary Science Centre, Banff Park Museum Commemorative plaque, ISPG Legacy Cairn, CSPG Special Bulletin, AAPG Commemorative Plaque.

1992: "Geological Survey of Canada - Oil and Gas Forum '92 "(March 2-3, 1992, Calgary Convention Centre)

1992: Three holes were drilled in southern Saskatchewan and Manitoba under the Canadian Continental Drilling Program to examine the Cretaceous-Tertiary boundary and the Eagle Butte impact ejecta layer.

1993: The multidisciplinary Eastern Cordillera NATMAP project (originally referred to as "southern Alberta NATMAP project) was initiated to remap a portion of the southeastern edge (Outer Foothills of the Rocky Mountains) of the Canadian Cordillera, an important geological province with significant reserves and resource potential for natural gas, oil, sulphur, thermal coal, and coalbed methane.

1993: A multidisciplinary project was initiated under GSC's Industrial Partners Program on "The Lower Paleozoic: A New Frontier in the Western Canada Basin". Fourteen companies contributed to the study of the Lower Palleozoic strata in the subsurface of the basin.

1993: LITHOPROBE – Alberta Basement Transect project of deep seismic reflection surveys across Alberta was completed with five industry participants (Gulf Canada, Norcen, PanCanadian, Renaissance Energy and Saskoil). Results were presented in March 1993 at the third annual Alberta Basement Transect workshop.

1993: A very successful "Pangea Conference" was held as the Annual Convention of the Canadian Society of Petroleum Geologists (August 15-19, Calgary Convention Centre). The success of this major conference was due mainly to the efforts of several of the GSC staff in Calgary.

1993: A volume of the "Geology of Canada" series was released: "Sedimentary Cover of the Craton in Canada"

1993: A publication (Blue Book) on "Devonian Gas Resources of the Western Canada Sedimentary Basin" was released. The Devonian succession of the

Western Canada Sedimentary Basin accounts for a large portion of its proven natural gas reserves.

1994: Geological Atlas of the Western Canada Sedimentary Basins, edited by G.D. Mossop (GSC) and I. Shetson (AGS), was published by the Canadian Society of Petroleum Geologists and Alberta Geological Survey. This geological atlas of the energy-rich Western Canada Sedimentary Basin was the result of a major collaborative venture that involved many GSC scientists among the 150 scientists from industry, government and universities.

1994: GSC and 25 industry partners conducted The Peace River Arch Industry Seismic Experiment (PRAISE) one of the most successful LITHOPROBE surveys ever, extending 627 km from Dawson Creek, British Columbia, to Entwistle, Alberta. The objective was to better understand the role of the crystalline basement in the tectonic evolution of the Peace River Arch, an area of very active hydrocarbon exploration.

1994: Mannville IPP with Wascana (Leckie). Completed the first phase of this multi-phase regional stratigraphic study of the Mannville Group of the Western Canada Sedimentary Basin with the main objective to provide a consistent regional stratigraphic framework for this oil- and gas-bearing interval.

1994: CBM IPP in western Canada (Dawson). A project involving GSC and eight industrial partners investigated the relationship between the characteristics of coals and the related coalbed reservoir permeability.

1994: Coal Trace Elements IPP (Goodarzi). In partnership with TransAlta, Edmonton Power and Nova Scotia Power, GSC studied the types and levels of elements in emissions from the operators' coal-fired power plants.

1994-1995: Federal Government conducted a Program Review as part of its commitment to long-term fiscal restraint, resulting in a 32% reduction in overall resources for the Geological Survey of Canada.

1994: A publication (Blue Book) on "Triassic Gas Resources of the Western Canada Sedimentary Basin, Interior Plains" was released.

1995: "Geological Survey of Canada – Oil and Gas Forum '95 "(March 28-29, 1995, Calgary Convention Centre)

1995: The Lower Paleozoic project conducted under the Industrial Partners Program since 1993 was completed. Working with 13 industrial partners over two years (1993/94 and 1994/95), GSC collected, analysed and published data that clarified the relatively enigmatic relationship between the well-established Lower Paleozoic strata of the Rocky Mountains and the more poorly known strata of the subsurface of Alberta.

1995: A project involving 14 companies was initiated under the Industrial Partners Program on "Devonian Petroleum Systems of the Western Canada Sedimentary basin (WCSB)". The study was designed to re-evaluate petroleum potential, organic facies and maturity of Devonian source intervals, oil-oil and oil-source correlations, and hydrocarbon migration pathways within the Western Canada Sedimentary Basin.

1995: A project involving eight companies was initiated under the Industrial Partners Program on "Coalbed Methane in Western Canada". CBM resources in western Canada represented a vast untapped source of energy that only started to attract significant attention from the oil and gas sector in 1995.

1995: GSC in partnership with several operators of coal-fired power plants in Canada began studying the types and levels of elements in emissions from the plants, contributing to better understanding of the impact on the environment of the development and use of Canada's coal resources.

1995: "LITHOPROBE: Alberta Basement Transect" seismic reflection data collection was completed. The study helped develop a picture of the structure and tectonics of the older basement rocks that dip under the hydrocarbon-rich Western Canada Sedimentary Basin and disappear beneath the Rocky Mountains. This led to a better understanding of the relationship between basement structures and the hydrocarbon potential of the overlying sediments.

1995: GSC developed a new technique that determines temperatures to which sedimentary rocks have been subjected in the past by measuring the colour of organic material contained in microfossils.

1995: A publication on "Diamond Exploration Techniques Emphasizing Indicator Mineral Geochemistry and Canadian Examples" was released. This work, sponsored by ISPG, on indicator mineral geochemistry was central to the exploration program that led to the discovery of the first kimberlite in the Northwest Territories and subsequently the development of Canada's first diamond mine.

1995: A publication on "Coalbed methane: A comparison between Canada and the United States" was released providing an overview of geological factors in the San Juan and Black Warrior basins in the U.S. that allow economic coalbed methane production, and comparisons with major Canadian coal basins and their CBM potential.

1996: A "Geological Atlas of the Beaufort-Mackenzie Area" was published providing basic geological and geophysical data needed to understand the overall geological framework of the basin. It deals with an area of proven significant oil and gas reserves, and with the potential for a considerably greater number of discoveries to be found.

1997: A publication on “Geology and Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie” was released. This study drew together geological data and interpretations gather by GSC back to the Operation Porcupine work of the 1960s.

1997: Results from the Peace River Arch Industry Seismic Experiment (PRAISE) were released. These provided new insights into the fault history associated with hydrocarbon emplacement and tectonic evolution of the crust that hosts diamond-bearing kimberlites.

1997: A publication (Blue Book) on “Carboniferous and Permian Gas Resources of the Western Canada Sedimentary Basin, Interior Plains” was released.

1997: A publication (Blue Book) on “Mannville Gas Resources of the Western Canada Sedimentary Basin” was released.

1997: A publication (Blue Book) on “Upper Cretaceous, post-Colorado Group Gas Resources of the Western Canada Sedimentary Basin, Interior Plains” was released.

1998: Central Foreland NATMAP project was initiated, aimed at mapping an economically important area in the foothills of northeastern British Columbia. It involved a large contingent of up to 45 geologists from the GSC, industry, universities and the B.C. Geological Survey.

1998: A three year project was initiated for reconnaissance scale mapping (1:250,000) in the rugged northeastern regions of Ellesmere Island, facing Nares Strait. This was a collaborative and jointly-funded initiative of the GSC and the German geological survey (BGR).

1998: NRCan and the Japan National Oil Corporation (JNOC) conducted a dedicated gas hydrate research program at the Mallik Field, Mackenzie Delta, NWT.

1998: An integrated geophysical-geological transect study of the Williston Basin in southeastern Saskatchewan and southwestern Manitoba was completed. The region encompasses zones of significant petroleum activity and interest. The study resulted in a better understanding of known oil plays and revelation of possible new oil plays.

1999: A Western Canada Sedimentary Basin Committee was initiated by GSC (Calgary) and Alberta Geological Survey and included representation from all western provinces, NWT, Yukon and NEB. Pursuant to the Intergovernmental Geoscience Accord agreed to by Canada’s Mines Ministers in 1996, it helped to define projects and priorities for GSC’s Co-Operative Mapping Program.

1999: A Data Integration Initiative was initiated to develop and implement an Oracle/Public Petroleum Data Model (PPDM) geoscience data system for the sedimentary basins and orogens of western and northern Canada.

1999: The Devonian Petroleum Systems project conducted under the Industrial Partners Program since 1995 was completed. Working with 14 industrial partners over four years, GSC collected, analysed and published data that clarified the relatively enigmatic relationship between the well-established Lower Paleozoic strata of the Rocky Mountains and the more poorly known strata of the subsurface of Alberta.

1999: The final Mineral and Resource Assessment (MERA) reports for Bathurst Island were completed and submitted to Parks Canada for consideration in establishing their proposed national park.

1999: GSC's regional analyses of two major coal zones beneath the Alberta Plains identified potentially recoverable methane gas resources of more than 25 trillion cubic feet. GSC reports generated wide interest both in Canada and abroad.

1999: The GSC developed new ways to use molecular markers to differentiate oils derived from different levels of Paleozoic strata.

1999: First searchable database of GSC-Calgary's sample/analysis research collections (SAMS) was completed.

2000: A publication was released (Bulletin 487) on the petroleum source rocks of the Williston Basin to support industry in the deep rights reversion in Saskatchewan.

2000: A report (OF3780) on gas hydrate resources of Canada was released.

2000: The GSC completed three hydrocarbon assessments in northern Yukon: for the Kandik and Bonnet Plume basins and for the proposed Arctic Circle land management area along the Dempster Highway.

2000: The GSC studied the regional distribution of CO_2 storage capacity within two major coal zones underlying the Alberta Plains.

2000: LITHOPROBE: Alberta Basement Transect project was completed, providing an overview of the crustal evolution in the Alberta Basin and the effects of basement structure on the evolution of the basin. The reactivation of these old structures during younger sedimentation and petroleum migration, particularly in southwestern Alberta, is an area of controversy and ongoing research for the petroleum industry.

2000: A GSC Beaufort-Mackenzie research consortium was established with eight oil companies (Anderson, AEC, Petro-Canada, Shell Canada, Anadarko, Burlington Resources, Chevron and BP Canada Energy) to investigate the pressure, temperature and heat flow histories, detailed biostratigraphy, and source rock/oil geochemistry of the Mackenzie-Beaufort region. GSC resources were leveraged by significant cash contributions from industry.

2000: Research on petroleum fluid mixing in the Devono-Carboniferous Bakken/Madison petroleum systems of the Williston Basin in Saskatchewan pointed the way to new petroleum plays in the area, attracting significant interest from Canadian industry. This Bakken study also proved its utility world-wide as a model for petroleum expulsion, secondary migration and accumulation in unconventional reservoirs.

2000: GSC's Northern Basins Initiative was launched whereby the GSC and a number of territorial partners (NWT's C.S. Lord Centre, Yukon Economic Development, Canada-Nunavut Geoscience Office, Nunavut Tunngavik Incorporated) embarked on a one-year scoping study to examine gaps, needs, challenges and opportunities in northern basins and to lay down, through a concerted research plan, the foundation of a renewed geoscientific effort in the North.

2000: Mapping in the northeast B.C. phase of the Central Foreland NATMAP project was completed with the direct field collaboration of Gulf, Crestar, PetroCanada, Purcell and Talisman.

2000: Fieldwork was completed for the three-year collaborative mapping project with Germany's BGR on the geology of northeast Ellesmere Island.

2002: The Earth Sciences Sector (ESS) of the Department of Natural Resources Canada (NRCan) began an innovative strategy to integrate S&T into policy and decision-making at NRCan. At that time ESS ended all existing S&T activities and created a new program portfolio that was more clearly aligned with government objectives.

2002: NRCan and JNOC jointly led the Mallik 2002 Gas Hydrate Production Research Program.

2008: The Government of Canada launched the Geo-mapping for Energy and Minerals (GEM) program with an investment of $100 million over five years (2008-2013). The program was designed to provide the geoscience knowledge necessary for private sector exploration companies to guide investment decisions, as well as for government to make informed land-use decisions such as the creation of parks and other protected areas. The Mackenzie Delta Corridor project, Sverdrup Sedimentary Basin project, and Yukon Sedimentary Basins project were led by geoscientists at GSC-Calgary.

2010: The Calgary Geoscience Research Centre (CGRC) was established through a Collaborative Research and Development Agreement between the University of Calgary and Natural Resources Canada. The agreement formalizes a shared vision of the U of C's Department of Geoscience and the Geological Survey of Canada – Calgary, to enhance their combined world-class capability for geoscientific innovation and development of highly-qualified personnel.

Section 3 – Special Programs and Initiatives

❖ Early Mapping “Operations”

- Operation Franklin (1955)
- Operation Mackenzie (1957)
- Operation Eureka (1961-1962)
- Operation Prince of Wales (1962)
- Operation Porcupine (1962, 1970)
- Operation Bathurst (1963-1964)
- Operation Liard (1963-1965)
- Operation Grant Land (1965-1966)
- Operation Bow-Athabasca (1965-1966)
- Operation Norman (1967-1969)
- Operation Grinnell (1969)
- Operation Smoky (1969-1970)
- Operation Peel Sound (1970)

❖ Canada/USSR Arctic Science Exchange Agreement (1984-1991)

❖ Peace River Arch Project (1985-1990)

❖ Decade of North American Geology (DNAG) – Geology of Canada Series (1986-1993)

- Geology of the Innuition Orogen and Arctic Platform of Canada and Greenland
- Sedimentary Cover of the Craton in Canada

❖ Geological Atlas of the Western Canada Sedimentary Basin (1987-1994)

❖ Environmental Geoscience Initiatives (1989-ongoing)

- Research related to a Global Climate Change Program
- Research related to the mobility and distribution of trace elements in a landmass (environmental geochemistry)

- National Geoscience Mapping Program (NATMAP) (1991-2003)
    - Eastern Cordillera NATMAP Project (1993-1998)
    - Central Foreland NATMAP Project (1997-2003)

- Industrial Partners Program (1991-1999)
    - The Lower Paleozoic: A new frontier in the Western Canada Basin (1993-1996)
    - Trace Elements in Coal (1994-1999)
    - Coalbed Methane in Western Canada (1995-1999)
    - Devonian Petroleum Systems of the Western Canada Sedimentary Basin (1995-1999)

- Mineral Development Agreements (1992-1995)
    - Canada-Alberta Agreement on Mineral Development (1992-1995)

- LITHOPROBE (1984-2005)
    - Alberta Basement Transect Project (1993-1995)
    - The Peace River Arch Industry Seismic Experiment (PRAISE) (1994-1997)

- Northern Basins Initiative (2000-2005)

- Beaufort Mackenzie Research (2000-2013)

- Targeted Geoscience Initiative (2000-2015)
    - TGI-1 (2000-2003)
    - TGI-2 (2003-2005)
    - TGI-3 (2005-2010)
    - TGI-4 (2011-2015)

❖ Consolidating Canada's Geoscience Knowledge (CCGK) Program (2000-2006)

- Canadian Geoscience Knowledge Network (CGKN) (2001-2006)
- Cooperative Geological Mapping Strategies Across Canada (CGMS) (2003-2006)
    - Energy Synthesis Project (2003)

❖ Northern Resources Development Program (2004-2007)

❖ Geo-mapping for Energy and Minerals (2008-2013)

Operation Franklin camp
(1955)

Victoria Island field camp
(2010)

Early Mapping “Operations” in the Sedimentary Basins of Western and Northern Canada

In its attempt to complete the reconnaissance mapping of the geology of Canada the Geological Survey of Canada conducted large air-supported geological surveys in the 1950s and 1960s in the frontier areas of the Canadian Shield and of the sedimentary basins flanking it.

The Arctic Islands

- Operation Franklin (1955)
- Operation Eureka (1961-1962)
- Operation Prince of Wales (1962)
- Operation Bathurst (1963-1964)
- Operation Grant Land (1965-1966)
- Operation Grinnell (1969)
- Operation Peel Sound (1970)
- Operation Boothia (1975)

The Mackenzie Valley

- Operation Mackenzie (1957)
- Operation Norman (1967-1969)

The Northern Cordillera

- Operation Porcupine (1962, 1970)
- Operation Liard (1963-1965)

The Southern Cordillera

- Operation Bow-Athabasca (1965-1966)
- Operation Smoky (1969-1970)

The Arctic Islands

- *Operation Franklin (1955)*

By 1955 the development of aircraft had advanced to a stage suitable for sustained operation in the arctic. The helicopter became a reliable means of transportation for field geologists and made possible effective study of the Arctic Archipelago. The first large-scale geological reconnaissance in the Canadian Arctic Islands, referred to as Operation Franklin, was carried out in 1955. It extended over 518,000 square kilometres and relied on the use of heavy helicopters. In the attempt to map the main geological features of the Queen Elizabeth Islands, the area studied under Operation Franklin extended roughly from Axel Heiberg and Ellesmere islands on the north to Somerset Island on the south, and from Melville and Ellef Ringnes islands on the west to Devon Island on the east. Results led to more detailed investigations of specific areas to discover mineral and energy resources of economic value. [32]

- *Operation Eureka (1961-1962)*

A two-year program of reconnaissance mapping of Axel Heiberg and Ellesmere islands, in part suitable for publication at a scale of 1 inch to 8 miles, and in part 1 inch to 4 miles.

- *Operation Prince of Wales (1962)*

A helicopter-supported operation to complete reconnaissance geological mapping of Boothia Peninsula, and King William, Somerset, and Prince of Wales islands.

(Map-sheets 57 NE, NW, SW; 67 NE, SE, SW; 58 SE, SW; 68 SE, SW)

- *Operation Bathurst Island (1963-1964)*

Sedimentary Geology - A two-year study of the stratigraphy and structural geology of Bathurst Island.

(Map-sheets 68 G, H; 69 A, B)

The Bathurst Inlet region is underlain mainly by massive and gneissic granitic rocks.

- *Operation Grant Land (1965-1966)*

Northeastern Ellesmere Island and northwestern Greenland.

[32] Fortier, Y.O., et al., 1963 : Geology of the north-central part of the Arctic Archipelago, Northwest Territories, (Operation Franklin), Geological Survey of Canada, Memoir 320, 671p.

- *Operation Grinnell (1969)*

Designed to complete reconnaissance mapping and stratigraphic studies on Grinnell Peninsula and parts of southwestern Ellesmere Island.

Southwest Ellesmere Island and western Devon Island (Map-sheets 49 B, C: 59 A, D)

- *Operation Peel Sound (1970)*

An airborne geological study of the stratigraphy and structure of Prince of Wales Island and adjacent small islands. Several (570) landings were made, numerous ground traverses were completed and sections measured.

- *Operation Boothia (1975)*

A project to study various aspects of the bedrock geology of Boothia Peninsula and Somerset Island, NWT. The objectives were: 1) to produce up-to-date bedrock geological maps on 1: 125 000 or 1: 250 000 scale, as was appropriate; 2) to produce a comprehensive geological report covering all aspects of the bedrock geology of the project area in order to provide essential information for construction of a proposed natural gas pipeline, and for the discovery and evaluation of potential resources.

The Mackenzie Valley

- *Operation Mackenzie (1957)*

(From: Helicopter Operations of the Geological Survey of Canada, Bulletin 54, Chapter IV – Light Helicopter Reconnaissance in Interior Plains and Mountains by R.J.W. Douglas)

In 1957, the Geological Survey of Canada embarked on a helicopter-assisted geological reconnaissance of 100,000 square miles of southwestern District of Mackenzie in order to provide basic geological information for general distribution and to assess the oil and gas possibilities.

The region surveyed extends from lat. 60°, the north boundary of the provinces of Alberta and British Columbia, to lat. 64°, a distance of some 275 miles, and from the boundary of the Interior Plans on the east to long. 126° on the west. The longitude lies about 100 miles within the Franklin and Mackenzie Mountains. A part of Liard Plateau in southeast Yukon lies within the area.

The principal objectives of the Operation were:

1. *To acquire stratigraphic information on the sequence of bedrock formations throughout the area, to effect their correlation and to study variations and mode of origin.*
2. *To prepare geological maps of the plains part of the area on a scale of 1 inch to 8 miles, and of mountains on a scale of 1 inch to 4 miles.*
3. *To assess the economic possibilities of the area as a source of oil, gas, coal and minerals.*
4. *To collect data on the surficial deposits and also such other information as may have a bearing on the economic development of the area.*

❖ *Operation Norman (1967-1969)*

(Map-sheets 86D, E, L, M; 87B C; 96; 97A, B, C, D, F; 106A, B, G, H, I, J, O, P; 107A, D, E)

Operation Norman was a regional geological study of about 375,500 square kilometres in the lower Mackenzie River area between 64°N and the Arctic Ocean, and between 119 and 132°W. The work included reconnaissance bedrock mapping, stratigraphic studies and investigations of surficial Quaternary deposits.[33]

It was a helicopter-supported project to determine the stratigraphy, structure, and economic potential of sedimentary rocks in the area of 298,000 square kilometres in the Mackenzie and Franklin Mountains, Colville Hills, and Great Bear, Horton, Anderson and Mackenzie Plains.

The Northern Cordillera

❖ *Operation Porcupine (1962, 1970)*

(From: Norris, D.K., 1996: In The Geology, Mineral and Hydrocarbon Potential of Northern Yukon Territory and Northwestern District of Mackenzie, Geological Survey of Canada, Bulletin 422, p. 1-5.)

(Map-sheets 106 E, F, K, L, M, N; 116 F (E1/2), G, H, I, J, K (E1/2), N (E1/2), O, P; 117 A, B, C (E1/2), F (E1/2), G, H)

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[33] Aitkin, J.D., et al., 1968, 1969, 1970, 1971: Report of Activities, Geological Survey of Canada, Paper 68-1, 69-1, 70-1 and 71-1.

Operation Porcupine was the start of a succession of continuing field and laboratory studies in the northern Cordillera. It embraced approximately 207,000 square kilometres in the Yukon Territory and Northwest Territories, north of latitude 65°N and west of longitude 132°W. Operation Porcupine included parts of Peel and Anderson Plains, Peel Plateau, Yukon Coastal Lowland, British, Barn, White, Richardson, Mackenzie, Wernecke, and Ogilvie Mountains, Keele and Old Crow Ranges and Old Crow and Eagle Plains. The work led to a better understanding of the processes of orogenesis, epeirogenesis, mineralization and hydrocarbon entrapment.

- *Operation Liard (1963-1965)*

An air-supported reconnaissance geological survey in northeastern British Columbia, in the La Biche River (95 C), Maxhamish Lake (94 O), Toad River (94 N) Tuchodi Lakes (94 K), Fort Nelson (94 J) Trutch ((94 G), Ware (94 F), Toddogone River (94 E1/2) and Halfway River (94 B) map-areas.

The Southern Cordillera

- *Operation Bow-Athabasca (1965-1967)*

(From: Price, Raymond A., 2012: In Operation Bow-Athabasca; The Geological Survey of Canada Takes on the Rockies, Canmore Museum and Geoscience Centre, Canmore, Alberta.)

By the time the Canadian Pacific Railway was completed in 1885, and the world discovered the marvels of Banff and Lake Louise, the GSC's legendary George Mercer Dawson had already explored the mountains of southwestern Alberta and southeastern British Columbia. In 1887 the GSC published Richard McConnell's remarkably perceptive geological cross-section of the Rockies along the new railway. It outlined many sensational features, including the big overthrust fault that forms the eastern front of the mountains and now bears his name. Farther north, the geological wonders of Jasper National Park and Mt. Robson were revealed to science when the Grand Trunk Pacific Railway was completed in 1914. Yet the Canadian Rockies awaited a thorough geological field survey until the mid-1960s. Clearly, it was time to map the portion between the Bow River and the Athabasca River—the part that is most accessible and impressive—comprehensively and in detail.

GSC geologist Ray Price, who had done his doctoral research in the Flathead area southwest of Crowsnest Pass in 1958, proposed just such a survey. He had the backing of his supervisor and mentor, long-time Rockies authority R.J.W. Douglas. In 1964 the GSC's director, Yves Fortier, *approved Operation Bow-Athabasca to do the job. Ray was chosen to lead the effort.*

Maps were the main products of Operation Bow-Athabasca. The goal, as set out officially in GSC chief geologist Cliff Lord's 1965 "Field Instructions" to Ray Price, was to map the central Rockies at a scale of one inch to four miles (1:253,440). Ray suggested that more detail might be necessary in some places, and Cliff agreed. Prudently, and for convenience, Ray decided to use Canada's new series of 1:50,000 topographic maps as the base maps upon which to overlay the geology. This became the standard scale for the project. Ray figured that about sixty 1:50,000 maps would cover the essential geology of the region, which was 300 km long and 110–120 km wide. The total area was roughly 35,000 square kilometres (13,500 square miles), 85 percent as large as Switzerland and equally mountainous. The operation would be carried out among huge, precipitous peaks, with large glaciers and weather to match.

Operation Bow-Athabasca went down in history as one of the GSC's outstanding accomplishments. Not that 60 geological maps went rolling off the government's presses immediately. Gathering the field data was only the first part of the job. Much of that information had been marked onto air photos, and all of it—thousands of rock-unit boundaries, strike-and-dip measurements, fault traces and fold axes—had to be transferred to the topographic base maps. The process took months per map. Cross-sections had to be plotted, and these were equally painstaking. Then the hand-drawn originals were turned over to the GSC's cartographers, who required additional months to prepare fully drafted masters for color printing. All this added years to the release of the maps. The first set, Canmore East Half and Canmore West Half, with two cross-sections, was published in 1970. By 1980, twenty-seven beautiful "A-series" maps had been released.

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When Operation Bow-Athabasca concluded in 1967, the big picture of how the central Canadian Rockies had formed was beginning to emerge. The "Why are they there?" question was being answered. In the years that have followed, succeeding generations of investigators continue to confirm and enhance those findings in ever greater detail. Operation Bow-Athabasca stands as a monument to the golden age of geological exploration and discovery in Canada's favourite mountains.

- ❖ *Operation Smoky (1969-1970)*

Reconnaissance mapping of Pine Pass (93 O), Dawson Creek (93 P), Monkman Pass (93 I) and Wapiti (83 L) map-areas to determine the structural style and stratigraphic framework of the sedimentary rocks in the area.

Frontier Geoscience Program (1984-1988)

Canada's North began to look particularly attractive in the late 1960s with respect to investments in petroleum exploration. Major new discoveries of petroleum resources in the Western Canada Sedimentary Basin were dwindling. In the late 1970s the petroleum resource potential of the North began to be proven. The discovery of oil and gas in the North and offshore on the east coast was having an effect on Canada's evolving energy policies. In the early 1980s the extension of Canadian offshore boundaries to 320 kilometres (200 miles), or beyond, to the edge of the continental slope, resulted in an expansion of Canadian jurisdiction and commercial interest over an ocean area of almost 60% of the Canadian landmass. These developments placed an unprecedented demand on the Geological Survey of Canada to provide essential background geoscience data to both industry and government. In order to satisfy the data requirements for current and anticipated exploration and development in the frontier areas, the Government approved the Frontier Geoscience Program in June 1984 and the required resources were allocated to the GSC.[34]

The objective of the program was to ascertain the geological history and development for all frontier sedimentary basins. To realize this objective the plan was:

- To establish a minimum capability to acquire, store, analyze and synthesize offshore geoscience information;
- To systematically study the sedimentary basins in frontier areas;
- To develop new techniques and concepts; and
- To strengthen research logistics support in environmentally hostile Arctic areas.

In more specific geological terms the program objectives were:

- To establish the deeper geological controls on the development of the sedimentary basins in frontier regions;
- To outline the internal geology and evolution of the basins;
- To elucidate the processes governing the generation, accumulation and preservation of hydrocarbons;
- To identify and analyze natural hazards and constraints to development;
- To provide the essential supporting research, development, analyses and synthesis, and;
- To supply data and support to a database containing essential information necessary to appraise the nature and distribution of potential hydrocarbons within a basin.

[34] Frontier Geoscience Program – Annual Report 1986-87; Internal GSC Report prepared by D.D. Picklyk, Program Officer, Frontier Geoscience Program.

The Frontier Geoscience Program was subdivided into six tasks:

- East Coast
    - Scotian Shelf
    - Grand Banks
    - Northeast Newfoundland
    - Labrador/Baffin
    - Paleozoic Basins

- West Coast
    - Tofino Basin
    - Queen Charlotte

- Arctic Islands
    - Sverdrup Basin
    - Paleozoic Platform-Miogeocline
    - Continental Shelf

- Western Arctic
    - Mackenzie Delta-Beaufort Sea
    - Interior Plains
    - Northern Cordillera

- Support R&D

- Logistic Support
    - Logistics-Arctic Islands
    - Logistics-Western Arctic

The program was designed to focus attention exclusively on the sedimentary basins of each region. It was administered from The Institute of Sedimentary and Petroleum Geology in Calgary. In 1988, Cabinet decided that FGP funding should become a permanent part of the Survey's research responsibilities.

Several FGP projects involving geodynamic basin modeling contributed to the evaluation of hydrocarbon potential in various sedimentary basins.

Canada/USSR Arctic Scientific and Technological Exchange Agreement (1984-1991)

In 1984 a Canada/USSR Arctic Science Exchange Agreement was negotiated for a period of three years. An important theme was the comparison of the geological evolution and the hydrocarbon resources of the Arctic regions of both countries. In 1987 and again in 1989 the agreement was extended for two years. The program successfully opened channels of communication between researchers in both countries. Collaboration under this program resulted in the production of an important 1:6 million scale circum-Arctic geological map, along with numerous publications on the geology of circumpolar regions.

In 1991, a new initiative on anthropogenic contaminants in the Arctic Ocean commenced within the Canada-Russia Agreement on Cooperation in the Arctic and the North. The purpose of the project was to determine the distribution and concentration of trace and heavy metals, radionuclides, persistent organic toxins, and mutagenic and carcinogenic compounds in the seafloor sediments off Arctic Canada and Siberia.[35]

Canada - USSR joint field crews in the Canadian Arctic, June 1988

[35] Skibo, D.N. and Nassichuk, W.W., 1984: Persistent organic compounds in the Barents Sea: Canada-Russia collaboration on Arctic pollutants; in Current Research 1994-B; Geological Survey of Canada, P 1-9.

Joint Geological Survey of Canada/Alberta Research Council
Peace River Arch Investigation (1985-1990)

The Peace River Arch is one of a small number of discrete structural entities that has significantly disturbed the Phanerozoic cover within the Western Canada Sedimentary Basin. It has given rise to oil and gas accumulations within strata extending from Devonian to the Cretaceous.[36]

The investigation only began to address the following questions:

- When did the arch originate?
- What was its initial structural configuration?
- How was it modified through time?

A major crustal seismic refraction survey, one of the most ambitious programs of its kind in Canada, was completed in the Peace River Arch area of northwestern Alberta and northeastern British Columbia in July 1985. It was coordinated by ISPG personnel and involved personnel and equipment from the universities of British Columbia, Alberta, Saskatchewan, Western Ontario, Toronto, and Memorial University, as well as ISPG and the Earth Physics Branch. Results provided information on the relationship between the Peace River Arch, and basement and crustal structures and crustal and mantle densities. They helped constrain geodynamic models being developed of the mechanical and thermal evolution of the arch and similar structures in the Western Canada and other sedimentary basins.

A *Peace River Arch Project* was formalized in April 1987 by a Memorandum of Understanding (MOU) with the Alberta Geological Survey.

Results of the overall investigation were presented orally at the Basin Perspectives Symposium of the Canadian Society of Petroleum Geologists held in Calgary in May 1990. The society subsequently published in December, 1990, a special volume entitled: *Geology of the Peace River Arch, S.C. O'Connell and J.S. Bell (eds.). Bulletin of Canadian Petroleum Geology, Special Volume 38A, 281 p.*

[36] Geology of the Peace River Arch, S.C. O'Connell and J.S. Bell (eds.). Bulletin of Canadian Petroleum Geology, Special Volume 38A, 281 p.

Decade of North American Geology (DNAG) – Geology of Canada Series (1980-1993)

The Geology of North America series was prepared to mark the Centennial of The Geological Society of America. It was part of the Decade of North American Geology (DNAG) Project designed as a coordinated effort to integrate all available knowledge about the geology and geophysics of a crustal plate on a regional scale. The products of the DNAG Project presented the state of knowledge of the geology and geophysics of North America in the 1980s, and they pointed the way toward work to be done in the decades ahead.

Responsibility for the Canadian volumes for the DNAG Project was assumed by the Geological Survey of Canada. Responsibility for the following two volumes was then assigned to the Institute of Sedimentary and Petroleum Geology in Calgary:

- Geology of the Innuition Orogen and Arctic Platform of Canada and Greenland (led by H.P. Trettin)
- Sedimentary Cover of the Craton in Canada (led by D.F. Stott and J.D. Aitkin)

In 1987, the volume entitled *Sedimentary Cover of the Craton in Canada* was completed (published in 1993). The volume deals with three tectonic-stratigraphic provinces and their basins: Interior Platform, Hudson Platform, and St. Lawrence Platform. The volume entitled *Innuitian Orogen and Arctic Platform of Canada and Greenland* was submitted to the series editor (published in 1991).

In 1989, ISPG contributed to the construction of maps showing the distribution and magnitude of stress in Canadian sedimentary basins (Canadian stress map for the Decade of North American Geology, and World Stress Map for the International Union of Geodesy and Geophysics). The topic was of considerable growing interest for the Western Canada Basin particularly as related to the design and implementation of suitable enhanced petroleum recovery techniques.

Geological Atlas of the Western Canada Sedimentary Basin (1987-1994)[37]

Published jointly by the Canadian Society of Petroleum Geologists and the Alberta Research Council, in sponsorship association with the Alberta Department of Energy and the Geological Survey of Canada.

In the years since publication of the atlas entitled Geological History of Western Canada, compiled by McCrossan and Glaister (1964), the database of wells in Western Canada had increased many fold. Technical improvements in the resolution and reliability of subsurface measurements had resulted in quantum advancements. Geological ideas on the stratigraphic and structural evolution of the basin had been revolutionized, most centrally by the concepts of plate tectonics, which were not widely accepted at the time of compilation of the first atlas. In addition, there had been very considerable evolvement in basin analysis techniques, embracing previously uncharted concepts of facies analysis, sequence stratigraphy, basin architecture, thermal-organic maturity, and resource localization. The time was clearly ripe for a fresh regional synthesis. There was also growing realization that, although one of the primary benefits of a modern atlas compilation was the fostering of enlightened exploration for earth resources, there were crucial additional benefits with respect to sustainable development - environmentally sensible interaction between society and the solid earth upon which it is founded.

The compilation of the Geological Atlas of the Western Canada Sedimentary Basin was a complex endeavour involving scores of individuals and dozens of corporations and institutions - project sponsors, project staff, data donors, advisors and committee members, and authors and their employers. Twenty-seven geoscientists from the Geological Survey of Canada contributed their significant expertise to the preparation of the atlas. They were involved as authors or co-authors of most of the thirty-five atlas chapters.

[37] Mossop, G.D. and Shetsen, I., comp. (1994): Geological atlas of the Western Canada Sedimentary Basin; Canadian Society of Petroleum Geologists and Alberta Research Council.

Environmental Geoscience Initiatives (1989-ongoing)

Research related to a Global Climate Change Program

- **CO_2 Capture and Storage**

  This project focused on monitoring methods and assessment of the potential for biological and geological carbon sequestration within Canada's landmass. It included local/regional assessments of the potential for carbon sequestration in a variety of geological reservoirs, for a national capacity assessment.

Research related to the mobility and distribution of trace elements in a landmass (environmental geochemistry)

- **Trace Element Studies**

GSC Research into Mercury Emissions from Coal-Fired Power Plants

During the period 1982 to 2005 the GSC, in partnership with Canadian coal mining companies, coal-fired power plants, and universities, studied trace elements (including mercury) in emissions, and distributions around coal mines and coal-fired power plants.

This research took a holistic approach following mercury from the coals, into the burning process, through stack emissions and its subsequent deposition in surrounding areas.

The emissions in Alberta were high because of the large volumes of coal being burned and the fact that Alberta power plants were not completely modernized in terms of emissions reductions. The level of mercury emissions would even have been higher except for the fact that coals used in western Canadian power plants were generally low in mercury content (0.05-0.07 mg/kg) as compared to other coals around the world (averaging 0.02-1.0 mg/kg).

Studies by the GSC showed that, in addition to various stack reduction technologies, mercury emission levels could be further reduced by up to 35% by selective mining to avoid seams high in mercury, and by using coals with naturally high char (geological form of charcoal) content. This was important to western Canadian power companies because, even with modernization of plants, the long term planned reductions of as much as 70% could be difficult to achieve without this added factor.

It is noteworthy that this research also studied the relative distribution of mercury that originates from natural geological sources and mercury added to the soil from stack emissions providing background information for environmental analysis and assessment.

Establishing a Canada Wide Standard for Mercury Emissions

- Between 2002 and 2004 a consortium, including NRCan (CANMET-GSC), Environment Canada, the Canadian Electricity Association, and all coal-fired utilities (on a voluntary basis), worked to establish a *Canada -Wide Standard for Mercury Emission*. Funding for this study was provided by the electric utility companies.
- Most of the sampling was completed and data were studied for transfer to Environment Canada by 2005.
- The GSC contribution was to demonstrate methods of reducing emissions by studying the distribution of mercury occurring naturally in coal, and the distribution of natural char in coal.

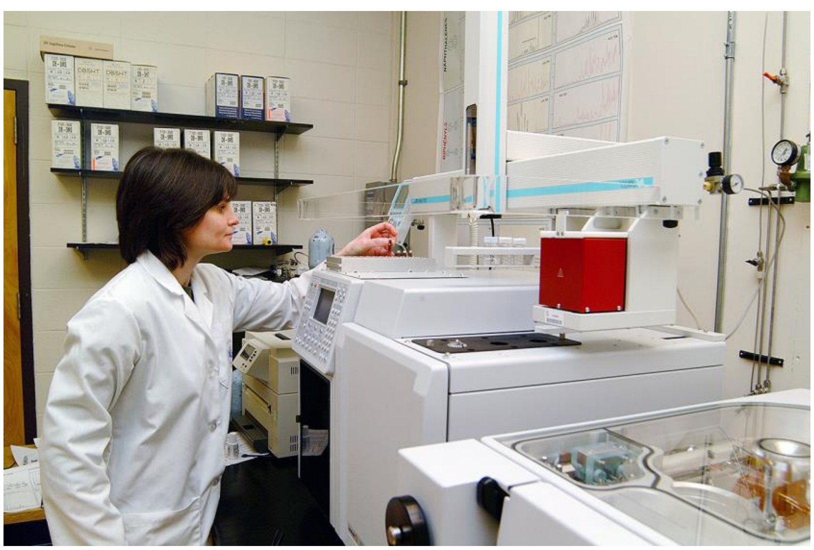
As part of the Geological Survey of Canada's Metals in the Environment Program (MITE) it published GSC Bulletin 573 "Deposition of Trace Elements in the Trail Region, B.C. This paper documents the contribution of the smelter to increased levels of arsenic, cadmium, copper, mercury, lead and zinc around the smelter.

A second unpublished study concerned the distribution of trace elements in samples from stream tributaries to the Columbia River. This study showed that the high trace element concentrations in most of the creeks are mostly due to the natural causes, although some creeks may be affected by aerial deposition from the smelter activities.

The GSC also experimentally leached soil and stream sediments. These studies showed that a significant portion of metals in sediments are not mobile under the existing environmental conditions. This study however did not examine slag in the Columbia River.

On December 15, 2003, the Canadian Broadcasting Corporation aired a segment on its evening newscast "The National" reporting that the United States Environmental Protection Agency (EPA) may be preparing to take legal action on behalf of Washington State residents who claim that slag from the Teck Cominco smelter at Trail, British Columbia, has seriously polluted the Columbia River, which flows into the United States approximately 20 km downstream from Trail. The slag, which has been produced at the Trail production site since it began to produce zinc from the recently-closed Sullivan mine over 100 years ago, is in a granular form and has been the focus of several studies. EPA studies have indicated that sediments in the Columbia River and Lake Roosevelt contain elevated levels of lead, zinc and mercury, however it cannot be determined if those metals were deposited as either airborne or waterborne materials. The company ceased releasing slag into the Columbia River in 1995 and has also undertaken extensive upgrades to environmental controls at the smelter.

Scanning Electron Microscope


Gas Chromatograph-Mass Spectrometer

National Geoscience Mapping Program (NATMAP) (1991-2003)

- Eastern Cordillera/ Southern Alberta NATMAP Project (1993-1998)
- Central Foreland/ Northern Cordillera NATMAP Project (1997-2003)

(Refer to Appendix III)

NATMAP was developed by the Geological Survey of Canada and started in 1991 to provide opportunities for collaboration among scientists from the GSC and provincial surveys, industry and universities in field-based geological projects across the country.

NATMAP provided coordination and funding support to mapping projects that assisted Canada's mining and petroleum industries, filled gaps in knowledge of Canada's geology, or addressed questions related to environmental or other societal issues.

NATMAP participants led the development of digital mapping standards and applications of digital technologies to interpret multiple datasets and to produce a wide variety of geological maps.

Criteria for approval of proposals as a NATMAP project included:

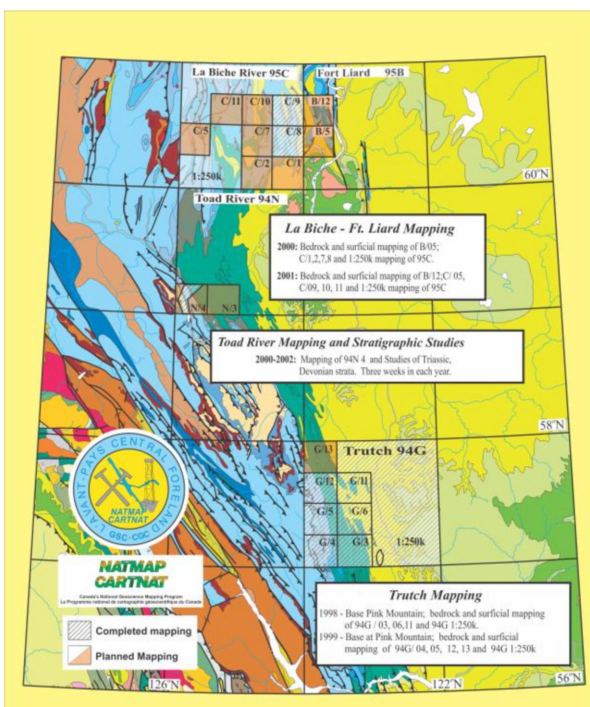
- Must produce geoscientific maps as major outputs
- Should be multi-disciplinary
- Should be cooperative (i.e. involving more than one agency)
- Should involve undergraduate and graduate students from Canadian universities
- Should capture new data in digital format

NATMAP was a resounding success in producing new thematic map-based geoscience information focussed on a number of key geological terrains in Canada. It was a major catalyst in bringing together a wide array of stakeholders to share resources and expertise. The results were new knowledge that can be applied to broad regions of Canada.

NATMAP projects, like the Central Foreland Project in the Liard area of B.C. and Yukon, which pulled together teams of provincial, territorial, university, industry and GSC researchers, are now the norm for most geoscience mapping projects, with a high level of synergy, innovation, impact on Canadian industry, and training of Canadian scientists.

The purpose of the Eastern Cordilleran NATMAP project was to remap the geology of a portion of the southeastern edge of the Canadian Cordillera - the name for the mountains of western Canada - in southern Alberta. The area of study, a swath in the Rocky Mountain Foothills some 50-100 km in width extending north-northwest 200 km from the Canada-US boundary, is an important geological province with significant reserves and resource potential for natural gas, oil, sulphur, thermal coal, coalbed methane and possibly diamonds, and significant groundwater concerns.

The primary objective of the *Central Foreland NATMAP project* was to produce modern geological maps of the bedrock and surficial deposits at regional (1:250,000) and more detailed (1:50,000) scales in four map areas stretching roughly 375 km from northeastern British Columbia to southern Yukon and Northwest Territories. Geological mapping would be integrated with existing oil and gas well data and geophysics to develop geological cross-sections depicting lithological and structural relationships at depth. The new geoscience information would provide a better understanding of the likelihood for oil and gas in specific regions of the project area and the potential for their economic development. As well, the study area and adjacent terrains have an abundance of base metal deposits, including potential lead, zinc and silver producers. The project would investigate these sediment-hosted deposits to establish the age of mineralization and relationship to the host rocks and, thereby, to possibly extend the area prospective for such deposits. Till geochemistry, and biostratigraphic programs were integrated with the bedrock and surficial mapping to support and augment the scientific results and maximize logistical efficiency.



Industrial Partners Program (1993-1999)

In 1993 GSC set up a special fund of $1.5 million per year under its Industrial Partners Program (IPP) to encourage scientists to develop joint projects with industrial partners in order to enhance GSC's response to the needs of its industrial clients. Successful projects were eligible to receive GSC matching funds up to $50,000. A few projects conducted under the IPP at the GSC in Calgary included the following:

The Lower Paleozoic: A new frontier in the Western Canada Basin (1993-1996)

This project was initiated under the Industrial Partners Program in 1993 with the primary objective of gaining a clearer understanding of the sedimentary packages that lie between the basement and the base of the Beaverhill Lake Formation. It encompassed studies of Cambrian clastic and carbonate units, Upper Ordovician carbonate units and basal Devonian carbonate, clastic, and evaporitic strata of the Western Canada Sedimentary Basin. Fourteen petroleum companies joined the project initially and contributed funds and made in-kind contributions.

Pursuant to the projects primary objective, the relatively enigmatic relationship was clarified between the well established Lower Paleozoic stratigraphy of the Rocky Mountains and the relative poorly known stratigraphy in the subsurface of Alberta.

Trace Element Studies (1994-1999)

GSC Research into Mercury Emissions from Coal-Fired Power Plants
(see Environmental Science Initiatives, p. 51)

Coalbed Methane (CBM) in Canada (1995-1999)

Coalbed methane (CBM) represents a potential in-place resource larger in magnitude than all known conventional gas supplies in Canada. It may be part of the solution to maintaining growth in gas production in the future.

Strong growth in demand for natural gas was forecast for electrical power generation, oil sands refining, other industrial uses and exports to the United States. The National Energy Board in its 2003 Energy Outlook expected domestic demand growth of 22% through 2010. Export requirements to the U.S. were forecast by the U.S. Energy Information Administration to grow by a similar amount over this period. Meeting this demand, even with the development of all frontier areas other than the Arctic Islands, was unlikely to be possible beyond 2010 according to the National Energy Board forecasts.

Canada has extensive coal deposits with potential for CBM that are distributed from the Atlantic to the Pacific to the Arctic coasts. These deposits have diverse geological characteristics that directly affect the economic viability of CBM production. Some of the largest and most prospective of these deposits occur in the Plains area of Alberta, Saskatchewan and British Columbia, in close proximity to points of end use.

NRCan has been a leader in assembling the essential knowledge base on Canada's coal deposits through the Geological Survey of Canada's (GSC's) National Coal Inventory. GSC's analytical methodologies were instrumental in the development of Canada's first commercial CBM production by the EnCana/MGV/Quicksilver Consortium announced in February 2002. GSC's baseline studies had been instrumental in focusing industries efforts on the areas of highest potential.

Deep coal seams that hold CBM can also be used to sequester $CO_{2,}$ with the associated enhancement of CBM production (CO_2 selectively displaces methane in coal reservoirs). This could provide part of the solution to abating greenhouse gas emissions while generating a revenue stream from CBM to offset the cost of CO_2 capture. Research was underway on this option by GSC through the Earth Science Sector's Climate Change Program.

In the U.S. (where most of the world's CBM was being produced) commercially viable production of CBM followed years of research to establish the necessary knowledge and technologies. CBM accounted for about 7% of U.S. gas production (1.4 Tcf/year from 14,000 wells). Success in CBM production in the U.S., and increases in natural gas prices, had accelerated CBM activity in Canada (British Columbia, Alberta and Nova Scotia). By 2003 petroleum companies exploring in Canada had more than 15 projects underway at the experimental, pilot and commercial stages of development.

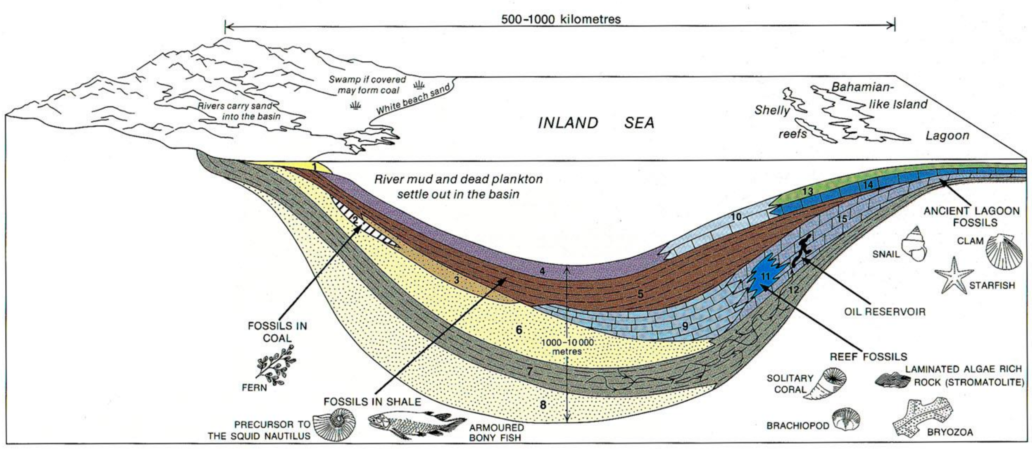
In place assessments of Canada's CBM resources were completed and published by GSC staff. These assessments put the *in place* potential at between 187 and 586 Tcf, rivaling all of Canada's conventional natural gas resources. Estimates of how much of this gas can ultimately be produced are unknown at present, however, as exploration to date has yielded only limited commercial success.

As of February, 2003, four companies announced commercial CBM production totaling 9.9 million cubic feet per day from 47 wells (MGV/Quicksilver, EnCana, Elk Point and Nexen). All of the announced production was from the Plains area of Alberta. More than 300 CBM exploration wells were drilled in 2003. Although significant and an important beginning much additional work needs to be done before CBM will make a substantial contribution towards offsetting the declines in conventional gas production.

Devonian Petroleum Systems of the Western Canada Sedimentary Basin (1995-1999)

This project was initiated in 1995 under the Industrial Partners Program and involved fourteen partners from the petroleum industry. The primary objective of the project was to enhance understanding of the Devonian petroleum systems by studying all the factors involved in petroleum accumulation. These factors included source rocks, migration pathways, reservoir rocks, seal, trap and the relative timing of hydrocarbon generation and migration, and trap and seal formation.

A Special Volume of the Canadian Society of Petroleum Geologists Bulletin on hydrocarbon-rich Devonian strata of Western Canada included a key paper by GSC scientists Martin Fowler, Lavern Stasiuk and Mark Obermajer (and a colleague from Shell Oil) on “Devonian Hydrocarbon source rocks and their oils”. This was a landmark paper demonstrating that most Devonian oils are derived locally from Devonian sources rocks and that they are generally not biodegraded. It also gave a regional overview of source rocks, distribution, and other characteristics. This paper had a significant impact on improving and expanding petroleum exploration strategies in Saskatchewan, Alberta and B.C., making a significant contribution to sustaining and expanding hydrocarbon development in western Canada.



Schematic of a sedimentary basin

Mineral Development Agreements (1992-1995)

Canada-Alberta Agreement on Mineral Development (1992-1995)

The Canada-Alberta Partnership on Minerals, commonly referred to as the Canada-Alberta MDA became effective on April 1, 1992. Its purpose was as follows:[38]

- To broaden and diversify the economic base of Alberta by developing the non-petroleum mineral industry;
- To enhance the geoscience database and understanding of Alberta's geology;
- To support research and development to increase productivity and efficiency of non-petroleum mining and minerals processing, and to address environmental concerns associated with these activities;
- To identify, document and promote opportunities for non-petroleum mineral development;
- To encourage private sector investment in the development of non-petroleum mineral resources;
- To enhance recognition of the role and contribution of both the federal and Alberta governments with respect to the mineral industry and Agreement activities; and
- To enhance the appreciation and awareness of the mineral sector's contribution to Alberta.

In summary, the prime purpose of the Canada-Alberta Mineral Development Agreement (Canada-Alberta MDA) was to assess the non-fuel mineral potential in Alberta, and to conduct studies to encourage mineral exploration.[39]

Contributions from GSC-Calgary:

- Tectonic evolution of the Precambrian Shield of northeastern Alberta (M.R. McDonough)
- Geochemical and stratigraphic setting of the Shaftsbury Formation in northern Alberta, and its potential to host ore deposits (R.W. Macqueen)
- Brine resources of Alberta (H.J. Abercrombie)

[38] Canada-Alberta Partnership on Minerals 1992-1995, Program Summary, 104 p., Alberta Energy and Natural Resources Canada.

[39] 1997: Exploring for minerals in Alberta: Geological Survey of Canada geoscience contributions, Canada-Alberta Agreement on Mineral Development (1992-1995), R.W. Macqueen (ed.). Geological Survey of Canada, Bulletin 500, 357 p.

LITHOPROBE (1984-2005)

Canada's Department of Energy, Mines and Resources, along with the Natural Sciences and Energy Research Council of Canada and Canada's universities launched LITHOPROBE in 1984 with the objective of relating surface geology to structures at depth within the lithosphere. It was designed to involve the use of combined geological and geophysical techniques, including multichannel seismic reflection, along with other advanced high resolution seismic techniques, and deep drilling.[40]

LITHOPROBE projects that involved the significant participation of GSC (Calgary) included:

- Central Alberta Transect 1992 Program (CAT 92)
- The Peace River Arch Industry Survey Experiment 1994 (PRAISE 94)

Central Alberta Basement Transect (CAT 92)[41]

The Central Transect seismic reflection data were acquired by LITHOPROBE during the summer of 1992. The Central Transect extends from the Alberta-Saskatchewan boundary northwestward to the town of Entwhistle west-northwest of Edmonton. It traverses the western part of the Archean Hearne Craton and crosses into the Paleoproterozoic rocks west of the Archean Rae Craton. The boundary between the Rae and the Hearne provinces coincides with the Snowbird Tectonic Zone, a structural and potential field discontinuity that can be traced from the foothills of the Canadian Cordillera eastward to Hudson Bay. The seismic line extends across the strike of the north-northeast-trending domains of potential field fabric that typify the basement.

Peace River Arch Industry Survey Experiment (PRAISE 94)[42]

The PRAISE-'94 survey was conducted between July 8 and August 17, 1994. The survey extended from Farmington, B.C. (20 km northwest of Dawson Creek) to Entwhistle Alberta with a total line length of 627.5km. The transect crossed the Peace River Arch, an enigmatic regional structure characterized by a Phanerozoic subsidence history that is anomalous with

[40] Clowes, R.M., et al., 1984 : LITHOPROBE – A national program for studying the third dimension of geology, Journal of the Canadian Society of Exploration Geophysicists, vol. 20, no. 1 (Dec. 1984), p. 23-39

[41] http://www.lithoprobe.ca/transectsWebSites/ab/le_cat92.htm

[42] http://www.lithoprobe.ca/transectsWebSites/ab/le_praise94.htm

respect to the Western Canada Sedimentary Basin (WCSB) as a whole. Underlying basement domains are associated with the Early Proterozoic (2400 to 1780 Ma) collision of Archean microcontinents that was accompanied by magmatism and crustal deformation. The general objectives of the transect were to determine the crustal geometry, nature and characteristics of the basement tectonic domains and their relationship to the development of the WCSB.

This program established a number of significant new milestones for LITHOPROBE. Foremost among these was the nature of funding for the seismic survey: this was the first LITHOPROBE seismic survey to derive the majority of its funding from industry sources. A consortium of 25 oil companies sponsored the project and contributed $625K toward the acquisition and processing contracts. In February, 1994 those companies that had already indicated an interest in the project were consulted to determine what modifications to LITHOPROBE acquisition parameters would best suit industry needs. This consultation process led to a number of revisions to the previous LITHOPROBE acquisition parameters, including shortened group interval (changed to 25 m from 50 m), higher sweep frequencies (high end of sweep changed to 80 Hz from 56 Hz) and a higher sampling rate (changed to 2 ms from 4 ms). To accommodate the need for long offsets for deep recording whilst maintaining a shorter group interval, the number of channels was increased from 240 to 480. In addition, based on experience from the previous year's LITHOPROBE survey, where extended correlation techniques for some of the profiles were used effectively to trace dipping reflections to depths of 70 km in the mantle, uncorrelated records have been archived for the entire dataset.

A schematic cross-section across the Peace Rive Arch was developed, showing the postulated accretionary history that began with subduction of oceanic crust (green) beneath Archean crustal blocks at approximately 2.4 Ga.

A model for the formation of fracture-controlled dolomite reservoirs, such as the Tangent field, was established showing its origin might have resulted from reactivation of basement fault zones.

Reference

Ross, G.M., 1990: Deep crust and basement structure of the Peace River Arch region: constraints on mechanisms of formation; Bulletin of Canadian Petroleum Geology, v. 38A, p. 25-35.

Parrish, R.R., Villeneuve, M.E., and Bouring, S.A. 1991: Geophysics and geochronology of the crystalline basement of the Alberta Basin western Canada; Canadian Journal of Earth Science, v. 28, p. 512-522.

Northern Basins Initiative (2000-2005)

By 2000 the energy industry had greatly renewed its interests in the sedimentary basins of northern Canada. Buoyed by spectacular gas discoveries in the Liard area of NWT and fueled by rising continental gas demand, rapid depletion of major gas reservoirs throughout North America, high market prices, plans for major pipeline developments, and favourable signals from aboriginal communities, the renewal of interest and activity in the north extended to all the sedimentary basins of the Yukon, Northwest and Nunavut territories. Several energy companies were committed to invest nearly a billion dollars over the next few years in the Beaufort-Mackenzie Delta area, where significant proven gas reserves were known to occur. Several plans for pipeline expansions were being considered, each of which would link major producing areas of the North with southern markets, and each with its own promise to increase industrial capacity and to bring some form of prosperity to various northern regions and to all of Canada. First Nations, many of which had settled their land claims since Justice Berger's report on the Mackenzie Valley Pipeline Inquiry was published in 1977, sent positive signals indicating their willingness to cooperate and be active partners in developing northern resources. The re-emergence of northern oil and gas prospects also spurred significant mineral exploration and development activities. This resource-based economic activity, and the genuine prospect for much more in the future, took place against the realization that the North was likely to be affected more rapidly and more dramatically than any other area by climate changes in the future. Rising temperatures would have a range of effects from the thawing of sea ice, the flooding of coastal areas, the melting of permafrost and the destabilization of gas hydrates. The advent of Nunavut, the remaining unresolved sovereignty issues over the Arctic Archipelago and other issues relating to the Law of the Sea added a political dimension to an already-busy northern agenda. As a result, stories about Canada's North were being featured almost daily in the national press, and many governmental agencies were calling for increased funding for a variety of existing and new northern initiatives.

It was being recognized increasingly that hydrocarbon exploration and development would have a significant impact on northern populations and would add significant stress to a sensitive environment that was already under stress by climate change. These issues added to an increasingly visible northern political agenda. Demand was increasing for northern geoscientific research and information on the landmass.

While there was clearly a significant demand for an increase in scientific research in the northern regions of Canada, a gap was growing quickly between the geoscientific needs of Canada's North and the capacity of the Geological Survey of Canada and its territorial partners to address those needs. This gap stemmed from

- years of cutbacks and attrition,
- early retirements and early departures,

- non-rejuvenation and lost know-how, stagnation and low morale,
- decline in monitoring capacity,
- loss of interest and reduced funding to university-based northern research,
- fewer graduate students carrying out research in the North,
- increasing logistic costs and reduced funding to the Polar Continental Shelf Program (PCSP), and
- an existing work force stretched to the limit.

As a result, Canada's collective northern geoscientific know-how was in the hands of a rapidly-shrinking number of people, scattered over a small number of government offices and university departments. Not surprisingly, Canada's scientific leadership over its own northern jurisdiction was rapidly eroding, and it was increasingly up to well-funded teams from the USA, Sweden or Germany to set the tone for the kind of research that was being done north of 60^0N in Canada, from the study of Axel Heiberg's fossil forest to monitoring changes in the Arctic permafrost. While NSERC and SSHRC were recognizing that the state of Canadian university-based northern research was in a state of crisis, it was important for NRCan to come to a similar conclusion and to start to rebuild a northern geoscience capacity.

A Northern Basins Initiative (NBI) was developed by the GSC to look into the many facets of northern oil and gas exploration and development. With a number of territorial partners, the GSC embarked on a one-year scoping study to examine the gaps, needs, challenges and opportunities in northern basins and to lay down, through a concerted research plan, the foundation of a renewed geoscientific effort in the North.

The background to this initiative, at the time, was:

- There is a renewal of oil and gas interest in the Yukon, NWT and Nunavut driven by market forces and economic forecasts.
- Exploration and development will have a profound impact on northerners.
- This activity will add significant stress to a sensitive environment already pressured by climate change and global warming.
- These issues add to a northern political agenda that is increasingly visible in the southern media.
- There is a significant demand for a sizeable increase in northern research.
- A gap is growing quickly between the geoscientific needs of Canada's North and the capacity of the GSC and its partners to act responsively.

The overarching issues were:

- *Gaps*: Where are the holes in our knowledge for each basin?
- *Needs*: What are the needs and priorities of various stakeholders?

- *Opportunities*: What are the current and future opportunities?
- *Capacity*: How can we start rebuilding S&T capacity?
- *Logistics*: Does PCSP have the necessary resources?
- *Industry*: What role should industry play in a Northern Basins Initiative?
- *University*: What kind of partnership should be created?
- *Northerners*: What kind of partnerships with northerners (Territorial governments, First Nations, Land Managers) should be established to ensure that they are part of the S&T decision-making process?

A major outcome of the scoping study was a *Business Plan* that laid the foundations for a Northern Basins Initiative. It included justifications and recommendations for an application for a new funding envelope, a set of priorities, a timetable, a management structure, links to other agencies and existing governmental initiatives, etc. An important component of the business plan was a *Research Plan* that described the state of our current knowledge, identified the gaps, outlined and prioritized the needs and pointed out the opportunities to conduct a full range of geoscience activities in the sedimentary basins of Canada's North. Proposed studies related to oil and gas activities, mineral exploration, groundwater problems, marine geoscience, environmental stewardship, natural hazards, climate change, geoscience of continental margins, just to name a few. Importantly, the *Research Plan* contained a portfolio of potential projects to be carried out during future funding cycles.

- **Hans Island Issue Boundary Dispute (2004)**

Articles appeared in several newspapers and in some radio broadcasts concerning a dispute over ownership of Hans Island, which lies between Canada and Greenland. The official position on Canada's sovereignty over Hans Island was outlined and the geological and physical comparisons of the island to Canada and to Greenland were described.

Hans Island is one of four boundary disputes in the Arctic, the others being the Northwest Passage, the Yukon-Alaska boundary and the continental shelf in the high Arctic between Canada and Russia. The island is important in determining the course of the international boundary between Greenland and Arctic Canada.

Hans Island is physically and geologically related to both coastal Greenland and Canada but is geologically subtly more similar to Greenland.

Beaufort Mackenzie Research (2000-2013)
(see Appendix IV)

Exploration for hydrocarbons in the Beaufort-Mackenzie was spurred by the discovery of oil at Prudhoe Bay, Alaska in 1967. For more than two decades, exploration continued vigorously and 53 significant gas and oil discoveries were made. Exploration came to a halt in 1992 when prospects of a pipeline were dim and economics were unfavourable. In 1999, potential shortages of natural gas sparked a renewed interest in exploration, and in 2001 the first Mackenzie Delta well in nearly a decade was drilled by PetroCanada and Anderson Exploration. Since then, 12 wells were drilled to 2007, with significant discoveries at Tuk M-18 and at Langley K-30.

During the thirteen year period of 2000 to 2013 GSC conducted several government and government-industry funded research projects in the Beaufort-Mackenzie Basin (BMB).

- 2000-2010: GSC-Industry consortium (Beaufort Mackenzie Research Consortium) conducted research on petroleum systems, led by L. Snowdon and D. Issler

- 2001-2002: Project on “Quantitative analysis of hydrocarbon systems of the Beaufort-Mackenzie Basin” was led by D. Issler, under Secure Canadian Energy Supplies Program

- 2003-2007: Project on “Geoscience for Sustainable Communities and Economic Development in the Mackenzie Delta Region”, was led by D. Issler, to provide a firm geoscience basis for evaluating resource potential, to assist community-based decisions on land use, and to attract global investment dollars for exploration, development and related job creation

- 2007-2013: Project on “Mackenzie Delta Corridor” was led by R. MacNaughton under the Geo-mapping for Energy and Minerals (GEM) - Energy Program

The general purpose of this research was to develop a better understanding of geological factors that controlled the formation and occurrence of petroleum in a region where recent petroleum discoveries pointed to substantial, undiscovered resources. An assessment of the petroleum resource potential in the BMB was also an objective.

The BMB research resulted in:

- New datasets
  - Data from new lab tests, interpretations and analyses
  - Quality-assessed compilations of legacy data

- Improvements of petroleum systems models
  - Source rock models
  - Thermal history models
  - Petroleum accumulation models

- Revised methodology for resource assessment
  - Variable dependencies
  - Correlation in resource aggregation
  - Reserve growth

- Consideration of improved oil recovery scenarios
  - Trend analysis of historical oil recovery factors
  - Examples of improved recovery through reserve development planning and management (success and failure analyses)

Interpreting petroleum well geophysical logs

Targeted Geoscience Initiative (TGI)

- TGI-1 (2000-2003)
- TGI-2 (2003-2005)
- TGI-3 (2005-2010)
- TGI-4 (2011-2015)

In 2000 the Government of Canada introduced the $15 million, three-year Targeted Geoscience Initiative (TGI) to produce new geological maps and data about underexplored areas with high potential for mineral deposits and to make this information more accessible through the Internet. This initiative was led by GSC. The primary goal of TGI was to turn resource potential into new social and economic benefits by increasing the level and effectiveness of private sector mineral exploration – to help stimulate new investments in the mining sector.

- **TGI-1**

  A Targeted Geoscience Initiative project was established in 2001 for the Northwest Territories in partnership with Alberta and the GSC to pursue an integrated and comprehensive study investigating the potential for carbonate-hosted Mississippi Valley-type (MVT) lead-zinc deposits in Alberta and NWT. The abandoned open-pits of the Pine Point lead-zinc mine, located near Hay River on the south shore of Great Slave Lake, and a wealth of rock core collected during years of mineral exploration, provided much of the fundamental data for the project.

  The primary goal of the project was to delineate and evaluate the origin, distribution and potential of carbonated-hosted lead-zinc deposits in the region and develop an understanding of the relationships of fluid flow and ore deposition to the regional framework of stratigraphy, structure and diagenesis. The source, flow-path, and timing of fluid movement and their relationships to mineralization were important considerations for identifying regions or strata of enhanced mineralization potential elsewhere in the project area.

  The project resulted in the hypothesis that a close relationship exists between MVT deposits and their associated hydrothermal dolomite with fault –zone processes throughout the Western Canada Sedimentary Basin[43].

[43] 2006: Potential for Carbonate-hosted Lead-zinc Mississippi Valley-type Mineralization in Northern Alberta and Southern Northwest Territories: Geoscience Contributions, Targeted Heoscience Initiative, (ed) P.K. Hannigan; Geological Survey of Canada, Bulletin 591.

Hydrothermal dolomite in bedding parallel bands

Carbonate-hosted Mississippi Valley-type deposit, NWT

- **TGI-2**

A TGI project entitled Geoscience Experience for Northern Communities (GENCOM) was initiated in 2003 with the objectives of coordinating, facilitating and delivering geoscience outreach to northern communities. It provided readily understandable geoscience information to northern communities through community and school based programs. It assisted communities in making informed decisions on resource development and land-use planning.

Consolidating Canada’s Geoscience Knowledge Program (CCGK) (2000-2006)

Canadian Geoscience Knowledge Network (CGKN) (2001-2006)

CGKN was an initiative of the National Geological Surveys Committee (NGSC) to provide an Internet portal to Canadian geoscience information, making Canada a global leader in providing rapid access to its knowledge assets. Under CGKN comprehensive catalogues were created describing geoscience data, publications and maps available from Canadian government geoscience agencies, and a new Internet search engine was implemented.

Cooperative Geological Mapping Strategies Across Canada (CGMS) (2003-2006)

The Cooperative Geological Mapping Strategies was a ten-year federal-provincial-territorial initiative to ensure that Canada’s public geoscience knowledge base continued to provide a significant competitive advantage in attracting investment in mineral and energy resource exploration in Canada.

One of the initial projects conducted by GSC-Calgary under this initiative was entitled “Energy Resources – Status of Knowledge”. The primary objective of the project was to consolidate all geoscience knowledge about the distribution of Canada’s oil and gas resources, including identification of recent knowledge gains and gap assessments resulting from recent geoscience investments by ESS, Provinces and Territories. Outputs were coordinated with the CGMS planning project for prioritizing future energy resources geoscience studies.

Secure Canadian Energy Supply Program

- Energy Synthesis Project (2003)
    - Sedimentary Basins of Canada Map (2004)

      Over many decades reference to Canada’s sedimentary basins by name and geographic position had become very inconsistent in published reports. A project to carefully name, define and describe these basins was conducted to allow consistent use of terminology in future. A large number of petroleum wells drilled in recent decades allowed a higher resolution of basin boundaries than was possible previously.

Northrock Resources Ltd., a subsidiary of Unocal, announced a significant new oil and gas discovery in the NWT and attributed NRCan's Geological Survey of Canada as a major factor in their success. A significant part of their exploration strategy in the Mackenzie Valley was based on petroleum analyses provided to them through work of the Geological Survey of Canada's (GSC) staff and laboratories. They acknowledged that the GSC's source rock assessment addressed "arguably the largest single risk factor incorporated into their investment decision".

- Two of the principle outcomes of the Geological Survey of Canada's new Secure Canadian Energy Supply Program were:
    - Reduction of risks for exploration and development; and
    - Attraction of new investments

- This was an example of how the GSC would achieve those outcomes with fundamental geoscience that directly aides the industry and encourages exploration and development.

- This also contributed significantly to an intermediate outcome of the new Secure Canadian Energy Supply Program in that exploration investment in the Mackenzie Valley exceeded $10 million per year, with new reserves exceeding 1 Tcf of gas equivalent.

Northern Resources Development Program (2004-2007)

The Northern Resources Development Program was established to create and make accessible new, comprehensive mineral and energy geoscience products, such as regional databases, maps and reports. The objective was to encourage development by raising private-sector awareness of investment opportunities in the North and reducing the risk inherent in exploration.

Geoscience in the Mackenzie Delta Region (see p. 63)

This study, led from GSC-Calgary, was initiated in response to increased demand for updated geoscience information and interpretations to support the increasing exploration and development activities in the region. Modern quantitative basin-analysis and modelling techniques were used to better understand the history of hydrocarbon generation, migration and accumulation in the Mackenzie-Beaufort Basin.

L. Lane’s camp at Shingle Point, Yukon Coast

Geo-mapping for Energy and Minerals (GEM) (2008-2013)[44]

The Government of Canada invested $100 million over five years (2008-2013) in its Geo-mapping for Energy and Minerals (GEM) program to provide the geoscience knowledge necessary for private sector exploration companies to guide investment decision, as well as for governments to make informed land-use decisions such as the creation of parks and other protected areas. GEM was delivered federally by the Geological Survey of Canada (GSC) and the Polar Continental Shelf Project (PCSP), Earth Sciences Sector (ESS), Natural Resources Canada (NRCan). GEM funding announced August 26th, 2008 by the Prime Minister of Canada was $12M for the first year, and $22M in succeeding years.

GEM focused mainly on mapping the Arctic. Modern geological methods and standards were used to identify the potential for energy and mineral resources. In large areas of the North there was insufficient public geoscience knowledge to guide and inform effective investment and land-use decisions. While new geological mapping was important to all three territories, the need was particularly acute in Nunavut and the Northwest Territories; for example, adequate geological knowledge existed for only about one third of Nunavut. GEM also filled critical information gaps in the knowledge base needed to increase exploration investment in the provinces. About 75% of the federal funds were allocated for public geoscience in the North, and 25% in the provinces. In the latter case, GEM operated on a co-funded basis. In addition, GEM emphasized the training of the next generation of Canadian geoscientists required to remedy current and future capacity gaps, and contribute to the creation and retention of prosperity and well-being in Canada's North.

GEM was delivered via three *Strategies*: GEM-Energy, GEM-Minerals and GEM-Knowledge. Partnered project portfolios were in place in Nunavut, the Northwest Territories, the Yukon and most of the Provinces, after extensive consultations with jurisdictional geoscience agencies.

The GEM-Energy Component included a project (led by D. Issler) to research the *Beaufort-Mackenzie Basin* with the purpose:

> To constrain petroleum generation, migration, & trapping histories in order to reduce exploration risk and to improve resource assessments.

[44] NRCan's Earth Sciences Sector website, February 2013

http://www.nrcan.gc.ca/earth-sciences/about/current-program/geomapping/7131

The integrated petroleum systems analysis approach was:

> To develop/use state-of-the-art methods to characterize petroleum source rocks, organic maturity, thermal history, temperature, pressure, and permafrost distribution, reservoir properties, stress regime, stratigraphy, water chemistry, fluid flow, and diagenesis.

Scientific outcomes included:

- Improved understanding of petroleum source rocks, regional T/P regime & influence of structure/tectonics; consistent with vertical migration in a leaky petroleum system
- Established a regional, process-oriented framework for ongoing studies (oil-source relations, diagenesis, regional stress, thermal history, resource assessment)

The GEM-Energy Component also included a project on the *Mackenzie Delta Corridor* (led by R. MacNaughton) with the objectives:

- To provide the first quantitative petroleum resource assessment for the region;
- To produce modern bedrock geology maps for the region around the Norman Wells oil-field; and
- To generate new data to aid oil and gas exploration.

Highlights of this work included:

- A new model for the tectonic and stratigraphic evolution of the oil and gas-bearing Cambrian basin in the northern Northwest Territories.
- Recognition that large oil and gas resource potential may exist in the offshore rift margin of the Beaufort-Mackenzie Basin, and may extend northward to offshore Banks Island.
- Improved understanding of microfossil recycling in Tertiary strata in Beaufort-Mackenzie Basin, and its implications for stratigraphic correlation.
- Development of standardized approaches for assessing thermal maturity when combining new and legacy data from vitrinite reflectance.

Section 4 – A Few Examples of Significant Accomplishments

(Excluding reference to the hundreds of bedrock geology maps produced)

The following selection of publications is a small sample intended to show the nature and scope of geoscientific research conducted by the GSC in the sedimentary basins of western and northern Canada. These reports were selected mainly from those published by the Geological Survey of Canada. A very large number of reports on GSC's research findings were published in national and international scientific journals.

1921: The Mackenzie River Basin. Canada Department of Mines, Geological Survey, Memoir 108.

1963: Devonian stratigraphy of northeastern Alberta and northwestern Saskatchewan. Geological Survey of Canada, Memoir 313.

1971: Comparative study of the Castle River and other folds in the eastern Cordillera of Canada. Geological Survey of Canada, Bulletin 205.

1973: Lower Cretaceous Bullhead Group between Bullmoose Mountain and Tetsa River, Rocky Mountain Foothills, northeastern British Columbia. Geological Survey of Canada, Bulletin 219.

1974: Triassic rocks of the southern Canadian Rocky Mountains. Geological Survey of Canada, Bulletin 230.

1975: The Cretaceous System in northeastern British Columbia; in The Cretaceous System in the Western Interior of North America, W.G.E. Caldwell (ed.). The Geological Association of Canada, Special paper 13, p. 441-467.

1975: Degree of diagenesis, stratigraphic correlations and potential sediment sources of Lower Cretaceous shale of northeastern British Columbia. Geological Survey of Canada, Bulletin 250.

1975: Upper Cretaceous stratigraphy, Yukon Coastal Plain and northwestern Mackenzie Delta. Geological Survey of Canada, Bulletin 249.

1975: Structural style influenced by lithofacies, Rocky Mountain Main Ranges, Alberta – British Columbia. Geological Survey of Canada, Bulletin 233.

1977: The origin and migration of petroleum in the Western Canada Sedimentary Basin, Alberta – A geochemical and thermal maturation study. Geological Survey of Canada Bulletin 262.

1978: Carboniferous biostratigraphy and correlation, northeastern British Columbia and southwestern District of Mackenzie. Geological Survey of Canada, Bulletin 266.

1981: Organic geochemistry of the Upper Cretaceous-Tertiary delta complexes of the Beaufort –Mackenzie sedimentary basins, Northwest Territories. Geological Survey of Canada, Bulletin 291.

1981: Cretaceous and Tertiary stratigraphy and paleogeography, northern Interior Plains, District of Mackenzie. Geological Survey of Canada, Memoir 398.

1982: Upper Ramparts River (106G) and Sans Sault Rapids (106H) map areas, District of Mackenzie. Geological Survey of Canada, Memoir 388.

1982: Jurassic and Lower Cretaceous subsurface stratigraphy of the Mackenzie Delta-Tuktoyaktuk Peninsula, NWT Geological Survey of Canada, Bulletin 349.

1982: Lower Cretaceous Fort St. John and Upper Cretaceous Dunvegan Formation of the foothills and plains of Alberta, British Columbia, District of Mackenzie and Yukon Territory. Geological Survey of Canada, Bulletin 328.

1984: Geology and depositional setting of the Late Cretaceous, Upper Bearpaw and Lower Horseshoe Canyon formations in the Dodds-Roundhill coalfield of central Alberta – A computer-based study of closely0spaced exploration data. Geological Survey of Canada, Bulletin 361.

1984: Cenozoic stratigraphy of the Mackenzie Delta, Northwest Territories. Geological Survey of Canada, Bulletin 336.

1984: The Mesozoic of Middle North America: A Selection of Papers from the Symposium on the Mesozoic of Middle North America, Calgary, Alberta, Canada, May 1983, Donald F. Stott and Donald J. Glass (eds.) Canadian Society of Petroleum Geologists, Memoir 9.

1985: Stratigraphy, sedimentology, and depositional environments of the coal-bearing Jurassic-Cretaceous Kootenay Group, Alberta and British Columbia. Geological Survey of Canada, Bulletin 357.

1986: Evaporitic deposits of western Canada. Geological Survey of Canada, Paper 85-20.

1986: The stress regime of the Western Canada Basin and implications for hydrocarbon production. Bulletin of Canadian Petroleum Geology, v. 34, p. 364-378.

1987: The Prairie Creek embayment and Lower Paleozoic strata of the southern Mackenzie Mountains. Geological Survey of Canada, Memoir 412.

1989: Uppermost Devonian and Lower Carboniferous stratigraphy, sedimentation, and diagenesis, southwestern District of Mackenzie and southeastern Yukon Territory. Geological Survey of Canada, Bulletin 390.

1989: Uppermost Proterozoic formations in central Mackenzie Mountains, Northwest Territories. Geological Survey of Canada, Bulletin 368.

1989: Coal resources of Canada. Geological Survey of Canada, Paper 89-4; (also in French: Ressources canadiennes en charbon, Étude 89-4, 152p.).

1990: Geology of the Peace River Arch, S.C. O'Connell and J.S. Bell (eds.). Bulletin of Canadian Petroleum Geology, Special Volume 38A.

1990: The gas-bearing Devonian Manatoe facies, Yukon and Northwest Territories. Geological Survey of Canada, Bulletin 400.

1990: Western Canada Sedimentary Basin - A Case History. B.D. Ricketts (ed.) Canadian Society of Petroleum Geology, Chapter 13, p. 307-320.

1990: Ordovician oil shale-source rock sediments in the central and eastern Canada mainland and eastern Arctic areas, and their significance for frontier exploration. Geological Survey of Canada, Paper no. 90-14.

1991: The Neocomian Parson Group, northern Yukon and adjacent Northwest Territories. Geological Survey of Canada, Bulletin 406.

1991: The Ice Brook Formation and post-Raptian, Late Proterozoic glaciation, Mackenzie Mountains, Northwest Territories. Geological Survey of Canada, Bulletin 404.

1991: Coals of Canada: Distribution and compositional characteristics. In: Recent Advances in Organic Petrology and Geochemistry: a Symposium Honoring Dr. P. Hacquebard. W.D. Kalkreuth, R.M. Bustin, and A.R. Cameron (eds.). International Journal of Coal Geology, v. 19, p. 9-20.

1992: 150 Years of the Geological Survey of Canada. Bulletin of Canadian Petroleum Geology, A special issue celebrating 150 years of the Geological Survey of Canada, Volume 40, No. 3, September 1992.

1992: Stratigraphy, sedimentology, coal geology and depositional environments of the Lower Cretaceous Gething formation, northeastern British Columbia and west-central Alberta. Geological Survey of Canada, Bulletin 431.

1992: Stratigraphy and sedimentology of the Lower Cretaceous Hulcross and Boulder Creek formations, northeastern British Columbia. Geological Survey of Canada, Bulletin 440.

1992: Stratigraphy of the Mesozoic strata, Eagle Plain area, northern Yukon. Geological Survey of Canada, Bulletin 408.

1992: Upper Cretaceous to Paleocene sequence stratigraphy of the Beaufort – Mackenzie and Banks Island areas, northwest Canada. Geological Survey of Canada, Bulletin 407.

1992: Foreland Basins and Fold Belts, Roger W. Macqueen and Dale A. Leckie (eds.) American Association of Petroleum Geologists, AAPG Memoir 55.

1993: Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (ed.). Geological Survey of Canada, no.5; (also Geological Society of America, The Geology of North America, v. D-1.)

1993: The Devonian succession in the subsurface of the Great Slave and Great Bear plains, Northwest Territories. Geological Survey of Canada, Bulletin 393.

1993: Evolution of the Western Interior Basin, W.G.E. Caldwell and E.G. Kauffman (ed.). Geological Association of Canada, Special Paper 89. (Numerous contributions from the staff at GSC-Calgary).

1994: Geological Atlas of the Western Canada Sedimentary Basin. G.D. Mossop and I. Shetsen (eds.). Canadian Society of Petroleum Geologists/ Alberta Research Council.

1994: Paleoenvironmental and environmental implications of the boron content of coals. Geological Survey of Canada, Bulletin 471.

1994: Structural style of the Kootenay Group, with particular reference to the Mist Mountain Formation on Grassy Mountain, Alberta. Geological Survey of Canada, Bulletin 449.

1994: Stratigraphy and coal resource potential of the upper Cretaceous to Tertiary strata of northwestern Alberta. Geological Survey of Canada, Bulletin 466.

1994: Paleoenvironmental and environmental implications of the boron content of coals. Geological Survey of Canada, Bulletin 471.

1995: Sedimentology and source-rock potential of the Lower Kaskapau Formation (Cenomanian and Lowermost Turonian), northwestern Alberta. Geological Survey of Canada, Bulletin 490.

1995: Significant Paleozoic petroleum source rocks in the Canadian Williston Basin: Their distribution, richness, and thermal maturity (southeastern Saskatchewan and southwestern Manitoba). Geological Survey of Canada, Bulletin 487.

1995: Diamond Exploration Techniques Emphasizing Indicator Mineral Geochemistry and Canadian Examples. Geological Survey of Canada, Bulletin 423.

1996: Geological Atlas of the Beaufort-Mackenzie Area. Geological Survey of Canada, Miscellaneous Report 59.

1996: Coal forming environments and sedimentology of coal-bearing formations. Proceedings of the 30th International Geological Congress, August 4-14, 1996, Beijing, China. Summary of Symposium 10-5.

1997: Exploring for minerals in Alberta: Geological Survey of Canada geoscience contributions, Canada-Alberta Agreement on Mineral Development (1992-1995), R.W. Macqueen (ed.). Geological Survey of Canada, Bulletin 500.

1997: Geology and mineral and hydrocarbon potential of northern Yukon Territory and Northwestern District of Mackenzie, D.K Norris (ed.). Geological Survey of Canada, Bulletin 422.

1997: Stratigraphy of the Middle Cambrian platformal succession, southern Rocky Mountains. Geological Survey of Canada, Bulletin 398.

1998: Permian and Triassic stratigraphy of the Mackenzie Delta, and the British, Barn, and Richardson mountains, Yukon and Northwest Territories. Geological Survey of Canada, Bulletin 528.

1998: Fernie Formation and Minnes Group (Jurassic and lowermost Cretaceous), northern Rocky Mountain Foothills, Alberta and British Columbia. Geological Survey of Canada, Bulletin 516.

1998: A Petrographic Atlas of Canadian Coal Macerals and Dispersed Organic Matter, J. Potter, L. Stasiuk and A. Cameron (eds.).

1999: Lower Paleozoic stratigraphy of northern Yukon and northwestern District of Mackenzie. Geological Survey of Canada, Bulletin 538.

1999: Sedimentology, micropaleontology, geochemistry, and hydrocarbon potential of the shale from the Colorado Group in western Canada. Geological Survey of Canada, Bulletin 531.

2000: Geology of the northeastern Niddery Lake map area, east-central Yukon and adjacent Northwest Territories. Geological Survey of Canada, Bulletin 553.

2000: An assessment of coalbed methane exploration projects in Canada. Geological Survey of Canada, Bulletin 549.

2002: Lithostratigraphy, sedimentology, paleontology, organic petrology, and organic geochemistry of the middle Devonian Ashern, Winnepegosis, and Eyot formations in east-central Alberta and west-central Saskatchewan. Geological Survey of Canada, Bulletin, 572.

2002: Sedimentology, sequence stratigraphy, organic petrology, geochemistry, and palynology of Mannville Group coals in south-central Alberta. Geological Survey of Canada, Bulletin 571.

2002: Chemical and mineralogical characteristics of the milled coal, ashes, and stack-emitted material from Unit No. 5, Battle River coal-fired power station, Alberta, Canada. Geological Survey of Canada, Bulletin 570.

2003: Deposition of trace elements in the Trail region, British Columbia; an assessment of the environmental effect of a base metal smelter on land. Geological Survey of Canada, Bulletin 573.

2004: The Horseshoe Canyon Formation in southern Alberta: Surface and subsurface stratigraphic architecture, sedimentology and resource potential. Geological Survey of Canada, Bulletin 578.

2004: Subsurface Proterozoic stratigraphy and tectonics of the western plains of the Northwest Territories. Geological Survey of Canada, Bulletin 575.

2004: Sedimentary Basins of Canada. Geological Survey of Canada, Open File Map 4673.

2006: Potential for carbonate-hosted lead-zinc Mississippi Valley-type mineralization in northern Alberta and southern Northwest Territories: Geoscience contributions, Targeted Geoscience Initiative, P.K. Hannigan (ed.). Geological Survey of Canada, Bulletin 591.

2010: Detailed outcrop measured sections of the Colorado Group in the Foothills of the Calgary region, Alberta, with reference to shale gas potential. Geological Survey of Canada, Open File 6503.

2011: GIS compilations of depth to overpressure, permafrost distribution, geothermal gradient, and regional geology, Beaufort-Mackenzie Basin, northern Canada. Geological Survey of Canada, Open File 5689.

2011: Saturate fraction gas chromatography and mass spectrometry data for selected crude oils from Triassic reservoirs in Western Canada. Geological Survey of Canada, Open File 6756.

2011: Preliminary analysis of the GIC Alberta groundwater data - a prospective data source for regional scale aquifer assessment. Geological Survey of Canada, Open File 5573.

2012: Devonian of the Northern Canadian Mainland Sedimentary Basin (a contribution to the Geological Atlas of the northern Canadian Mainland Sedimentary Basin). Geological Survey of Canada, Open File 6997.

2012: GIS-enabled structure maps of subsurface Phanerozoic strata, north-western Northwest Territories, Canada. Geological Survey of Canada, Open File 7172.

2013: Permafrost investigation by well logs, and seismic velocity and repeated shallow temperature surveys, Beaufort-Mackenzie Basin. Geological Survey of Canada, Open File 6956.

2013: A GIS petroleum prospectivity map of the northern mainland of Canada (Mackenzie Corridor). Geological Survey of Canada, Open File 7110.

2013: Fluid and gas analyses of formation waters in the Mackenzie Corridor. Geological Survey of Canada, Open File 7335.

2013: Formation water and gas analyses of the Beaufort-Mackenzie Basin. Geological Survey of Canada, Open File 5697.

2013: Stratigraphic context of petrographic samples, Katherine Group and Mount Clark Formations, eastern Mackenzie Mountains, N.W.T. in Petrographic assessment and stratigraphy of Neoproterozoic and Cambrian sandstones from measured sections, eastern Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Open File 7472.

Arctic Islands

1958: Cornwallis and Little Cornwallis Islands, District of Franklin, Northwest Territories. Geological Survey of Canada, Memoir 294.

1963: Geology of the north-central part of the Arctic Archipelago Northwest Territories (Operation Franklin), Geological Survey of Canada, Memoir 320.

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Section 5 - Vignettes

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- Helen Belyea (1913-1986)

On the occasion of the 25th Anniversary
of the
Institute of Sedimentary and Petroleum Geology

(AAPG Convention in Calgary, June 21-24, 1992)

Presented by
The American Association of Petroleum Geologists

A plaque was also presented to the Institute of Sedimentary and Petroleum Geology, with the following inscription:

RESOLUTION OF APPRECIATION

Whereas, the Institute of Sedimentary and Petroleum Geology is celebrating its twenty-fifth anniversary; and

Whereas, The Institute has made significant contributions to the science of geology of great benefit to petroleum geologists in Canada and throughout the world;

Be it resolved by the Executive Committee of the American Association of Petroleum Geologists, that the Institute of Sedimentary and Petroleum Geology be congratulated on the occasion of its twenty-fifth anniversary and commended for the excellence of its past and ongoing contributions to our science and profession.

Assessing Canada's Oil and Gas Potential
(Extracted from: Proctor, R. and Taylor, G., 1992: GEOS, Vol. 21, No. 1, winter/spring 1992)

How much oil and gas does Canada have?

Policy-makers at Canada's Department of Energy, Mines and Resources placed that question before the GSC early in 1972, launching the first of three phases of modern resource analysis within the Survey. At the time, politicians were concerned about Canada's long-term energy supply and the wisdom of ever-increasing oil exports.

The department also felt it needed an independent assessment of the nation's petroleum resources instead of relying on data produced by the petroleum industry. The GSC had a long tradition of studying Canada's resources – recognizing early on the importance of the Athabasca tar sands and the significance of oil and gas discoveries in the western provinces in the 1920s. But it had not yet developed a program for preparing quantitative estimates of oil and gas.

GSC scientists began by devising a rather crude volumetric methodology, incorporating the 'new' concept of expressing the uncertainty associated with the estimates. Those estimates were revised in 1973 using a much improved approach that recognized the number and type of petroleum plays (a collection of geologically related prospects and oil and gas pools having the same history of development) in each basin. This play approach, known within the resource analyst community as the 'Canadian' method, became the basis of all future estimates.

Phase two of GSC resource analysis occurred when planners, wishing to develop forecasts of future supply and economics, realized that questions such as the size, character and number of individual petroleum accumulations were more important than the total quantity of resources alone. The GSC needed to acquire and consider much more geological data and to devise new methods of interpretation. Survey researchers continued to develop and expand computer-based methodology with probabilistic and statistical analyses of potential, using working committees of experts for each element. Knowledgeable scientists were drawn from different parts of GSC as well as from other sectors of EMR, Indian and Northern Affairs, and the National Energy Board.

By the early 1980s, the department formally created a Petroleum Resource Assessment Panel (PANEL) to both report resource estimates and provide a mechanism for setting priorities for future studies. PANEL topics required analyses with very specific time deadlines on such issues as frontier exploration incentives, pipelines, northern development, sovereignty, boundary disputes and gas export justification. To be effective, results had to be delivered on time, and

GSC quickly developed an enviable reputation by producing more than 50 petroleum resource reports up to 1990.

The third phase of GSC resource analysis development occurred as the PANEL sought to fully integrate studies of petroleum reserves, potential and supply economics. This required a higher level of database integration and development of additional data from the resource analysis program. In 1988, the Publication of “Conventional Oil Resources of the Western Canada” began the practice of releasing resource assessments, geological framework and supply economics as separate parts of a single document.

The GSC’s on-going research program in resource evaluation methodology has made it an internationally recognized leader in the field. Methodology developed by GSC is now being used in China, several countries in Southeast Asia, South America, Europe and North America, partly as a result of international assistance programs and sponsorship of the International Union of Geological Sciences.

Examples of petroleum resource reports - ”Blue Books”

Change Flows from Tradition
(Extracted from: Energy, Mines and Resources, Entre nous, Vol.8 no. 6, September 1990, p. 4.)

Why do scientists join and stay with the GSC, the country's oldest scientific service? Because the GSC's tradition of excellence binds and obligates all members – mostly for a professional lifetime.

During the last decade a new challenge has been recognized and accepted to sustain and help cure our global environment.

"One must look back at 1842 when the GSC was formed, and when its standards of excellence were established," explained Walter Nassichuk, Director of the Survey's 23-year-old Institute of Sedimentary and Petroleum Geology (ISPG) in Calgary.

This division assesses the sedimentary basins of western and Arctic Canada and the nation's fossil fuels and is also the GSC's highly respected centre for palaeontological and geochemical research.

Nassichuk stressed that old traditional standards are of particular importance now, at a time when "global change in our environment has given a new dimension to our work".

"To our traditional tasks of nation's surveyor and explorer and adviser to government has been added assessor of man's impact on the environment."

"This new role encompasses even more," Nassichuk went on. "It requires an awareness of a scientist's obligation to society in general. It includes visiting our schools to teach students the merits of science, for example, in understanding our environment."

"We need to promote interaction between universities, governments and industry in Canada if we want to get the most out of our national scientific resources. Without such interaction there would be few major scientific breakthroughs in Canada."

"So, in addition to providing data to industry and government we now must add to our scientific mandate a greater social responsibility: We must be conscious of and respond to society's needs."

Nassichuk related how the ISPG's northern observations complemented the government's current Green Plan "which suggests that all of our activities have an environmental connotation."

Nassichuk recalled a field trip in 1975 to Donets Basin, the coal-based industrial heartland of the Ukraine. “The terrible smog and pollution was ignored in favour of getting bread on the table. Now they have recognized that this pollution affects the very bread they were talking about.”

Nassichuk’s point is that the necessary research into the chemical composition of coals and their environmental effects have been ongoing at the ISPG for years at a time when other nations are only beginning to look at this problem.

Indeed, a recognition of ISPG’s competence recently came from the Soviet Union. The All-Union Scientific-Research Geological Institute of Coal Deposits formally requested collaborative research with the ISPG.

The ISPG’s environmental concern for the Arctic went on red alert during a visit to Moscow in 1984 by Nassichuk, Bill Hutchison (then head of GSC), Bernie Gingras (National Research Council), George Hobson (Polar Continental Shelf Project) and Vera Lafferty (EMR).

Mineral exploration and exploitation, especially of oil and gas, had taken place in the Soviet Union, notably in Siberia. “An explosion of activity had compromised the environment,” Nassichuk recalled.

He pointed to the major gas pipeline leading from the Urengoi terminal in western Siberia to central and western Europe, and a considerable domestic pipeline network, “all crossing mountain ranges, rivers, forests and swamps and some of them scouring Arctic terrain.”

“As well, at least five major river systems are draining from the Soviet Union into the Arctic Ocean, carrying along pollution from all parts of the country. There, those pollutants mix with others introduced by all Arctic nations and seriously affect mammals at the end of the food chain.”

“The Arctic Ocean is a major engine of global climate,” Nassichuk explained. About 85 per cent of the drainage from the industrialized part of the Soviet Union pours into the Arctic Ocean and the chemistry of the ocean influences Arctic climate. Clockwise circulation in this largely ice-covered ocean eventually brings all of the pollutants our way.”

“Situated between two superpowers during the Cold War, we were aware that Canada could serve as an environmental intermediary. So we helped set up the 1984 Canada-USSR protocol on Arctic co-operation which since has become an international model.”

“Our institute has been intensely involved with the geoscience and petroleum ‘theme’ of this Arctic agreement.”

Soviet President Mikhail Gorbachev's famous Murmansk speech in 1987 brought official recognition that the exploitation of Arctic resources was causing social problems, that social costs could exceed perceived economic gains.

"During the early 1970s we had the first perturbations about the environment. During the last decade our stance has changed to proactivity, and in conjunction with the USSR we have actually been doing something about it," Nassichuk concluded .

Digby McLaren, ISPG's first Director (1967-73), now retiring and President of the Royal Society of Canada, considers Walter Nassichuk to be the embodiment of the message contained in the title of this article. "A gifted field geologist, Nassichuk quickly made his mark with a series of paleontological and stratigraphic publications arising from his own field observations in Western and Arctic Canada. His discoveries led to worldwide recognition including his appointment as Secretary of the International Commission on Stratigraphy. His influence was central at a time when the global basis for geological correlation was being worked out. He was ambassador for Canadian science, universally liked and respected. Latterly, his encyclopedic knowledge of the environment and fuel resources of Canada, coupled with wise leadership, have added to ISPG's reputation as an important contributor to economic and environmental geology based on good scientific research."

Canadian Society of Petroleum Geologists

President's Special Recognition Award
Presented to
The Geological Survey of Canada (Calgary)
December 9, 2008

For outstanding technical programs and projects, for sharing geoscience knowledge, for transferring technologies, and for collaboration with industries, universities and other governments. All of which are vital to support exploration and development of Canada's natural resources, and to the creation of wealth in our nation.

and

In recognition of the contributions made by GSC (Calgary) to the CSPG. The CSPG would not exist today without the dedicated volunteer participation of the Calgary GSC staff and the strong support of the GSC over the last four decades.

Canada, Soviets Forge New Links
(Extracted from: Horst Heise, Calgary Herald, 5 September 1989.)

A good measure of a program's success is the resulting response.

For the Institute of Sedimentary and Petroleum Geology, response to its work under Canada's Artic co-operation agreement with the Soviet Union has been most rewarding.

Predictably, this also is stretching the budgetary and personnel limits of the institute, the Calgary-based sedimentary and Arctic arm of the Geological Survey of Canada.

ISPG director Dr. Walter Nassichuk said during an interview: "Basically all Soviet scientists visiting Canada come here (to the ISPG)".

Not surprisingly then, on his visit to the Soviet Union this month, he also has to look up contacts and give lectures in, for instance, Baku, Sinferopol, Sebastopol, and other localities.

Nor do the requests stop there. The ISPG contacts in the Soviet Union "also want to know from me how to establish joint ventures with the oil industry here. This has gone to the point of one minister asking to change dates so that he could establish meetings, with trade and related topics in mind."

That's gratifying in that it shows that visitors to the ISPG have come to trust and rely upon it. It also is a reflection, perhaps, of the makeup and interrelationships of the various oil industry and scientific establishments in the Soviet Union.

Nevertheless, Nassichuk feels that he "is filling a void here which really is not my department's task, although it is interesting for me, personally. Other (Soviet) agencies are approaching us for linkages on other than Arctic issues, say about oil and gas.

"So this institute is recognized as an authority on oil and gas. We have no official mandate for this (the resulting special requests), but maybe there is a linkage which can be established."

Ever the discreet civil servant, he wouldn't expand on the issue but one would think that, for instance, External Affairs or International Trade would be interested.

And still, that's not enough. Somehow, the oilpatch must be involved, perhaps in a way which takes account of the still-entrenched departmentalization of the Soviet Union. It's a topic worthy of detailed discussion between our oil industry associations.

The new attitude is don't hide, but have a mutual exchange instead. "Since (Soviet Leader Mikhail) Gorbachev's Murmansk speech there has been a Russian will to be part of the Arctic nations. The next meeting will be in Leningrad Sept. 24-26," Nassichuk said.

"This is helped by the recognition of the Arctic Ocean driving the global climate. Out of all this has come the realization that the Arctic environment is increasingly important."

Geologists now are looking at very recent sedimentary deposits in lake bottoms and peat bogs, to get, for instance, carbon content cycle data: do the Arctic Ocean and lakes act as carbon sink for the CO2-content of the atmosphere?

"There is this recognition by a number of establishments in the Soviet Union (of our scientific expertise), prompting their thinking that we can provide (guidance)."

While the two countries have had a general agreement for exchanges since 1971, and for scientific and technical co-operation in the Arctic and the North since 1984, advances in dealings under the agreements really go back to the Gorbachev phenomenon. Since his 1987 speech in Murmansk, and the subsequent meeting (on Arctic problems and co-operation) in Leningrad last year, things have moved.

"Prime Minister Brian Mulroney will visit Gorbachev in November. He wants to sign this (already active) scientific agreement with the Soviet Union. We quietly hope that the PM will see fit to give his host a copy of the circumpolar geological map as a sign of what has been accomplished under the agreement."

It's the first production of the joint Arctic geology program, containing the work and data from both sides, and was just printed in Canada. A second map on the Quaternary (recent surface deposits) also is ready for printing in the Soviet Union.

Nassichuk readily admits that, yes, there is "pride about the degree to which this institute has interacted with the Soviet Union and its agencies."

Diamond Indicator Minerals
(A note by W.W. Nassichuk, Director of ISPG)

Stewart Blusson and Charles Fipke, co-discoverers of the Ekati Mine in the Slave Craton, were exploring for diamond indicator minerals when I met them while I was doing field work on Ellesmere Island in the summer of 1982. Stewart and I were classmates in geology (Class of 1960) and after receiving his PhD from the University of California (Berkeley) in 1964, he joined the Geological Survey of Canada. He conducted field work in the Yukon with the Survey until 1991, when he resigned to devote all his time to prospecting for diamonds with his friend and colleague, Chuck Fipke.

Following lengthy discussions on the geology of Ellesmere and adjacent islands, Chuck invited me to visit his heavy minerals laboratory (C.F. Minerals Ltd.) in Kelowna and to give a talk on Arctic geology to the Kelowna Prospectors Club. I was highly impressed with the scientific rigor and quality controls exhibited by technicians in his laboratory and encouraged C.F. Minerals to bid on a contract that the Survey in Calgary had recently opened to separate phosphatic conodonts from limestones. I was Director of the Calgary office at the time. C.F. Minerals won the contract and provided excellent service to our Calgary Paleontology Laboratory for the next 4 years.

Between 1982 and 1984, I delivered 3 more talks to the Kelowna Prospectors, but in that period, I also learned about extraordinarily important research that Chuck was conducting on Diamond Indicator Minerals with Professor John Gurney, the world's leading authority on diamond chemistry in South Africa. Chuck was conducting his diamond research and field work on borrowed money, but time was running out on him and bankers were threatening him with foreclosure. I expressed great concern about the possible collapse of his research with John Gurney and promised that I would try to help him find a solution to his financial problems.

In 1983, I was working with other Survey managers trying to get a significant infusion of new resources into the Survey through the "Frontier Geoscience Program". This proved successful and new monies were made available to the Calgary Office for Arctic work at the beginning of the 1984 fiscal year. I failed however to convince other managers in Ottawa that FGP money should be expended on Diamond Indicator Minerals; the prevailing view at the time was that commercial diamonds in Canada was a "pipe dream". Nevertheless, I also learned early in 1984 that the Federal Department of Supply and Services had opened up an "Unsolicited Proposal Program" whereby research proposals from industry might be funded if they were deemed to have potential economic merit and if the proposal would be supported to some minimal extent by a government department. Accordingly, C.F. Minerals submitted an "unsolicited proposal" to Supply and Services and I agreed to review the proposal, which I did and committed $20,000 from 'my' budget should the proposal be accepted for funding by Supply and Services. In short, the proposal was funded and Chuck Fipke received $300,000 to continue with his Diamond Indicator Mineral research. The project was managed by me and resulted in production of a 1200 page report, which was submitted to the Calgary Survey office, and the publication of a GSC Bulletin on Diamond Indicator Minerals.

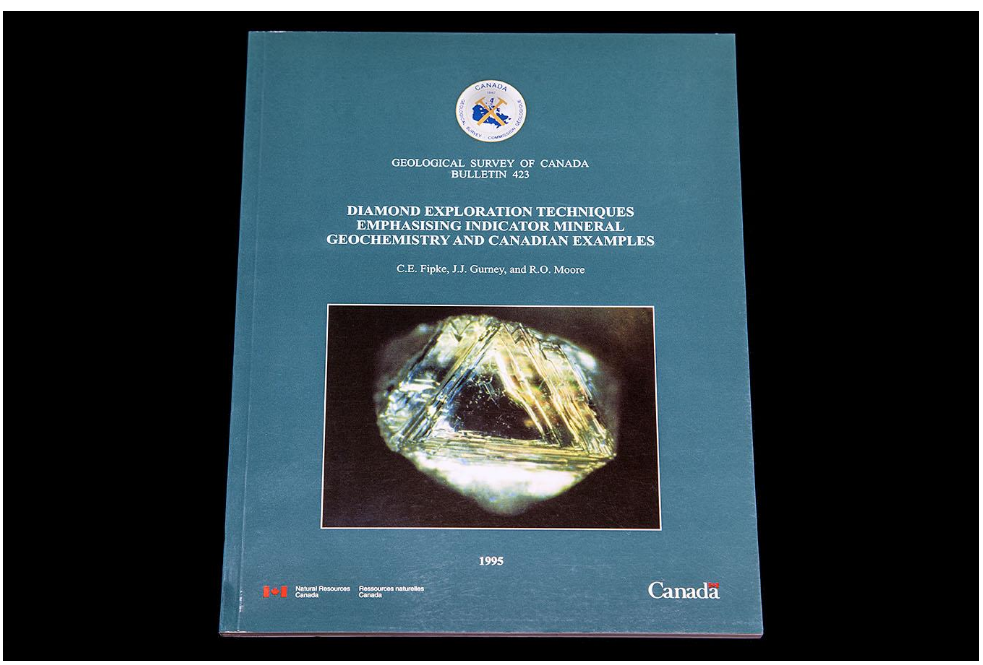
By 1986, it was completely evident that the research was successful and new techniques were employed to assess the economic potential of kimberlite pipes by examining the chemistry of mineral populations that were formed under the same pressure and temperature conditions as diamonds deep within the earth's crust. Using this technology, the discovery hole for the Ekati "play" was drilled in 1991 and abundant diamonds were found in the core along with all the indicator minerals that were anticipated to be associated with the diamonds.

Chuck Fipke insists to this day that without the help of the Survey in funding his chemistry project at a crucial time, diamonds might never have been discovered in the Slave Craton.

(Signed by: W.W. Nassichuk)

In the cover of a copy of their Geological Survey of Canada Bulletin 423 on "Diamond exploration techniques emphasizing indicator mineral geochemistry and Canadian examples", Chuck Fipke, John Gurney and Rory Moore wrote

> *"To our undying friend Walter Nassichuk, whose sole support provided the first diamond exploration technology for Canadian mining and ultimately provided the foundation for the discovery of the NWT diamond project and mine."*



Former Director of ISPG Retires
(Extracted from: Energy, Mines and Resources, Entre nous, Vol.8 no. 6, September 1990, p. 4.)

Officially, Don Stott retired in December, 1989 after 34 years and five (student) summers with the GSC.

Excepting his years as Director of the Institute of Sedimentary and Petroleum Geology (ISPG) from 1973 to 1980, Stott has been out in the field pretty well every year. In the early years that meant backpacking, loading packhorses and travelling by canoe much of the time.

Hired in 1957, the GSC sent him to Calgary in 1961. “In those days our Calgary library could be listed on three, double-spaced pages. Today, the ISPG library is one of the best, holding more than 100 000 volumes,” he said.

“My research has focused on northeast B.C., with some work in the Alberta foothills, some in the Northwest Territories, and some in the Arctic. But the Cretaceous of northeast B.C. has remained may main interest all along.”

Walter Nassichuk, ISPG’s current and longest-serving director, observed that by 1980, “Don had become the leading authority on Jurassic and Cretaceous lithostratigraphy of the Eastern Cordillera and Western Great Plains area.”

“Stott’s studies have been fundamental in the exploration and exploitation of coal and hydrocarbons, and have played a key part in their discovery,” Nassichuk emphasized.

Stott’s work in the Arctic resulted in the first comprehensive map of Ellef Ringnes Island and was instrumental in later discoveries of natural gas.

He was also an active participant in professional societies, serving, for instance, as President of the Canadian Society of Petroleum Geologists.

During his term as Director of the Institute, Stott saw a boom in the oil industry. “Digby (McLaren, ISPG’s first director) and I lived through the golden years. There was tremendous research into coal, starting in the 1970s, and petroleum and Arctic research was emphasized.”

“The evolution of the oil industry was paralleling ISPG’s own evolution,” Nassichuk filled in. “This has continued from the early days under Digby McLaren over Don Stott to me.”

“The Institute’s staff has quadrupled to about 160 people,” Nassichuk continued. “ISPG’s total budget in 1967 was close to 2 million dollars and today it is about $15 million.”

Nassichuk stressed the continuity of ISPG's standards and attitudes under its three directors, "Each contributed in his own way." For instance, each continued to pursue his scientific studies.

Don Stott distinguished himself through extraordinary geological accomplishments in Western and Arctic Canada and he will be sorely missed in the geoscience community in Calgary. Nevertheless, as he settles into retirement in Victoria there is no doubt that a principle love in his life – Cordilleran geology – will continue to attract much of his attention.

Don Stott – Director ISPG, 1973-1980

Walter Nassichuk – Director ISPG, 1980-1991

Raymond Thorsteinsson (1921-2012)
(Written by Walter Nassichuk and Tom Frisch, May 2012.)

Raymond Thorsteinsson OC, PhD, FRSC, one of Canada's most highly honoured geologists, died in Calgary on 23 April, 2012 at the age of 91. Ray began working for the Geological Survey of Canada (GSC) as a summer field assistant (1945-1951), then as full-time geologist from 1952 until he retired in 1992. Following retirement, Ray remained with the Survey as an Emeritus Research Scientist for the rest of his life.

During the 62 years, including 39 field seasons that Dr. Thorsteinsson spent studying the geology of Canada's Arctic Archipelago, he produced 80 benchmark geological maps, books and other publications, all of which were fundamental to the discovery of important mineral and petroleum occurrences within the high Arctic. At the time of his death, Ray had already been recognized as a legend in the Arctic Islands for decades. Indeed, no name is more inextricably linked to the geology of those islands than his and it is quite unlikely that his record of achievement in mapping, stratigraphy and paleontology will ever be duplicated.

Ray was born in Saskatoon in 1921, the second of five children born to his Icelandic-Canadian father, Peter Thorsteinsson, and his English-Scottish mother, Elizabeth (nee Readman). In 1905, the Thorsteinsson family established a homestead overlooking Big Quill Lake in the area of the town of Wynyard, which is about132 kilometers west of Yorkton, Saskatchewan and some of that original homestead still bears the Thorsteinsson name. Ray was proud of his Icelandic heritage and he learned to speak the language as a child in order to communicate with his unilingual (Icelandic) grandparents.

Even as a child, when he milked cows and worked in the grain fields on his farm during the "Dust Bowl" and Depression in the 30's, Ray always found hard work to be rewarding. In his spare time, he took long hikes to observe the abundant diversity of wildlife in the area and to hunt for arrowheads and other native artifacts. Those activities inspired his life-long interest in exploration and particularly in paleontology.

Throughout his life, Ray never failed to return to his home farm in Wynyard, sometimes several times a year, to help his closely-knit family with farm work and to hunt for geese and ducks with his father and older brother, Stanley. Ray was always fascinated by astronomy and his daughter, Anna explained that when she and her brother Erik were still small children, their father always enjoyed identifying specific stars and constellations for them on the farm where the night sky always seemed brighter than in the city. Ray's sister, Thora often accompanied Ray and his family when they drove from Calgary to Wynyard and she explained that Ray loved to listen to classical music and, occasionally a few popular songs during the trip. Moreover, Ray also enjoyed playing his mouth organ on the farm, and his rendition of “Freight-Train” was always a special treat for Thora.

In 1944, Ray took his B.A. degree in geology from the University of Saskatchewan. There, he was recognized as a promising scholar as well as a skilled boxer in the university’s sports program. In late December, 1944, Ray married Jean Kristjansson, from Leslie, Saskatchewan who bore him Erik, in 1945, and Anna Ingrid in 1961. “Jeannie” was the special joy in Ray’s life and she provided him with inspiration as well as the domestic stability that enabled him to spend extraordinarily long seasons in the field and long days in his office up until the time she died, in 1998.

From the time Ray graduated from the University of Saskatchewan in 1944 until he completed his master’s degree in Toronto in 1949, he worked on field mapping parties for the Geological Survey, first, with Dr. Stan Duffel in the Ashcroft-Lillooet area in southern British Columbia, then with Dr. R.J.W. (Bob) Douglas in the Livingstone Range in southwestern Alberta (1946-1947) and finally, as leader of his own field party at Grande Cache, in west-central Alberta (1948, 1949). While working in the field with Bob Douglas in 1947, Ray told him that he had read a number of books written about the Arctic by the great Icelandic-Canadian explorer, Vilhjalmur Stefansson and that he, himself would also like to work in the Arctic someday. Bob promised that he would pass that information on to the Director of the GSC in Ottawa.

In 1949, when Ray was completing his Master’s degree at the University of Toronto and was preparing to leave Toronto to begin his PhD studies at the University of Kansas, Tim Tozer arrived at Toronto to complete his own graduate studies. They became close friends and both joined the GSC on a permanent basis in 1952. Subsequently, they worked together in the field for more than a decade and published many papers together on new and important geological phenomena within the Arctic Archipelago.

Following the completion of his M.A. degree at Toronto in 1949, Ray began his PhD studies in Kansas under the direction of the renowned paleontologist, R.C. Moore. In early 1950, Ray was invited to join Dr. Yves Fortier in the Arctic Islands to initiate geological investigations and the preparation of reconnaissance maps for Cornwallis and Little Cornwallis islands. Ray was ecstatic and quickly accepted the invitation.

Throughout his career, Ray was often asked about the circumstances that led to his working in the Arctic Islands in the first place. He was always quick to credit his friends Bob Douglas and Yves Fortier for “that particular stroke of luck”. Sometimes, he would add that Winston Churchill also played a role in that decision. Indeed, when Churchill delivered his famous “Iron Curtain speech” at Westminster College in Fulton, Missouri, in March 1946, he announced that the “Cold War” had already begun and that he was worried about Stalin’s ambitions along the Soviet Union’s Arctic frontier. America suddenly became terrified by the possibility of some sort of Soviet incursion into the North American Arctic. Within a few months of Churchill’s speech, an American icebreaker and several supply ships travelled westward to Melville Island to select sites suitable for the construction of a network of joint Canada-U.S. weather stations. The purpose, of course, was to record precise meteorological, data and to “keep an eye” on the Soviet military. By 1950, five weather stations were operational across the Archipelago at Resolute, Mould Bay, Eureka, Isachsen and Alert. The presence of such a network of stations inspired the Geological Survey to initiate a new, modern era of accelerated research and mapping in the Arctic Islands by utilizing the network’s air strips and communication facilities.

In early June, 1950 Ray travelled to Edmonton to meet Yves Fortier and his other assistant, Trevor Harwood an engineer with Canada’s Defence Research Board, who had previously worked for the Hudson Bay Company in the Arctic Islands. It was Dr. Fortier’s plan to initiate the mapping of Cornwallis Island by circumnavigating it in a seven meter freighter-canoe powered by a five horsepower outboard motor. Accordingly, they flew to Resolute Bay in the cargo area of an R.C.A.F. Lancaster Bomber, with their large freighter-canoe squeezed into the bomb bay. It was Ray’s first flight to the Arctic and indeed, his first flight in an airplane. Moreover, it was a terribly cold flight because the large freighter-canoe prevented the bomb bay doors from closing properly and the temperature in the cargo area was well below zero. Upon arrival in Resolute, Yves, Ray and Trevor discovered that the sea-ice was completely locked against all the shores of Cornwallis Island, rendering travel by canoe impossible. Accordingly, they conducted traverses on foot around Resolute Bay to gain at least a simplistic impression of the geology in the area.

While waiting for the sea-ice to disappear from Cornwallis Island, Ray and Yves were invited by J. Glen Dyer, Chief of the Arctic and Antarctic weather stations for the U.S. Weather Bureau to accompany him on a “mail run” to the new weather stations to the west, at Mould Bay on Prince Patrick Island and to the north, at Isachsen on Ellef Ringnes Island. Visibility was unlimited and the pilots flew their U.S. Air Force DC-4 as high or as low as Ray and Yves required and they even circled around to give a better view of the geology. Shortly thereafter, Ray and Yves accepted another invitation by Dyer to ride along on another mail run to Eureka on northern Ellesmere Island.

By mid-July, the sea-ice finally began to disappear from the shores of Cornwallis Island, and on July 21st, Ray, Yves and Trevor loaded their freighter canoe with some 4,000 pounds of fuel, provisions, and other equipment and departed from Resolute Bay. Their first stop was Assistance Bay, eight miles to the southeast of Resolute Bay, where the ships of Captain Penny and Sir John Ross spent the winter of 1850-51 while searching for the lost Franklin Expedition. In spite of encounters with polar bears and walruses, Ray and his companions successfully circumnavigated Cornwallis Island, without maps, but with the aid of British

Admiralty charts on August 22. The geological structure and stratigraphy of the island were far more complex than Yves had anticipated so he invited Ray to continue with the mapping project on his own, and to develop his PhD dissertation from the project.

The very next summer (1951) Ray revisited the south coast of Cornwallis Island and discovered a note that was left in a cairn east of Assistance Bay by Captain Sir John Ross who had been searching for the lost Franklin Expedition exactly 100 years earlier, in 1851. It was common practice for early explorers to leave written records describing their discoveries in cairns built up from loose rocks. Two years later (1953) Ray completed his field studies on Cornwallis and Little Cornwallis islands. He submitted his dissertation to the University of Kansas in 1954 and was awarded his PhD degree in 1955.

The reconnaissance flights to Mould Bay, Isachsen and Eureka that Ray and Yves undertook in June, 1950, while waiting for the sea-ice to leave Cornwallis Island, proved to be invaluable for interpreting the tectonic and structural character across much of the Arctic Archipelago. They had observed the magnificent sequences of folded Paleozoic rocks on Bathurst and Melville islands (Parry Island Fold Belt) which were overlain by little-deformed Mesozoic strata on Melville Island. Moreover, they saw, on the Ringnes islands and Axel Heiberg Island, numerous piercement structures (salt domes) poking through the Mesozoic strata.

Building upon those observations and the published literature, they coauthored an insightful summary paper with A.H. McNair describing the structural character of the vast territory between northern Greenland and the Beaufort Sea. Moreover, they included in that report the first published statement on the prospects for petroleum exploration and discovery within the Arctic Islands.
In 1955, Ray and Tim Tozer participated in Yves Fortier's large, helicopter supported "Operation Franklin," which was based in Eureka, on northern Ellesmere Island and which resulted in geological maps and reports covering at least 260,000 square kilometers across much of the archipelago. During Operation Franklin, Ray assumed responsibility for describing upper Paleozoic (Carboniferous and Permian) stratigraphy and Tim, the same responsibility for Mesozoic stratigraphy.

During the Spring of 1956 and 1957 Ray and Tim used two sleds, 20 dogs and two Inuit dog-drivers to enable them to travel quickly over the sea-ice into the narrow, often steep-walled fiords of northern Axel Heiberg and northern Ellesmere islands to examine rock successions. Moreover, they collected abundant fusulinaceans and ammonoids, which they identified to establish biostratigraphic frameworks for their upper Paleozoic and Mesozoic sequences.
In 1958, Ray and Tim pioneered the use of low pressure tires on a fixed wing Piper Super Cub aircraft to map the western Queen Elizabeth Islands, an area of some 34,000 square kilometers, approximately the size of Vancouver Island. In

achieving that goal, their pilot, the renowned Arctic aviator Welland (Weldy) Phipps (O.C.) flew 300 hours and made some 400 landings with either Ray or Tim aboard. In 1959, Ray and Tim were joined by R.L. Christie and J.G. Fyles in successfully mapping the geology of Banks, Victoria and Stefansson islands, using two Super Cubs with oversize low-pressure tires.

Ray's knowledge about the history of exploration in the Arctic Islands was truly encyclopedic and he gained abundant geological information from books and other reports written by, and about the early explorers. Indeed, during the 1958 field season, Ray found cairns holding the records of discovery of W.E. Parry (1820) on Melville Island, F.L. McClintock (1852) also on Melville Island and Vilhalmur Stefansson (1915) on Brock Island. The most memorable recovery for Ray was the record of Stefansson, who had discovered Brock, Borden, and Mackenzie King islands in 1915. In 1958, Ray and E.T. (Tim) Tozer located Stefansson's cairn on Brock Island and retrieved his discovery message from it. Stefansson had named Brock Island for Dr. R.R. Brock who was the Director of the Geological Survey of Canada, which had provided some financial support for Stefansson in 1915. In 1959, Ray delivered several talks to the Geology Department at Dartmouth College in Hanover, New Hampshire, where Stefansson lived. Ray showed Stefansson his Brock record, 44 years after Stefansson had written it and was delighted to hear Stefansson say that he thought it particularly fitting that another member of the Geological Survey and fellow Icelandic-Canadian should have headed the second party to visit Brock Island.

By 1960, Ray and Tim had already assembled sufficient structural and stratigraphic data to define the Sverdrup Basin, which extended along the northern and western islands of the Archipelago, which contained, in the main, at least 13 kilometers of upper Paleozoic and Mesozoic strata.

Between 1961 and 1986, a total of 176 wells were drilled in search of petroleum in the Arctic Islands, mostly within the Sverdrup Basin where significant oil and gas resources were discovered. It is quite clear that Ray and Tim were the "guiding lights" for most of that extraordinary period of exploration.

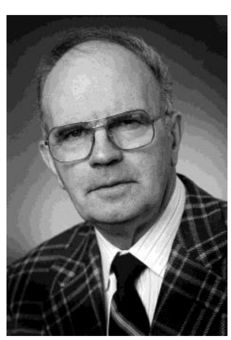
Ray continued to map the geology and refine the upper Paleozoic stratigraphy of Axel Heiberg and Ellesmere Island for decades beyond 1960 and, in 1974 his benchmark paper on the subject (GSC Bulletin 224) was published, along with 15 new geological maps.

Paleontology was Ray's special passion and all through his career he assembled huge collections of time sensitive fossils, such as the lower Paleozoic graptolites and upper Paleozoic fusulinaceans that he studied and identified in order to determine their precise ages. He was extraordinarily versatile and became a well recognized authority on the taxonomy and biostratigraphy of both of those fossil groups. Ray received plenty of encouragement from R.C. Moore, his former mentor at the University of Kansas, who stressed that time, determined from the relative ages of fossils was one of the most important fundamental constituents of stratigraphy.

Ray was also recognized globally as an authority on primitive jawless fish-like creatures known as heterostracans, of Silurian and Devonian ages. Heterostracans have an anterior exoskeleton comprised of bony plates and belong to the same phylum as man, himself. Ray began collecting these fossils from Somerset, prince of Wales, and other small islands near southern Cornwallis Island during the 50's and 60's and had studied them with specialists in Stockholm, Sweden (1965-1967). After many decades of painstaking study, Ray had nearly completed a huge and highly important monograph on his Arctic heterostracans at the time of his death. However, plans are already well advanced to publish that work posthumously.

Ray was widely praised for both his geological and geographical accomplishments and received many prestigious awards, including the Founders Medal, Royal Geographic Society, London, for distinguished contributions to exploration and development in the Canadian Arctic, 1969; Willet G. Miller medal, Royal Society of Canada, for outstanding achievement in earth sciences, 1973; Logan Medal, Geological Association of Canada for outstanding contributions to geology, 1979; Massey medal, Royal Canadian Geographical Society for outstanding personal achievements, 1981; R.J.W. Douglas medal, Canadian Society for petroleum Geologists for outstanding achievements in geology. In 1983, Dr. Thorsteinsson was designated "Member" of the Order of Canada and in 1989, he was upgraded to "Officer" of the Order of Canada.

Dr. Raymond Thorsteinsson was a gracious, self-effacing, innately modest man who was revered and loved by all who knew him and worked with him. His work ethic in the field and in the office was nothing short of legendary, but nevertheless, he had a delightful sensed of humour and loved to laugh. His interests were broad and varied, ranging from history and politics to classical music and poetry. It was indeed Canada's good fortune to have had Ray's brilliant leadership to resolve the geology of her northernmost Arctic territory for more than six decades. He was a delightful friend and companion in the field and he never tired of explaining the geology and history of exploration of the Arctic Islands to us from his vast reservoir of knowledge on those and many other subjects.



Helen Belyea (1913-1986)
(Extracted from: Digby J. McLaren, F.R.S.C., 1987: Helen Belyea 1913-1986, Transactions of the Royal Society of Canada, Series V, Volume II.)

Helen Reynolds Belyea, who had been associated with the Geological Survey of Canada for forty-one years, died in Calgary on 20 May, 1986, at the age of seventy-three years. Born in St. John, New Brunswick, on 11 February, 1913, from united Empire Loyalist stock of French Huguenot origin, she received her earlier education in St. John, her B.A. and M.A. in geology from Dalhousie University, her PH.D. from Northwest University with a thesis on “The Geology of Musquach Area, New Brunswick.” She began World War II as a high school teacher and ended as a lieutenant in the navy’s WRCNS. In 1945 she joined the Geological Survey of Canada as a sub-surface stratigrapher.

The discovery of oil in the Devonian rocks at Leduc, Alberta, in 1947 sparked a decision by the Geological Survey to establish an office in western Canada, and in 1950 the Calgary office was opened; the first geologists were R.T.D. Wickenden and Helen Belyea. This small beginning led eventually to the formation of the Institute of Sedimentary and Petroleum Geology, which was opened in 1967. Although described as a sub-surface geologist, Dr. Belyea developed, in fact, into a field geologist of considerable ability and looked at rocks wherever she could find them, from the tops of mountains to the bottoms of oil wells. As a result of Leduc, she began work on the rocks in which the discovery was made - the Devonian System. She spent her life explaining and synthesizing knowledge of these important and difficult rocks over the vast region of the western sedimentary basin from the Montana border to the Mackenzie River country, and from the Canadian Shield to the Rocky Mountain Trench. In the early 1950s her concepts were few. Little was known about limestones, and less about the detailed structure of reefs and their disposition and relations with adjoining sedimentary basins. Through the 1950s and 1960s concepts changed and interpretation was built on evidence from increased drilling activity as well as increased field work. It was in this environment that Helen undertook the unending task of trying to put sense into the Devonian of the Western Plains.

In her paper, “Notes on the Devonian System of the North Central Plains of Alberta” (1952), she plunged straight into the maelstrom of trying to understand the facies relations in the upper Devonian and the meaning of the reef-off reef sequences. This was followed in 1955 by another important paper on “Cross-sections through the Devonian System of the Alberta Plains,” which outlined the southern margin of the reef complexes and began what was almost a lifetime wrestle with the problems of relationships in the upper part of the succession, above the Woodbend reefs and biostromes. The reef pattern was becoming known, and in this paper she brought together much information. In all this she rapidly won the support and approval of her colleagues in industry, and indeed, they were well served.

In the late 1950s the Geological Survey was mapping in the southern Northwest Territories from Buffalo River south of Great Slave Lake westwards to the mountains beyond Liard River and northward to Wrigley on the Mackenzie River. This necessitated accurate and painstaking stratigraphic work involving the correlation between outcrop and sub-surface. Helen Belyea played an important role in the development of the stratigraphic framework of the area west from Hay River south of the Mackenzie. Her accurate and painstaking work on material obtained from the relatively few wells drilled in that region, coupled with her broad knowledge of regional geology, produced a synthesis and terminology for the Devonian rocks of the region, which still stand. Major recognition came in the early 1960s when she was asked to make a contribution to the volume on the "Geological History of Western Canada," widely known as "The Atlas"." She took the responsibility for the whole of the Upper Devonian, and published maps and sections of various kinds, as well as a detailed and authoritative text for the whole western basin. Further recognition came in the First International Devonian Symposium which was sponsored by the Alberta Society of Petroleum Geologists in 1967. This symposium attracted Devonian workers from all over the world and coincided with the official opening of the Institute of Sedimentary and Petroleum Geology, when the Calgary office of the Geological Survey at last moved to its splendid new quarters. In 1971, Dr. Belyea published one of her most important studies: the "Middle Devonian Tectonic History of the Tathlina Uplift, Southern District of Mackenzie and Northern Alberta." This complex and authoritative work laid the foundation for considerable exploration activity over the years that followed. She kept up a steady output of authoritative and meticulously prepared reports based on the interpretation of huge amounts of data from the sub-surface and from her own field work. Although officially retired in 1975, she continued to work as a Research Scientist emeritus at ISPG until the onset of her final illness.

Helen Belyea began to work in Alberta when the petroleum industry was a man's world. But this small determined woman, with a daunting intellect, who never suffered fools gladly, was quickly accepted as a valued colleague, as well as being admired and loved as a warm, humorous, and generous friend. Helen was a "woman of parts"; her circle of friends was far wider that the geological profession. She was an athlete who enjoyed mountaineering, walking, skiing, swimming, and was an able equestrian and lover of pack-horse journeys. She travelled widely as a geologist and as an interested traveller and lectured in France, which she loved, and other countries of Europe. She was interested in the arts and music, a member of the Calgary Philharmonic Orchestra League and an Associate Director of the Calgary Zoological Society. I collaborated with her over many years in the field and in the laboratory, quarrelled with her on mountainsides, argued with her over stratigraphic correlations, and published several papers jointly with her. There are many like me who miss her sorely and who honour the memory of a brave and determined human being.

During her lifetime Helen Belyea received many honours that acknowledged her contributions to Canada and to Canadian geology. She was elected a Fellow of the Royal Society of Canada in 1964 and was made an Honorary Member of the Canadian Society of Petroleum Geologists. In 1956 she was awarded the Barlow Memorial Medal by the Canadian Institute of Mining and Metallurgy. She received honorary degrees from Windsor and Dalhousie universities and in 1976 was named and Officer of the Order of Canada.

Sample Collections

Library

Bookstore

Section 6 - Geoscience Research Support Infrastructure

The geoscience research conducted by the Calgary Division of the Geological Survey of Canada was supported by an infrastructure of Division-managed central services until about 2005, when the management and control of these services were centralized at the Departmental level in Ottawa. The objectives of the Division-managed central services, under the direction of the Assistant Director, were:

1. To facilitate the achievement of the Division's scientific program objectives by providing efficient and effective information, editing, publications production, administration, and building and shop services, and

2. To help project a favourable image of the GSC in the public perception, especially where the Division interacted directly with the public, as in the provision of product and reference services through the library, core and sample repository and publications distribution office (bookstore).

The following describes the Division's geoscience support infrastructure prior to 2005. On site services included:

- Electronic data processing (information technology and information management) services
- Scientific and copy editing services
- Publication production services, including cartography, photography, photomechanical/reproduction and document composition services
- Administration services, including finance & accounting, procurement & payment, materiel management, human resources and records management services
- Building and grounds services
- Machine shop services mainly in support of building and laboratory equipment maintenance
- Reference services, including library and sample collections services
- Product promotion and distribution (bookstore) services

Electronic Data Processing Services

The computer has spread into all fields of geology since the 1960's. Major advances in the application of computers to the earth sciences proceeded throughout the 1970's. By the end of the decade electronic data processing (EDP) had become increasingly essential to many research activities at ISPG. EDP personnel developed and/or enhanced computer programs (software) according to the requirements of the geoscientists. They procured the computers and computer-related equipment (hardware) required by the Institute, and ensured its effective maintenance.

By the mid-1980's no scientific activity at ISPG had escaped the effects of computers. In addition to the traditional high dependency on EDP for petroleum and coal resource assessment activities, various other activities associated with regional geological mapping and interpretation, paleontology, petroleum geology, curation, library and materiel management had been automated. Also, computer aided drafting (CAD) systems for cartography, word processing, document composition and other office automation facilities, and specialized computer-based hardware for laboratory analysis (e.g. mass spectrometry facilities) had become increasingly pervasive. ISPG had personnel dedicated to programming database and applications software, geomathematical systems and a centralized cluster of mainframe computers and storage devices. Microcomputers (i.e. desktop systems) were just becoming widespread for word processing, resource assessments, palynology reports, graphic displays, personal data files, access to mainframes, etc.

Examples of specific initiatives include:

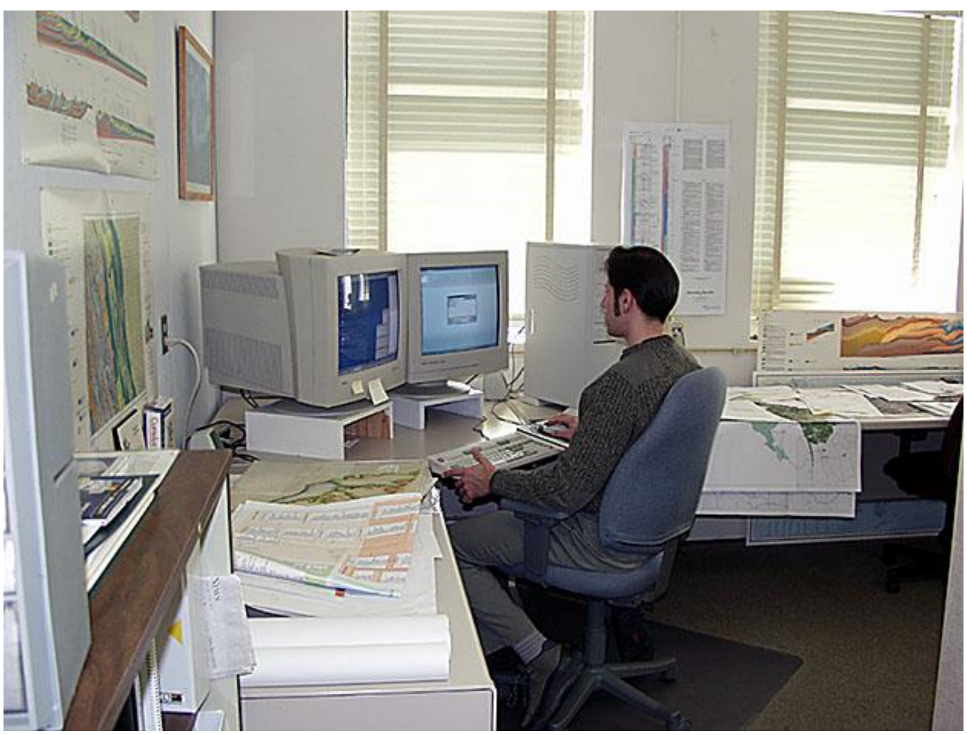
- Network development and support
- UNIX systems and internet access and support
- HP3000 support
- PC hardware and software support
- Y2K preparedness (1999)
- Government-on-line (GOL) (2001)
- Standard Desktop Computing (SDC)
- Data integration

Publications Production Services

Manuscripts produced by ISPG for publication by the GSC proceeded through the various processes of critical reading, editing, word processing/ document composition, cartography and graphics production, and printing. In-house resources were available to produce publications to the print-ready stage. A Publications Production unit provided the following services:

- Scientific and copy editing
- Photography
- Graphics production and cartography
- Photomechanical/ reproduction
- Document composition (word processing/typesetting and layout)

By 2001 this unit had been transformed into a Geoinformatics unit. Digital GIS-(Geographical Information Systems)-based databases and retrieval and display systems were starting to dominate the way in which results from GSC's research was being made publicly accessible. Printed reports were on the decline. Maps were being produced increasingly in a digital format.



Administration Services

The research and general operations of the GSC in Calgary has been supported by a full range of administrative services required by a regional office to function efficiently and according to Federal Government requirements. In addition to basic services, the Division has a crew of Building Services personnel to operate and maintain the Department-owned building facilities.

General Administration & Records Management

- Health and Safety
    - Canada Labour Code compliance
    - Accident-Incident investigation and reporting
    - Emergency response procedures
    - Standard First Aid and Wilderness First Aid training
    - Firearms training
- Security
    - Commissionaire/reception services (secure access)
    - Business resumption plans
- Telecommunications
- Office services
- Postage and courier services
- Travel
- Government credit cards
- Divisional plans
- Records management
- Office supplies
- Office equipment
- Employee Merit Award Program
- Access to Information and Privacy (ATIP) requests

Human Resources

- Classification
- Staffing
- Staff relations
- Collective agreements interpretation
- Workforce adjustment (de-staffing)
- Employee relocation
- Occupational health and safety
- New staff orientation
- Summer students

- Volunteers Program
- Training
- Human resources planning
- Compensation and benefits
- Salary forecasts

Materiel Services

- Sourcing and costing goods and services
- Procuring goods and services
- Shipping
- Receiving
- Warehousing
- Assets inventory
- Assets disposal
- Chemical storage
- Hazardous waste disposal
- Vehicle scheduling
- Procurement advice
- Field support services

Accounts and Finance

- Financial management
- Cost recovery/ revenue generation accounting
- Expenditure commitments
- Accounts verification (Financial Administration Act Section 34)
- Payments (Financial Administration Act Section 33)
- Delegation of Authority framework
- Travel advances and expense claims
- Travellers cheques
- Credit cards

Building & Shop Services

- Building maintenance and modifications
- Heating, ventilation and air conditioning
- Utilities (electricity, natural gas, water)
- Janitorial services
- Grounds maintenance
- Waste disposal
- Electrical systems
- Mechanical systems
- Vehicle maintenance
- Instrument Shop services
- Departmental Real Property Management initiatives
- Energy efficiency and water management programs (Departmental showcase)
- Environmental compliance

Institute of Sedimentary and Petroleum Geology (2000)

Vignette on

A successful energy and water management project at the facilities of the Geological Survey of Canada (Calgary)

Ten years of energy and water conservation initiatives
(Report of July, 2003)

NRCan is committed to becoming the most energy efficient department within the Federal Government. The Geological Survey of Canada in Calgary is recognized for its innovative leadership in pursuit of energy and water management opportunities.

The research of the Geological Survey of Canada in Calgary is conducted in large measure to facilitate the exploration and development of Canada's energy resources. Its facilities are a model of responsible energy use.

The main building of GSC-Calgary is ideally situated to showcase NRCan's commitment to energy efficiency. It is a relatively small commercial size building of fairly modern construction (1966/67) and therefore not overly difficult to modify.

It is located in the University Research Park next to The University of Calgary, and has a significant level of client traffic.

Serious efforts began in 1991 to reduce wastage of energy and water by designing modern conservation technologies into new installations and by encouraging staff to switch-off lights and equipment whenever practical.

Existing installations were upgraded for greater efficiencies.

- Vari-speed drives were installed on ventilation fans, replacing the existing full speed drives.
- Digital systems were installed to control air flow in work space during and after normal working hours. Constant volume air controllers were replaced by variable volume air controllers.
- Digital ventilation controls were installed on laboratory fume hoods to optimize safe ventilation efficiently.
- Some building spaces were de-lamped where appropriate.
- Fluorescent lighting throughout the facilities was upgraded by a) replacing magnetic ballasts with high efficiency electronic ballasts, b) installing T8 lamps for improved lighting efficiency and quality, and c) using specular reflectors for improved fixture efficiency.
- Mercury vapour lighting in the Core & Sample Repository was replaced by T8 fluorescent with solid state ballasts. Mercury vapour

exterior security lighting was replaced by high density sodium lighting.
- Occupancy sensors and timers were installed in warehousing space.
- Original exterior window caulking was replaced and upgraded.
- Water recirculating chillers were installed to reduce the use of flow through city water for cooling laboratory equipment.
- Presence sensing flush-o-meters were installed in the mens' washrooms resulting in a 50% reduction in water used there.
- Low NOx, high efficiency burners were installed on the boilers to reduce emissions.

The primary motivation for promoting and implementing conservation initiatives at GSC-Calgary was based on environmental concerns. Those engaged in conducting geological surveys are commonly in situations where they can truly appreciate the value of our pristine natural environment. At the outset in the early 1990s the costs for electricity and natural gas in Alberta were among the lowest in North America. Therefore, economic benefits would result in long payback periods on conservation investments. A decade later however costs have changed and the economic benefits are significant.

The average annual cost of electricity, natural gas and water at GSC-Calgary over the past four years is $285,000 less than the average for the four year period prior to the start of implementing conservation measures, when today's unit costs are applied to consumption. In other words, we would be paying $285,000 more each year for electricity, natural gas and water if we had done nothing. Our total investment was about $800,000. Use of electricity has been reduced by 47%. Consumption of natural gas is 17% less. Water use is down by 84%.

The conservation efforts at the facilities of the Geological Survey of Canada in Calgary demonstrate a successful case study of NRCan's mission to lead Canadians in the responsible development and use of our energy resources. Economic benefits are real. Greenhouse gas production is reduced significantly. The organization is committed to investigating and implementing all practical means by which it can exercise even more leadership in matters of energy and environmental stewardship.

Reference Services

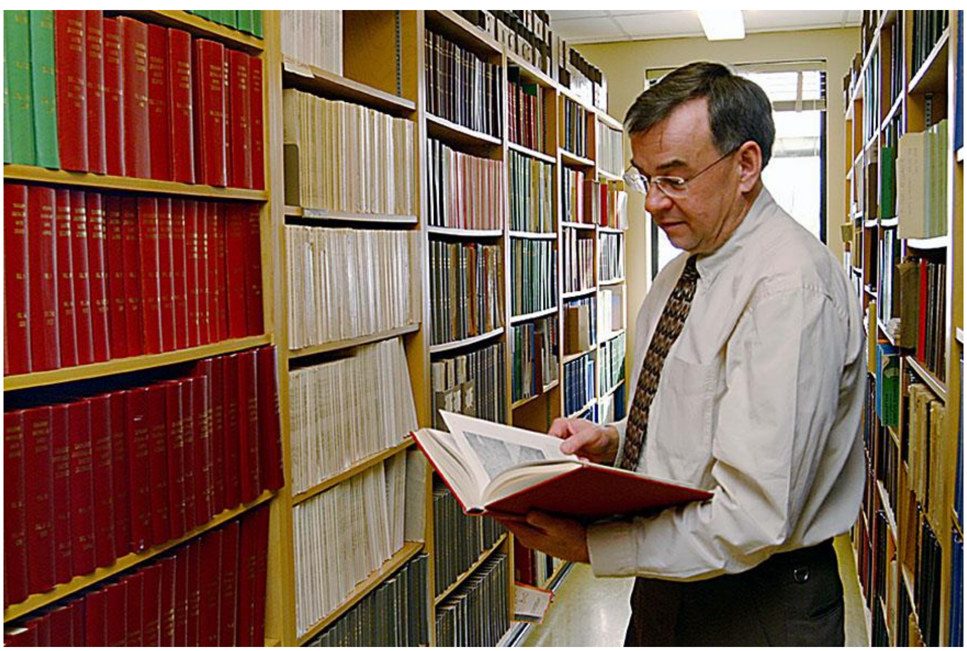
Reference services at GSC (Calgary) include:

- Library services
- Sample collections services
- Product promotion and distribution (bookstore) services

Library Services

The purpose of the library is to provide a well organized and readily accessible collection of published materials to meet the needs of Divisional staff. It provides an information resource in the geological sciences and related areas at both the specialized and general levels in support of the Division's research activities. It works with other ESS libraries and libraries at the University of Calgary, local oil and gas companies and other government agencies in providing efficient and comprehensive reference services. Library services include:

- Acquiring materials
- Cataloguing holdings
- Displaying new materials
- Circulation
- Interlibrary loans
- Shelving and retrieving materials
- Reference research



Sample Collections Services

"Scientific collections are surely, first and last, a tangible expression of the human innate thirst for knowledge, of the need to make sense of our surroundings"[45]

".... the process of curation must be designed on the premise that the full extent of the scientific value of a specimen was probably not perceived by its collector, and may still not necessarily be fully comprehended by the curator."[46]

".... the basis of all science is that observations by one worker can be verified by others."[47]

Researchers of the Geological Survey of Canada have been collecting geological samples since its inception in 1842. The samples are reviewed/screened, archived and preserved for research, reference, teaching and display. Collections include fossils, rocks, minerals, unconsolidated materials (marine, surficial and soft sediment), oils/extracts, meteorites and other geological samples. The primary materials are mainly in the form of surface field samples, sea floor samples and subsurface drill cores and cuttings. The collections include derivatives of the primary materials, such as thin sections, polished sections, powders, residues, pellets and hydrocarbon extracts. All materials have associated documentation regarding their provenance and history. Sample collections are housed in repositories at GSC facilities across Canada, including Calgary.

[45] Besterman, Tristan, 1997. The Value and Valuation of Natural Science Collections, Proceedings of the International Conference, Manchester, 1995; J.R. Nudds and C.W. Pettitt, eds, Geological Society of London, p.xi, 1997.

[46] Earl of Cranbrook, 1997. The scientific value of collections. In: The Value and Valuation of Natural Science Collections, Proceedings of the International Conference, Manchester, 1995; J.R. Nudds and C.W. Pettitt, eds, Geological Society of London, p. 9, 1997.

[47] Hounsome M.V. 1984. Research: Natural science collections. In: Manual of Curatorship - A Guide to t Museum Practice Thompson, J.M.A. (ed.). Butterworths, London, p.150-155.

Geological materials in the collections are available to internal and external clients for research, reference, teaching and display. In addition to ensuring proper cataloguing and storage of samples, collections managers provide reference, retrieval and loan services.

Collections management activities include acquisition, cataloguing, storage, retrieval, lending and disposal processes.

Samples are catalogued and stored systematically to ensure preservation and to facilitate retrieval. Collections databases are maintained for the storage and retrieval of information about the samples. A collections tracking system is used to monitor the status of loans. On site sample examination facilities at some locations are made available to clients. .

The primary objectives of sample management activities at GSC-Calgary are to:

- Provide a full range of sample archival services in support of the needs of internal Federal Government clients and external clients in governments, universities, industry and other research institutions. Services include:
  - receiving, cataloguing and storing incoming rocks and fossil collections, and petroleum cores and cuttings,
  - archival reference and search assistance, and
  - loans administration.
- Maintain safe and appropriate sample storage facilities, suitable for the long term preservation and efficient retrieval of samples.
- Monitor and report on client usage and satisfaction.

Databases are maintained that pertain to:

- Loan information including: loan no., date loaned, date due, purpose and borrower.
- Catalogued information for each sample including: collector, date, purpose, location coordinates and any supporting information available.
- Inventory information including: storage location, catalogue no., and type and condition of sample.
- Loan information including: loan no., date loaned, date due, purpose and borrower.
- Sample status of sample information including: current status of sample (lost, discarded, consumed) and unsatisfied requests.
- Primary information on the analysed properties of the processed samples, recorded separately in database systems such as SAMS (Sample and Analysis Management System) or LIMS (Laboratory Information Management System).

Geological samples acquired during the course of GSC's research are preserved for research, reference, teaching and display. Initially, samples constitute the **research or working collections** of the collectors. They are analysed for physical and chemical properties. Resulting information contributes to the collective knowledge of Canada's landmass. It provides the basis for interpreting the character of the landmass and the potential for resources to occur therein. It provides baselines for assessing some types of environmental hazards, past climate changes, and groundwater resources.

At the completion of a project, a select subset of the research/working collection is commonly preserved to form part of a **reference collection** (some of which form Canada's National Type Collections). Key samples on which published scientific findings are based are preserved and available to verify the scientific integrity of the work.

The reference collections are a publicly accessible resource for new or expanded research in the areas they represent. They reduce or eliminate the need to recollect samples. Reference collections are useful for:

- Comparative studies when examining parts of the landmass outside of the area originally represented by the samples.
- Testing for attributes that were not ascertained previously (possibly out of the scope of earlier studies).
- Analysing using modern techniques that may not have been established at the time of previous analysis. This can result in enhanced or additional information on samples that can lead to significant geological re-interpretations.
- Reproducing results - a fundamental principal of scientific research.

Some specific significant examples of occasions when existing GSC samples have been re-examined for purposes not considered originally include:

- Assessing petroleum reservoir characteristics (including previously abandoned reservoirs) in light of new enhanced petroleum recovery techniques.
- Searching for diamond indicator minerals in surficial samples to assist diamond exploration.
- Analysing samples for trace and minor elements for use in environmental baseline studies.
- Analysing surficial materials for evidence of past climate change.
- Analysing coals for assessing coalbed methane resource potential.

In each case, the availability of existing samples eliminated or reduced the need for the collection of new samples in pursuit of new needs.

Some future uses of the samples remain unforeseen as new analytical techniques develop over time.

Users of Sample Collections

- Internal (GSC's Researchers)
- Industry (Petroleum, Minerals, Environmental, etc.)
- Other Federal Government Agencies (e.g. National Energy Board)
- University Researchers
- Provincial Government Agencies
- Educators
- National and International Research Institutions (e.g. Smithsonian Institute)

Management of Sample Collections

Objectives

- To ensure proper cataloguing and accommodation of new samples resulting from current programs.
- To provide a catalogue of all archived samples (geospatially referenced).
- To provide access to information already ascertained from archived samples.
- To provide efficient access to archived samples and their derivatives.
- To provide efficient lending services for samples and their derivatives.
- To ensure safe and efficient use of space to store the samples.
- To preserve the samples through appropriate storage measures.
- To optimize the size of collections and costs for their maintenance.

Curation of Collections

To be useful, GSC's sample collections must be properly stored, preserved and documented. Like libraries, the collections are catalogued and indexed to facilitate retrieval. At GSC, this archival information is not yet maintained in a corporate database.

Activities of GSC's curators of sample collections include:

- Managing the receiving, cataloguing, storing and retrieving of samples
- Providing archival reference and search assistance
- Arranging loans to internal and external clients
- Maintaining loan records to track materials in use
- Monitoring usage and client satisfaction
- Managing materials and information derived from the primary samples
- Implementing conservation and safety measures related to the collections (e.g. handling and storage of radioactive materials)
- Arranging the culling of collections

The Geological Survey of Canada (Calgary)/Institute of Sedimentary and Petroleum Geology has, under formal arrangements with other government agencies, provided storage and public examination facilities for

1. samples collected pursuant to the Canada Oil and Gas Act (1983) by the Canada Oil and Gas Lands Administration (COGLA), later becoming the National Energy Board of Canada,
2. the continued operation of the facilities for the Government of Yukon, pursuant to the Canada Yukon Oil and Gas Accord (1999), and
3. one set of petroleum drill cutting samples required by the British Columbia Ministry of Energy and Mines (1998).

Background to the

Storage, conservation and access of well materials and records from Canada Lands

(Memo by G. Smith of 24 March 1997)

In 1984 the Geological Survey of Canada (GSC) and the Canada Oil and Gas Lands Administration (COGLA) signed agreements on

1. The storage and conservation of drill-cuttings, cores and seabed samples from Canada Lands, and

2. Access to confidential geological and geophysical data and materials on Canada Lands.

The agreements applied mainly to cuttings and cores from wells in the Yukon Territory, Northwest Territories, and adjacent offshore areas including the Beaufort Sea and Arctic Islands offshore. In return for the provision of curation, storage and public examination facilities for COGLA's materials, GSC staff was given access to confidential geological and geophysical data and materials on Canada Lands. The information and materials were very useful in support of petroleum resource assessments and geoscientific research conducted at GSC-Calgary. The public examination facilities operated by GSC-Calgary were appreciated by those in the petroleum industry, geoscience consulting and universities involved in geoscience research in Canada Lands.

In 1994 Parliament formally transferred responsibilities for regulating frontier oil and gas operations to the National Energy Board (NEB). NEB interpreted amendments to the Canada Petroleum Resources Act to have reduced the amount of discretion they have in sharing information provided to them by companies. Although access by GSC staff can continue, each individual request must be submitted in writing for NEB approval. In December 1994 NEB drafted a new Memorandum of Understanding between GSC-Calgary and NEB on "Storage and Management of Well Materials and Records and Access to Privileged Geological and Geophysical Data and Well Materials".

GSC-Calgary is reviewing its provision of curation, storage, management and public access services for NEB materials in consideration of:

1. Restrictions and conditions on GSC's access to NEB's privileged information and materials imposed in their proposed MOU.

2. The strain on GSC-Calgary's resources, in times of declining budget allotments, for providing curation, storage and public access facilities for NEB's materials.

It costs GSC-Calgary in excess of $100,000 per year to store and handle NEB's materials. NEB contributes no resources (financial or personnel) for this activity.

NEB is responsible for storing, managing and handling well materials and records from Canada Lands.

GSC access to NEB's privileged information is no longer exclusive. Through working and business relationships with petroleum companies, most of the same information can now be accessed from the companies that generated the information. Historically, access to NEB's privileged information has not had a significant impact on GSC's scientific studies.

Products Promotion and Distribution Services

The Geological Survey of Canada has had a publications distributions office in Calgary since the opening of ISPG in 1967. Prior to 1992 the office was dedicated mainly to the distribution of topographic maps as a consignment centre for the Canada Map Office; few resources remained to be directed at disseminating information and products of the GSC. By early 1992 the ISPG was no longer a consignment centre for the Canada Map Office and was better positioned to focus on serving GSC clientele. Funds were secured in fiscal 1992/93 to upgrade the publications distribution facilities (bookstore) to allow better visibility of GSC's published products in a user-friendly environment. Efforts began to upgrade ISPG's publications marketing and customer service capabilities. Overall objectives in implementing changes were to

- Promote a broader awareness of the availability and value of GSC's products
- Disseminate, efficiently and effectively, information related to the mandate of GSC
- Promote a broader awareness of the value of geoscience to Canadians

GSC-Calgary is a major source of information on the geology, geophysics, geochemistry and resource potential of sedimentary basins in western and northern Canada. The products of its work are produced in the form of highly technical maps and reports, and electronic data files. Pamphlets and brochures are produced for the non-specialists and the general public. It serves a broad range of clientele including those from the petroleum, coal and mineral industries, educational institutions and the lay public.

By 1995 the GSC had accelerated its move to fully digital on-demand printing of maps and reports, and increased the release of digital products such as interactive, multimedia CD-ROMs. The new Earth Science Information Centre was being developed to provide a one-window entry to GSC information by providing clients with access to library holdings, the Canadian geoscience database GEOSCAN, the GSC expertise database, and a scientific and technical enquiries service.

The GSC-Calgary bookstore closed in 2009 when the distribution of publications was transformed to digital downloads from a central server in Ottawa. Prior to this bookstore personnel responded to more than 10,000 inquiries annually.


The Geological Survey of Canada

Section 7 - External Factors Affecting Research Programs
(E.g. Government initiatives, administrative distractions, etc.)

1973: Government produced "An Energy Policy for Canada"

1973: OAPEC oil embargo – "Oil Crisis"

1976: Berger Commission regarding a Mackenzie Valley pipeline

1984: Introduction of Frontier Geoscience Program

1986: Merger between the Geological Survey of Canada and Earth Physics Branch to form the Earth Sciences Sector

1987: Geological Survey of Canada Planning Conference – Mont Ste. Marie, Quebec.

1989: Peer Review – Institute of Sedimentary and Petroleum Geology; for the Committee on Federal Science and Technology Expenditures (Sen. Pierre Lortie, Chairman) of the National Advisory Board on Science and Technology, (Hon. Brian Mulroney, Chairman)

1989: New "Program Activity Structure"

1989: Completed relocation of the Petroleum Resources Subdivision to Discovery Place in the University Research Park

1990: Deputy Minister's Mission Plan Task Force

1990: Start of new Government environment/global change priority

1991: Re-engineering the public service (to reduce size)

- Customer focus
- Relevancy
- Remove duplication
- Assess the value of our work

1991: Revenue generation priority for NRCan – Industrial Partners Program (IPP) for ESS

1992: PSAC strike (Sept)

1993: ISPG "downsizing"

1993: GSC Priority Setting Exercise

1993: "GSC Program Evaluation Study" by Alconsult

1994: Federal Government's "Program Review" (32% reduction of GSC's overall resources)

1994: ISPG Management Retreats to plan 1995 downsizing

1994: ISPG Client Satisfaction Survey

1995: Federal Government downsizing (Paul Martin 1995-1998)

1996: "Service Standards" implementation

1997: "Managing the Program" (Bronson Consulting Group, George Neufeld) – Matrix Management

1997: Sectoral Common Operating Environment (COE) for desktop IT environment

1997/8: Classification Re-engineering – Universal Classification Standards – Broad-band Work Descriptions

1998: NRCan's Integrated Procurement and Payment System (IPPS) implemented.

1998: "La Releve" program resulted in the hiring of four new staff members from the Strategic Recruitment Initiative

1999: Departmental "Management Self-Assessment" implemented.

1999: NRCan's "Upward Feedback" process implemented

1999: ISPG Client Satisfaction Survey results from information collected during the period April 1, 1997 to December 31, 1998 were compiled and analyzed.

1999: GSC Impact Analysis; case studies regarding 1) Liard area gas exploration, 2) Franklinian lead-zinc potential, Arctic Islands, 3) Western Canada Foothills exploration, and 4) Geological Atlas of the Western Canada Sedimentary Basin.

1999: Y2K preparedness – safeguards for Mission Critical Systems was introduced and certified.

1999: Self-serve library circulation system was fully implemented

1999: Electronic publishing process implemented

1999: Management Self-Assessment (National Quality Institute) (nonsense)

2000: Divisional results of the ESS Employee Survey were evaluated and an action plan was developed to address areas where needs for improvement were identified.

2000: New ESS Project Approval System (PAS) implemented

2000: Focus on impacts – show socioeconomic impacts of the work

2001: Specified Purpose Accounts (SPAs) initiated for funding from external sources

2001: Assessment of Earth Sciences Sector Project Management Practices (NRCan Audit and Evaluation Branch)

2001: ESS – An Issues-Driven Organization (responsive to the priorities of Government)

2001: Government-On-Line (GOL) initiative began

2001: PSAC strike (Sept)

2002: ESS Services Study (Susan Till, Assoc. Assistant Deputy Minister)

2002: NRCan's Standard Desktop Computing (SDC) implemented

2003: NRCan Support Services Review (Deloitte Consulting)

2004: PSAC strike (Sept/Oct)

2004: NRCan's Shared Services Office (SSO) established

2005: Reassignment of staff to the new Shared Services Office

2006: New "Career Progression Management Framework for Federal Researchers"

Teachers Workshop

Rock ‘n’ Fossil Road Show

Section 8 – Community Outreach Activities

Key Elements -1988 to 2012: Prepared by Godfrey Nowlan
with contributions from Sandy McCracken and Roger Macqueen
19 December 2012

- **1988:** Publication of *Science and the Public* by E.R.W. Neale as a report of the Royal Society of Canada (23 p.). Report based on the results of a conference held in Ottawa 4-5 March 1988. The conference was based on the premise that individual scientists can be motivated by their societies to view their work in a social context and to recognise their obligation to explain it to the public. Involved 75 participants, including representatives of 30 societies.

- **1988:** Conference at the University of Calgary on science literacy in Canada organized by Edna Einseidel, a professor at the university.

- **April 1989:** A meeting to form the Calgary Science Network held in the boardroom of the Geological Survey of Canada. Community leaders from the academic world, educational organizations, print media and scientific societies gathered to establish a grassroots network to deliver programs in the public awareness of science. GSC-Calgary scientists were already visiting classrooms to talk about Earth science, particularly Rocks and Minerals in Grade 3 and Planet Earth in Grade 7. (Kathy Mottershead ran this informal arrangement).

- **1989:** Establishment of the Science Alberta Foundation, initially as a funding agency for science outreach; it later became the "science centre without walls".

- **1989:** Completion of video program entitled *Life in the Balance: The Study of Extinction* completed by Rogers Cable 10 TV channel, featuring scientists from the GSC: Helmut Geldsetzer, Godfrey Nowlan, Terry Poulton, Walter Nassichuk and Art Sweet. It was co-produced by GSC scientist Terry Poulton and David Campbell of Rogers. Several other members of staff made appearances in the program conducting laboratory procedures: Janet Felker, Al Heinrich, Roger Michie, Marg Northcott and Bernd Walker. It aired several times on the Rogers Cable channel and gained a lot of local attention. It was given a special award by the Canadian Cable Television Association in 1991.

- **1990:** Formal establishment of the Calgary Science Network (CSN) as a not-for-profit society of volunteers. The establishment documents included signatures from ISPG people Ward Neale, Godfrey Nowlan and Kathy Mottershead. All meetings of the fledgling CSN were held at the GSC office from 1989 (before it was established formally) until 2007. Many GSC-Calgary employees served on the board of CSN over the years including Godfrey Nowlan (first President and other offices over several years), Sandy McCracken (Treasurer for several years), Rob MacNaughton (Secretary for one year) and Rod Smith (Board member for three years). And, of course, Ward Neale was the first Past President and a major force in the formation of CSN.

- **1990:** Publication of *Communicating Science: Why and How* by the Royal Society of Canada compiled and written by David Spurgeon. This was a report from the second Royal Society of Canada-sponsored conference held in Ottawa on March 25-27, 1990. Delegates included Ward Neale and Godfrey Nowlan from GSC-Calgary.

- **1990:** Publication of *Scientific Literacy: A Survey of Adult Canadians* by Edna Einseidel of the University of Calgary. This study served to quantify and describe the poor state of science literacy in Canada and allowed comparison with similar studies conducted elsewhere. It became a major motivator of science outreach across Canada.

- **1990:** Industry Canada instituted National Science and Technology Week (NSTW): the Calgary Science Network mounted a major campaign of events. There was an opening event together with proclamation made by the mayor (Al Duerr) and a banner was placed over City Hall. Manned displays were put up dealing with scientific equipment and services and science strolls were conducted in the downtown area. GSC's main contribution was the Pet Rock and Fossil Clinic (reviving the 1975 craze "Pet Rocks") held at the GSC building all day on a Saturday with several volunteer scientists on hand to help identify rocks, minerals and fossils brought in by members of the public. This show, first held in 1990 was held every year at the building until 1998. Attendance was always in the hundreds: it peaked at 800 in 1995 and then declined until only 100 showed up in 1997. At one point, the display included a mock-up of an Arctic field camp with tents and demonstrations of communications by radio. Overlapping this program, GSC-Calgary took their rock, mineral and fossil display to a charitable event at the Olympic Oval called Hullabaloo (see 1996). The Pet Rock and Fossil Clinic was re-born in 2004 as a library-based program, happening twice a year (April and October) starting in 1990 (see bullet for 2004 Rock 'n' Fossil Road Show); later years (2011, 2012 and 2013) had only one event in the year, as part of NSTW in October.

- **1990:** Publication of poster entitled Fossils/Les Fossiles. Artwork by Dennis Budgen (Alberta College of Art and Design) and booklet by Godfrey Nowlan and Terry Poulton explaining the panels and images on the poster. This won the Golden Trilobite Award of the Paleontological

Society. It was reprinted twice such that more than 20,000 posters were distributed. Sadly, the original art work has been lost.

- **1991:** Formal establishment of the Science Hotline of the Calgary Science Network (CSN). CSN hired a coordinator to provide a professional interface between teachers and volunteer scientists to provide a curriculum-based school visiting program. Several GSC scientists have been volunteers with this program for more than twenty years. It is now known as the Scientists in the School Program. Hundreds of visits have been made to schools by GSC scientists under these programs, since 1991 when the program got onto its formal footing with funds supplied by the Science Alberta Foundation and the federal Innovators-in-the-Schools Program. The GSC supplies and loans out minerals, rocks and fossils to all CSN volunteers who visit schools to teach geology-related aspects of the curriculum. For many years the program has been funded across Alberta by the provincial government. The Calgary Science Network is in a partnership with similar organizations from Edmonton, Medicine Hat, Lethbridge, Red Deer and Grande Prairie.

- **1992:** Celebrations of ISPG 25th and GSC 150th Anniversaries through an exhibit, lectures and a school program at the Glenbow Museum. Other anniversary activities directed toward the general public included, among others: unveiling of a Tyrrell bust at the Royal Tyrrell Museum of Paleontology in Drumheller; Earthly Riddles exhibit at the Calgary Science Centre; plaque unveiling at the Banff Park Museum commemorative event; lectures at events such as the Canadian Nursing Sisters Annual Meeting, the Desk and Derrick Club, etc.; media coverage.

- **1993:** Golden Trilobite Award for Fossil/Les Fossiles Poster from the Paleontological Society

- **1995:** Workshops for Teachers program started by CSN. GSC-Calgary provided annual one-day workshops on Grade 3 Rocks and Minerals and Grade 7 Planet Earth topics from 1995 – 2011, as well as workshops on other subjects as requested (Fossils, Regions of Canada, Bow River Basin). These workshops were taken on the road and conducted in Yellowknife, Whitehorse and High Level under the GSC's Northern Program in 2005 and 2006. Workshop instructors included Godfrey Nowlan (almost all of them), Larry Lane, Steve Grasby and Rod Smith. Workshops have been conducted for an estimated 2000 teachers by GSC-Calgary staff.

- **1995:** Establishment by the Geological Association of Canada of the E.R.W. Neale Medal to recognize significant contributions to the public awareness of geoscience. Ward Neale and Godfrey Nowlan received the medal in 1995.

- **1996:** McNeil Medal of the Royal Society of Canada received by Godfrey Nowlan in recognition of outstanding ability to promote and communicate science.

- **1996:** From1996-2001, the Survey took its rock, mineral and fossil display to the nearby Olympic Oval joining an annual charity family event run by William Roper Hull foundation called Hullaballoo. The event filled the entire oval with activities aimed mainly at underprivileged children and their families.

- **2002:** Publication of Calgary Geoscape Poster, Terry Poulton and Paul Wozniak led GSC-Calgary's effort. This poster included panels on landscapes (prairie, foothills, mountains), mountain building, earthquakes and volcanoes, aggregate and limestone resources, building stone and bricks, glacial history, energy resources, landslides, flooding and water resources. Partners in this venture were the Alberta Geological Survey, Canmore Museum and Geoscience Centre and the University of Calgary. It spawned the preparation of many public talks on the geological history of the region and its impact on social and economic development. These were delivered mainly by Terry Poulton and Godfrey Nowlan.

- **2004:** First Rock 'n' Fossil Road Show at the Crowfoot Library in northwest Calgary. This was a rebirth of the Pet Rock and Fossil Clinic of the 1990s put on by a partnership between Calgary Public Library, the Calgary Science Network and GSC-Calgary. This event was filmed and a TV show was produced in 2005 (see below). This event took place usually twice a year in April and October at libraries around Calgary from 2004 to 2012. To date, fourteen of these shows have been organized by Sandy McCracken and Godfrey Nowlan with an average of 10 volunteers per event and an average of about 300 attendees. More recently, the Alberta Palaeontological Society has been a partner with Dan Quinsey bringing parts of his large collections to each event.

- **2005:** Rock 'n' Fossil Road Show: Everybody's got a rock, every rock's got a story. 2005. Television Program and Video produced by Reel Girls Video and shown on Access TV. Featured members of the public, GSC scientists (Mike Cecile, Godfrey Nowlan…), Don Brinkman from the Royal Tyrrell Museum, and some APEGGA scientists from a similar event held at the Canmore Museum in Canmore in 2004.

- **2005:** Publication of the Bow River Basin Waterscape poster. Reference: Turner, R.J.W., Franklin, R.G., Grasby, S.E. and Nowlan, G.S. 2005. Bow River Basin Waterscape Poster, Geological Survey of Canada Miscellaneous Report 90. Also published Junior High Teacher's Guide and

Elementary Teacher’s Guide through the City of Calgary Waterworks. These were collaborative projects with teachers from the Calgary Board of Education and the Calgary Catholic School District, and GSC scientists Steve Grasby and Godfrey Nowlan.

- **2006.** Release of a video from the Minerals and Metals Sector: Our Community.....Our Future: Mining and Aboriginal Communities. Video available in English, French, Cree, Oji-Cree and Ojibwa providing information on mining for aboriginal communities. GSC-Calgary scientist worked on the script and was interviewed as part of the video.

- **2007:** Snowmobile poster developed by GSC scientists Karen Wallace Dudley and Godfrey Nowlan was published by the PDAC Mining Matters under the title: From Northern Lights to Urban Trails. It is a poster on the mineral and energy resources required to build and run a snowmobile.

- **2007:** A series of 32 fact sheets on mineral and energy resources developed by a team from GSC-Calgary (Sandy McCracken, Elizabeth Macey, Jo Monro Gray and Godfrey Nowlan) under the Northern Program and released at www.gac.ca/populargeoscience Specific sheets had input from Eva Zaleski, Karen Wallace Dudley, Grant Smith, Rod Smith, Grant Mossop, Kirk Osadetz, Alan Jessop, Charlie Jefferson and Rob MacNaughton.

- **2009**: Exhibition: "Eric Mountjoy - *Pioneer Geologist of Jasper National Park*". The exhibit consisted of photographs, geological maps and sections, equipment, and rock specimens from the Jasper region. It was created to honour the late Professor Eric W. Mountjoy (1931-2010) in recognition of his long career in study of the geology of the Jasper National Park region, beginning with his PhD thesis work in the Miette map-area (NTS 83 F/4; field seasons 1957 and 1958). Professor Mountjoy's long career included many field seasons in the Jasper region, and produced a number of geological maps and sections as well as regional and local stratigraphic studies by himself and a number of McGill University Master's and PhD students that he supervised. Funding for the exhibit was provided by Natural Resources Canada's Communications Branch in Edmonton, under the direction of Ms. Judy Samoil. Created by Ben Gadd (then resident in Jasper, Alberta) and Roger Macqueen (GSC-Calgary retiree), the Mountjoy exhibit was on display at the Jasper-Yellowhead Museum and Archives in Jasper from September 18, 2009 to January 3, 2010. The photographs that it includes are mostly digitized 35 mm slides from Roger Macqueen's collection - he was the senior assistant in the 1958 field season, the second year of Eric Mountjoy's PhD thesis project at the University of Toronto, which was a study of the Miette map-area that involved geological mapping and stratigraphic studies. A preliminary geological map of the Miette map-area was published in 1960;

the A-series coloured geological map 2158A, Geology, Miette, Alberta, appeared in 2010. The Mountjoy Exhibit was also on view at the Canmore Museum and Geoscience Centre in Canmore for about five months in 2010. It was on view at GSC-Calgary for about four months from May to September, 2011. Part of the exhibit was displayed during the 2012 CSPG Convention at the Calgary Convention Centre in May of 2012, where a one day special session honouring Professor Mountjoy was held. The Jasper-Yellowhead Museum and Archives owns the Mountjoy Exhibit, which is in storage at GSC-Calgary.

- **2010**. Publication of Geoscape Nunavut as Geological Survey of Canada, Popular Geoscience 95, poster. Poster developed in one phase by Godfrey Nowlan and Denise Then at GSC-Calgary.

- **2012:** Exhibition and published booklet with historical summary and exhibit catalogue on Operation Bow-Athabasca (1965-66) produced by the Canmore Museum and Geoscience Centre with the help of Ben Gadd and Roger Macqueen. Shown at the Canmore Museum for 3 months in 2012.

- **2012.** Sandy McCracken received the Pellikan Award (annual award for NRCan contribution to National Science and Technology Week) for organizing the Rock ‘n’ Fossil Road Show at public libraries around Calgary.

Section 9 – Social Environment

An innate spirit of congeniality among the staff of GSC-Calgary was enhanced by various social activities held over the years. These activities helped to promote a spirit of teamwork and pride in the accomplishments of the organization. They were organized mainly by a social club, “Club Fed”, comprising a group of volunteers.

Social activities since 1980 included:

- Burger burns
- Field trips
- Golf tournaments
- Stampede barbecues
- Bowling nights
- Curling nights
- Habitat for Humanity projects
- United Way Campaign socials (e.g. mini-golf, Oktoberfest, barbecues, etc.)
- Retirement “send-offs”
- Christmas events
- Calgary Flames hockey nights
- Comedy nights
- Skating parties

Burger Burns

Field Trips

Golf Tournaments

Stampede Barbecues

Bowling Nights

Curling Nights

Habitat for Humanity Projects

United Way Campaigns

Retirements

Christmas Events

Social evening at Grant Mossop's house
In honour of Ray Thorsteinsson and Tim Tozer

Farewell Tea for Mary Ellen Kovacs

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Appendices

Appendix I Staff List

Appendix II History of the Petroleum Industry in Canada

Appendix III NATMAP Projects

- Eastern Cordillera/ Southern Alberta NATMAP Project (1993-1998)
- Central Foreland/ Northern Cordillera NATMAP Project (1997-2003)

Appendix IV Beaufort - Mackenzie Research Project (2000-2012)

Appendix V Geological Survey of Canada (Calgary) – circa 2001

Appendix I – Staff List

Appendix II – History of the Petroleum Industry in Canada

History of the Petroleum Industry in Canada (frontier exploration and development)

Extracted from: Wikipedia, 5 February 2013 - History of the petroleum industry in Canada (frontier exploration and development)[48]

Canada's early petroleum discoveries took place near population centres or along lines of penetration into the frontier.

The first oil play, for example, was in southern Ontario. The first western natural gas discovery occurred on a Canadian Pacific Railway right-of-way. The site of the first discovery in the far north, the 1920 Norman Wells, Northwest Territories wildcat, was along the Mackenzie River, at that time the great transportation corridor into Canada's Arctic.

From those haphazard beginnings the search for petroleum spread to the fringes of continental Canada - and beyond those fringes onto the ocean-covered continental shelves.

Exploration in those areas involves huge machines, complex logistical support systems, and large volumes of capital. Offshore wells in the Canadian sector of the Beaufort Sea have cost more than $100 million. Across the International border, a well drilled in the US sector of the Beaufort - Mukluk by name - cost $1.5 billion, and came up dry.

For the petroleum sector, Canada's geographical frontiers are the petroleum basins in northern Canada, in the Canadian Arctic Archipelago, and off the coast of Atlantic Canada. These areas are difficult and expensive to explore and develop, but successful projects can be profitable using known production technology.

As the world's onshore oil reserves deplete, offshore resources in Canada, also known as frontier resources, become increasingly important. Those resources in turn will then undergo the full cycle of exploration, development, production and depletion.

Some frontier crude oil production - for example, Bent Horn in the Arctic and the Panuke discovery offshore Nova Scotia - have already been shut down after completing their productive lives. Similarly, some natural gas fields in the frontiers are now in later stages of decline.

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[48] Wikipedia, 5 February 2013 - History of the petroleum industry in Canada (frontier exploration and development)

http://en.wikipedia.org/wiki/History_of_the_petroleum_industry_in_Canada_(frontier_exploration_and_development)

In part, this history illustrates how important changes take place in the economies of newly producing regions, as frontier exploration shifts from wildcat drilling through oil and gas development into production. It also explores the ingenuity needed to drill in those inhospitable areas, and the deadly challenges explorers sometimes face.

True North

Northern Canada, defined politically.
The northern petroleum frontiers include the Beaufort Sea, the Canadian Arctic Archipelago and the long-established Norman Wells oil fields.

Norman Wells

The first great story in Canada's exploration of the geographical frontiers is that of Norman Wells in the Northwest Territories. During his voyage of discovery down the Mackenzie River to the Arctic Ocean in 1789, Sir Alexander Mackenzie noted in his journal that he had seen oil seeping from the river's bank. R.G. McConnell of the Geological Survey of Canada confirmed these seepages in 1888. In 1914, British geologist Dr. T.O. Bosworth staked three claims near the spot. Imperial Oil acquired the claims and in 1918-1919 sent two geologists of its own, and they recommended drilling. [49]

Led by a geologist, a crew composed of six drillers and an ox (Old Nig by name) later began a six-week, 1,900 kilometres (1,200 mi) journey northward by railway, riverboat and foot to the site now known as Norman Wells. They found oil - largely by luck, it turned out later - after Ted Link, later Imperial Oil's chief geologist, waved his arm grandly and said, "Drill anywhere around here." The crew began digging into the permafrost with pick and shovel, unable to put their cable tool rig into operation until they had cleared away the mixture of frozen mud and ice. At about the 30 metres (98 ft) level they encountered their first oil show. By this time, the river ice had frozen to 1.5 m (4.9 ft) and the mercury had

[49] Peter McKenzie-Brown, August 22, 2009 – From north to south: How Norman Wells led to Leduc

http://languageinstinct.blogspot.ca/2009/08/from-north-to-south-how-norman-wells.html plunged to −40 °C (−40 °F). The crew decided to give up and wait out the winter. They survived, but their ox did not. Old Nig provided many a meal during the long, cold winter.

Drilling resumed in the spring and a relief crew arrived in July. Some of the original crew stayed around to help the newcomers continue drilling. On August 23, 1920, they struck oil at 240 m (790 ft). The world's most northerly oil well had come in. In succeeding months, Imperial drilled three more holes - two successful, one dry. The company also installed enough equipment to refine the crude oil into a type of fuel oil for use by church missions and fishing boats along the Mackenzie. But the refinery and oil field closed in 1921 because northern markets were too small to justify the costly operations. Norman Wells marked another important milestone when in 1921 Imperial flew two all-metal 185 horsepower (138 kW) Junkers airplanes to the site. These aircraft were among the first of the legendary bush planes which helped to develop the north, and forerunners of today's commercial northern air transport.

A small oil refinery using Norman Wells oil opened in 1936 to supply the Eldorado Mine at Great Bear Lake, but the field did not take a significant place in history again until after the United States entered World War II.

This discovery indirectly contributed to post-war exploration in Alberta, and the decision to drill Leduc No. 1. Like Leduc, the Norman Wells discovery was drilled into a Devonian reef. After the Second World War, Imperial identified what it thought might be the same kind of structure in Alberta, and consequently located the great Leduc oil field. [50]

Canol: When Japan captured a pair of Aleutian Islands, Americans became concerned about the safety of their oil tanker routes to Alaska and began looking for an inland oil supply safe from attack. They negotiated with Canada to build a refinery at Whitehorse in the Yukon, with crude oil to come by pipeline from Norman Wells. If tank trucks had tried to haul the oil to Alaska, they would have eaten up most of their own load over the vast distance.

This spectacular project, dubbed the Canol Road - a contraction of "Canadian" and "oil" - took 20 months, 25,000 men, 10 million tonnes (9.8 million long tons or 11 million short tons) of equipment, 1,600 km (990 mi) each of road, and telegraph line and 2,575 km (1,600 mi) of pipeline. The pipeline network consisted of the 950 km (590 mi) crude oil line from Norman Wells to the Whitehorse refinery. From there, three lines carried products to Skagway and Fairbanks in Alaska, and to Watson Lake, Yukon. Meanwhile Imperial was drilling more wells. The test for the Norman Wells oil field came when the pipeline was

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[50] Peter McKenzie-Brown, August 22, 2009 – From north to south: How Norman Wells led to Leduc

http://languageinstinct.blogspot.ca/2009/08/from-north-to-south-how-norman-wells.html ready on February 16, 1944. The field surpassed expectations. During the one year remaining of the Pacific war, the field produced about 160,000 m^3 (1.4 million barrels) of oil.

The total cost of the project (all paid by U.S. taxpayers) was $134 million, in 1943 U.S. dollars. Total crude production was 315,000 m^3 (2.7 million barrels) of which 7,313 m^3 (63,000 barrels) were spilled. The cost of the crude oil was $426 per cubic metre ($67.77 per barrel). Refined petroleum product output was just 138,000 m^3 (1.2 million barrels). Cost per barrel of refined product was thus $975 per cubic metre, or 97.5 cents per litre ($3.69 a gallon). Adjusted to current dollars using the U.S. consumer price index, in 2000 dollars the oil would have cost $4,214 per cubic metre ($670 a barrel), while the refined product would have been worth an astonishing $9.62 a litre ($36.42 a gallon).

After the war, there was no use for the Canol pipeline. It simply fell out of use, with pipe and other equipment lying abandoned. The Whitehorse refinery kept on going - in a different locale. Imperial bought it for $1, took it apart, moved it to Edmonton, Alberta and reassembled it like a gigantic jigsaw puzzle to handle production from the fast-developing Leduc oil field near Devon.

The Norman Wells story is not yet complete. The field entered its most important phase in the mid-1980s, when a pipeline connected the field to the Canada-wide crude oil pipeline system. Oil began flowing south in 1985.

Northern Canada on a map of the polar region.
There are three ways to describe the Arctic. One is the area above the Arctic Circle. Another is the northern region which is barren of trees. The third is the area where average daily temperatures in July are 10^{o} Celsius (50^{o} Fahrenheit) or lower - in this isothermic map, the area circumscribed by the red line.

Norman Wells was a frontier discovery. It was not Arctic exploration, however, since it was located south of the Arctic Circle and also outside the narrowly defined Arctic environment (see map).

The definitive push into the Arctic took place in 1957 when Western Minerals and a small exploration company called Peel Plateau Exploration drilled the first well in the Yukon. To provision the well, some 800 km (500 mi) from Whitehorse at Eagle Plains, Peel Plateau hauled 2,600 tonnes (2,559 L/T or 2,866 S/T) of equipment and supplies by tractor train. This achievement involved eight tractors and 40 sleighs per train, for a total of seven round trips. Drilling continued in 1958, but the company eventually declared the well dry and abandoned. Over the next two decades, however, Arctic exploration gained momentum.

Arctic frontiers

Stirrings of interest in the Canadian Arctic Archipelago (Arctic Islands) as a possible site of petroleum reserves came as a result of "Operation Franklin," a 1955 study of Arctic geology directed by Yves Fortier under the auspices of the Geological Survey of Canada. This and other surveys confirmed the presence of thick layers of sediment containing a variety of possible hydrocarbon traps.

Petroleum companies applied to the Government of Canada for permission to explore these remote lands in 1959, before the government had begun regulating such exploration. The immediate result was delay. In 1960, the Diefenbaker government passed regulations, and then granted exploration permits for 160,000 square kilometres (61,776 sq mi) of northern land. These permits issued mineral rights for work commitments - that is, for agreeing to spend money on exploration.

The first well in the Arctic Islands was the Winter Harbour #1 well on Melville Island, drilled in the winter of 1961-62. The operator was Dome Petroleum. Equipment and supplies for drilling and for the 35-man camp came in by ship from Montreal. This well was dry, as were two others drilled over the next two years on Cornwallis and Bathurst Islands. All three wells were technical successes.

The federal government's eagerness to encourage Arctic Islands exploration, partly to assert Canadian sovereignty, led to the formation of Panarctic Oils Ltd. in 1968. That company consolidated the interests of 75 companies and individuals with Arctic Islands land holdings plus the federal government as the major shareholder.

Panarctic began its exploration program with seismic work and then drilling in the Arctic Islands. By 1969 its Drake Point gas discovery was probably Canada's largest gas field. Over the next three years came other large gas fields in the islands, establishing reserves of 500 billion m³ (4,324 billion barrels) of sweet, dry natural gas.

There were two significant blowouts during this drilling program. Panarctic's Drake Point N-67 well, drilled in 1969 to 2577 m on the Sabine Peninsula of Melville Island, was the first major discovery in the Arctic Islands. This giant gas field has been delineated by 14 wells, (including the 1969 discovery well and two relief wells drilled to control a blowout of the discovery well). A well drilled in 1970 on King Christian Island resulted in another blowout, though of spectacular proportions. King Christian D-18 blew wild for 91 days, and, after catching fire, was the source of an 80-metre (250 ft) column of flame. It may have been emitting as much as 200 million cubic feet (5,700,000 m^3) of gas per day.

Panarctic also located oil on the islands at Bent Horn and Cape Allison, and offshore at Cisco and Skate. Exploration moved offshore when Panarctic began drilling wells from "ice islands" - not really islands, but platforms of thickened ice created in winter by pumping sea water on the polar ice pack.

The company found lots of gas but also some oil. In 1985, Panarctic became a commercial oil producer on an experimental scale. This began with a single tanker load of oil from the Bent Horn oil field (discovered in 1974 at Bent Horn N-72, the first well drilled on Cameron Island). The company delivered its largest annual volume of oil - 50,000 m³ (432,424 barrels) - to southern markets in 1988. Production continued until 1996.

Panarctic's ice island wells were not the first offshore wells in the Canadian north. In 1971, Aquitaine (later known as Canterra Energy, then taken over by Husky Oil) drilled a well in Hudson Bay from a barge-mounted rig. Although south of the Arctic Circle, that well was in a hostile frontier environment. A storm forced suspension of the well, and the ultimately unsuccessful exploration program languished for several years.

Mackenzie Delta and the Beaufort Sea

The Mackenzie River delta was a focus of ground and air surveys as early as 1957, and geologists drew comparisons then to the Mississippi and Niger Deltas, speculating that the Mackenzie could prove as prolific. For millions of years sediments had been pouring out of the mouth of the Mackenzie, creating tremendous banks of sand and shale - laminates of sedimentary rock warped into promising geological structures. Drilling began in the Mackenzie Delta-Tuktoyaktuk Peninsula in 1962, and accelerated during the early 1970s. The mouth of the Mackenzie River was not a Prudhoe Bay, but it did contain large gas fields.

By 1977, its established gas reserves were 200 billion m³ (1,730 barrels), and a proposal, the Mackenzie Valley Pipeline, was put forth. The ensuing Mackenzie

Valley Pipeline Inquiry headed by Justice Thomas R. Berger resulted in a moratorium on such a pipeline, which today is again under consideration.

The petroleum industry gradually shifted its focus into the unpredictable waters of the Beaufort Sea. To meet the challenges of winter cold and relatively deep water, drilling technologies in the Beaufort underwent a period of rapid evolution.

The first offshore wells drilled in the Beaufort used artificial islands as drilling platforms, but this was a winter drilling system, and was only practical in shallow water. In the mid-1970s, the introduction of a fleet of reinforced drillships extended the drilling season to include the 90 to 120 ice-free days of summer. This also enabled the industry to drill in the deeper waters of the Beaufort Sea. By the mid-1980s, variations on artificial island and drilling vessel technologies had extended both the drilling season and the depth of water at which the industry could operate. They had also reduced exploration costs.

The first well to test the Beaufort was not offshore, but was drilled on Richards Island in 1966. The move offshore came in 1972-73 when Imperial Oil built two artificial islands for use in the winter drilling season. The company constructed the first of these, Immerk 13-48, from gravel dredged from the ocean floor. The island's sides were steep and eroded rapidly during the summer months. To control the erosion, the company used wire anchored across the slopes topped with World War II surplus anti-torpedo netting. The second island, Adgo F-28, used dredged silt. This proved stronger. Other artificial islands used other methods of reinforcement.

In 1976, Canadian Marine Drilling Ltd., a subsidiary of Dome Petroleum, brought a small armada to the Beaufort. It included three reinforced drillships and a support fleet of four supply boats, work and supply barges and a tugboat. This equipment expanded the explorable regions in the Beaufort Sea. Drillships, however, had their limitations for Beaufort work. Icebreakers and other forms of ice management could generally conquer the difficulties of the melting icecap in the summer. But after freeze-up began, the growing icecap would push the drill ship off location if it did not use icebreakers to keep the ice under control. CanMar's fleet eventually grew to include 5 drillships, the SSDC (Single Steel Drilling Caisson) and the Canmar Kigoriak, an Arctic Class 4 Icebreaker.

The most technologically innovative rig in the Beaufort was a vessel known as Kulluk, which originated with Gulf Oil. Kulluk was a circular vessel designed for extended-season drilling operations in Arctic waters. Kulluk could drill safely in first-year ice up to 1.2 m (3.9 ft) thick. Dome eventually acquired the vessel, which then passed progressively through acquisitions to Amoco and then BP. BP intended to sell this tool for scrap around 2000. Royal Dutch Shell subsequently purchased the vessel, however, and made plans to drill in the disputed waters of the Beaufort Sea in 2007.

The major Beaufort explorers experimented with a variety of new technologies and produced some of the most costly and specialized drilling systems in the world. Some of these were extensions of artificial island technologies; design engineers concentrated on ways to protect the island from erosion and impact. In shallow water, the standard became the sacrificial beach island. This island had long, gradually sloping sides against which the vengeance of weather and sea could spend themselves.

Beaufort Sea exploration activity followed oil prices: it was kick-started by the Arab Oil Embargo in 1973 and withered as prices fell in the early 1980s. Canada's National Energy Program, which was announced just as prices peaked in 1980, imposed price controls on Canadian oil and further suppressed investment.

In December 2005 Devon Energy started drilling the first offshore well in Canadian waters of the Beaufort sea since 1989, from the drilling rig *SDC*. The *SDC* (or Steel Drilling Caisson) was built for Canmar in 1982 by attaching the forebody of the Very Large Crude Carrier *World Saga* to the top of a steel barge with sloping sides (mimicking an artificial island); the barge can be ballasted to sit on the bottom for drilling operations. The Paktoa C-60 well was completed in 2006, but results are unknown as it was designated a "tight hole" - a well for which, for competitive reasons, no information could be released.

Appendix III - NATMAP Projects

- Eastern Cordillera/ Southern Alberta NATMAP Project (1993-1998)
- Central Foreland/ Northern Cordillera NATMAP Project (1997-2003)

NATMAP Projects

- Eastern Cordillera/ Southern Alberta NATMAP Project (1993-1998)
- Central Foreland/ Northern Cordillera NATMAP Project (1997-2003)

Eastern Cordilleran Geologic Mapping in Southern Alberta NATMAP Project (1993-1998)

(Summarized by Blyth Robertson, 31 July 2008)

Rationale and Geological Setting

The purpose of the Eastern Cordilleran NATMAP project was to remap the geology of a portion of the southeastern edge of the Canadian Cordillera - the name for the mountains of western Canada - in southern Alberta. The area of study, a swath in the Rocky Mountain Foothills some 50-100 km in width extending north-northwest 200 km from the Canada-US boundary, is an important geological province with significant reserves and resource potential for natural gas, oil, sulphur, thermal coal, coalbed methane and possibly diamonds, and significant groundwater concerns.

The Rocky Mountain Foothills lie between the structurally undeformed Interior Plains of western Canada and the topographically high-relief Rocky Mountains. The deformed sediments comprising the Rocky Mountains and Foothills have a cumulative stratigraphic thickness of up to 20 km or more. They were deposited on the western passive margin of the ancient North American craton prior to mountain-building events, as well in the Alberta foreland basin, which formed adjacent to the evolving mountain belt. The relatively subdued relief of the Foothills, in comparison to that of the adjacent Mountains, is due to the relative erosional resistance of the underlying bedrock. Whereas the bedrock of the Rocky Mountains is dominated by resistant Paleozoic carbonates and Proterozoic to earliest Paleozoic quartzites of the ancient passive margin, the Foothills are generally underlain by relatively recessive Cretaceous to Paleocene sandstones and shales of the foreland basin succession.

The Foothills are a prolific structural province for petroleum exploration, principally natural gas. Updated estimates by the Geological Survey of Canada (GSC) indicate that approximately 2.33×10^{12} m^3 (82.4 TCF) of gas remain to be discovered in the deformed Cordilleran foreland, or 41.6% of the total initial resource. Gas pools lie in structural traps formed by the faults and associated folds of the deformed sedimentary rocks. Reservoir rocks lie in both the Paleozoic carbonates and the Cretaceous siliciclastics. Although the largest discovered pools lie in thrust-repeated carbonate slices, new plays in the Cretaceous sandstones, defined in part because of this NATMAP project, are being actively explored and developed, especially in the area known as the “Triangle Zone” that forms the eastern edge of the Foothills belt.

The NATMAP project area lies within the Outer Foothills (the eastern half of the Foothills Belt), and encompasses the Triangle Zone. The NATMAP map areas were selected to replace the oldest GSC maps in a region with increasing industry activity. The area between the international border and the Turner Valley region (the location of the 1914 discovery oil well that led the rush to Foothills exploration) contained nine full and three half 1:50,000 scale map sheets that required remapping. Most of the southern Alberta Foothills were mapped at a scale of 1 inch to 1 mile (1:63, 360) in the 1930s through1950s, although some of the NATMAP map areas had only been mapped at a much larger, regional scale.

Critical elements in the geological understanding of the area that impelled the need to remap these sheets included recognition of the Triangle Zone structure, and improvements in the stratigraphic subdivision within the Cretaceous foreland basin clastic units. Bedrock exposures within the Outer Foothills are very good to excellent along the major rivers and creeks, but only good to poor through the intervening ridges and rangelands where generally only the more resistant sandstones crop out.

The Eastern Cordilleran NATMAP project brought together the disciplines of both bedrock and surficial mapping, using modern techniques and concepts to provide the surface picture of the region's geology at 1:50,000 scale. This knowledge was combined with available detailed reflection seismic data, reprocessed using modern techniques, plus drill hole samples and electric logs from hydrocarbon resource industry collaborators, to construct three-dimensional cross-sections of the region's stratigraphy and sub-surface structures. Development of a digital database facilitates the creation and publication of derivative maps involving a variety of data, including distribution of potential aquifers, potential sources of aggregate, level of thermal maturation in petroleum evaluation, as well as stratigraphic, structural and natural hazard information. The maps and databases are useful to petroleum explorationists, hydrogeologists, engineering geologists, land use planners, resource assessment agencies, academia and the public.

Project Delivery

The Eastern Cordilleran NATMAP project was principally coordinated and largely funded by GSC, with its main collaborators the University of Calgary and the Alberta Geological Survey. Additional participation was by the University of Western Ontario, the University of Lethbridge, Simon Fraser University, Dalhousie University, the National Museum of Canada and the Royal Tyrrell Museum of Paleontology. Ten petroleum companies made critical contributions to the project through their provision of proprietary seismic information. The Eastern Cordilleran project was among the first of the NATMAP projects, with bedrock and surficial mapping commencing in 1993 and completion of the project in 1998.

The project produced both GSC A-series (12 in total - all Quaternary) and Open File maps (14 in total - 10 bedrock and 4 Quaternary), as well as one GSC Bulletin, 16 GSC Current Research papers, 9 articles in outside refereed scientific journals, 5 geological guidebooks, and 27 published abstracts of formal presentations, both oral and poster.

Scientific Results

Scientific advances revealed through new maps, publications and presentations provided new ideas to help focus exploration strategies and spur future research.

Implications

Bedrock geology mapping studies:

- Completion of the 1:250,000 scale bedrock map will meet requests of industry for a tool to help visualize regional structural trends in the Alberta Foothills and Rocky Mountains in the search for deep and structurally complex gas pools.

- Bedrock mapping in the Lower Cretaceous section provided new data related to anomalous gold occurrences leading to definition of a new exploration target for gold.

Surficial geology mapping studies:

- Characterization by type and frequency of newly recognized landslides and others known previously, indicates that mass wasting processes along major thrust faults are progressively destabilizing slopes, making new, large scale rock avalanches on the scale of the infamous Frank Slide, likely.

- The late Wisconsinan age determined for the Foothills erratics train negates the 65-year-old theory that this was an ice-free corridor between two continental glaciers at the climax of the last glaciation through which the first humans entered North America from the northwest.

Recognized Impacts

- New geological maps and structural cross sections produced by the NATMAP project have greatly assisted industry in developing and successfully exploring new plays for oil and gas in Cretaceous sandstones of the triangle zone and Foothills in southwestern Alberta.

- In the Triangle Zone, 55 wells have been drilled since the start of the NATMAP project at an average cost (2006) of $2.3 million.

- These wells resulted in the discovery of 974 million m^3 of gas reserves (Alberta EUB gas reserves 2005), leading to the construction of at least one new gas plant ($7.5 million plant and $7 million gathering system cost; Win Energy Corporation).

- Maps showing the distribution of sandstone units that function as essential aquifers are being used by ranchers to guide the location of successful water wells in this drought prone area.

Conclusions

The Eastern Cordilleran NATMAP project was a success, from a scientific standpoint and from its impacts on helping to direct future resource exploration, but a number of factors did intervene to require some adjustments to the initially defined goals and products. Perhaps as an omen of these difficulties, the project was approved in April, 1993 just in time for one of the wettest summers on record in southern Alberta. Yet, despite these inclement conditions, mapping proceeded ahead of schedule in that first year. In the years immediately following, however, the primary researchers left the project, either to become managers or through reassignment to other projects, the project inevitably fell behind schedule, and the work was not extended as a "legacy" project following the end of the NATMAP Program in 2003. As a testament to the commitment of its research team, at least one major product was completed "after hours" without project support.

An added complication was a direct result of the new geoscience having had an immediate and significant impact in the area. As soon as each season's new mapping and stratigraphic work was released, it was used by industry in a new round of exploration in and adjacent to the Triangle Zone. A number of companies acquired a large amount of very high quality seismic reflection data, some 3D, and drilled new wells. As the bulk of these data are, or were, proprietary, the NATMAP project participants were reluctant to pursue additional work in the area without gaining access to some of these data, with permission to at least use this information to constrain subsequent maps and sections, if not having permission to publish it. As a result, project participants felt there was little point at that time in carrying out further studies whose synthesis and release wouldn't reflect the latest information and thinking because the proprietary data could not be incorporated.

Nonetheless, industry continued to view the GSC-led work in this area as relevant and important, as evidenced by continuing sellout enrolment in field trips offered through Canadian Society of Petroleum Geologists meetings and interest in GSC talks and publications. The primary aim of GSC geoscience mapping is to elucidate unknown or poorly known areas to allow companies to determine whether they are worth exploring. Once the Southern Alberta Foothills area “cools down”, companies will be more willing to open up their proprietary data, and this information can be used by the GSC and the Alberta Geological Survey to make new interpretations available in advance of the next round of exploration in that area, which always comes, as the petroleum industry has demonstrated time and again.

Acknowledgements

The eastern Cordilleran NATMAP project was carried out under the leadership of Dr. Margot McMechan, GSC-Calgary, from its inception in 1993 to 1995. Dr. Daniel Lebel, then at GSC-Calgary, assumed the leadership role until the project’s end in 1998. Much of the information referenced for this compilation came from the annual NATMAP progress reports prepared by these project leaders. As well, I am especially grateful for additional project material that was prepared by McMechan and her principal research colleague on the project, Dr. Glen Stockmal, and for their insights and those of Lebel on the impacts and adjustments made to the project that ensured its success.

(From: Blythe Robertson, July 2008)

Central Foreland NATMAP Project (1997-2003)

The first geological research in the Liard area began as early as 1944. Major geological maps of the area were published in the 1960's and 70's. In 1996 the NEB published a resource assessment of the area with substantial contributions from the GSC. From 1997 to 2003 the GSC led a renewed mapping and geological studies project in the area, the Central Foreland NATMAP Project.

The very first reconnaissance work of the GSC in 1944 led to the first discovery of gas at Beaver River (Journal of Petroleum Technology, 1978).

The GSC had established the fundamental geoscience framework that provided basic support to the new round of discoveries in the area commencing in 1994. This consisted of 1:250 000 scale geological maps of the region and basic stratigraphic and reservoir reports.

In 1996 the NEB published “A natural gas resource assessment of the S.E. Yukon and NWT” (unnumbered and available in Calgary) with substantial contributions from the GSC. This assessment embraced an area that included foothills, mountains, and plains north and south of 60^{o} N latitude. It concluded that at a mean probability some 5.2 Tcf of marketable gas could be expected from established plays and an additional 5 Tcf could come from immature and conceptual plays in this area.

In 2003, as part of a MERA to evaluate an extension of the Nahanni Park, the GSC re-assessed the potential of the foothills/mountains plays in the Yukon only and estimated potential resources of between 4.0 and 6.5 Tcf. This reassessment took into account new discoveries in the area.

From 1997 to 2003 the GSC led one the of the largest, highly partnered and most successful NATMAP (Central Foreland NATMAP Project) projects in this area. In addition to participation of the NWT and Yukon, partners included students from close to half of the universities in Canada, and direct participation in various forms from numerous petroleum companies. Through this project the GSC continued to provide expertise, workshops, and advice to numerous companies, and transferred information through distribution of its maps and geological reports for the area.

This NATMAP project produced a large number of geological reports and maps including new A- series 1:250 000 geological maps of Fort Liard and La Biche along with numerous 1:50 000 geological maps in areas of high economic interest.

At its height this project had more than 75 participants per year of whom less than one-third were employees of the GSC.

Industry Participation - 66 individuals in total from Crestar Energy, Chevron Canada, Conoco Canada, Gulf Canada, Murphy Oil, Petro-Canada, Pancanadian, AEC-Encana, Husky, Burlington, Talisman, Purcell, BP-Amoco, Nexen, Norcen, and Ruanco and 7 consultants from Pacific Paleoquest, Northern Geothermal, Hedinger, TEK, Apatite to Zircon, Inc. and Geostar.

Project Summary by Blythe Robertson, 31 July 2008

Rationale

The Central Foreland NATMAP project area was situated in the foothills of the northern Rocky Mountains of British Columbia and the southern Franklin Mountains of the Yukon and Northwest Territories, approximately between the Peace and Liard Rivers. Geologically, the region straddles the transition from the undeformed sedimentary rocks of the Western Canada Sedimentary Basin and the deformed strata of the foothills of the Rocky Mountains and Franklin Mountains to the west. The Canadian Cordillera, the name for the mountains and plateaus of western Canada, comprises five distinct, northwest trending geological and morphological belts. The easternmost Foreland Belt comprises a roughly 15 km-thick assemblage of sedimentary strata deposited between 700 and 50 million years ago just west of the old continental core. These rocks were then thrust eastward and deformed during mountain building between 100 and 55 million years ago. Previous geological mapping of the area had been carried out at a reconnaissance scale in the 1940s to 1960s in the northern part and in the 1970s in the southern part and had been the basis for mineral and hydrocarbon exploration. At least one area remained largely unexplored, despite its recognized potential for base metals, due to the lack of adequate geological maps covering the heavily forested terrain. Since then, major advances were made in understanding the nature and succession of the sedimentary units, largely through new knowledge of the subsurface obtained by industry through seismic surveys or examination of the rocks intersected in test drilling for oil and gas.

The primary objectives of the Central Foreland NATMAP project were to produce modern geological maps of the bedrock and surficial deposits at regional (1:250,000) and more detailed (1:50,000) scales in four map areas stretching roughly 375 km from northeastern British Columbia to southern Yukon and Northwest Territories. Geological mapping would be integrated with existing oil and gas well data and geophysics to develop geological cross-sections depicting lithological and structural relationships at depth. The new geoscience would provide a better understanding of the likelihood for oil and gas in specific regions of the project area and the potential for their economic development. As well, the study area and adjacent terrains have an abundance of base metal deposits, including potential lead, zinc and silver producers. The project would investigate these sediment-hosted deposits to establish the age of mineralization and relationship to the host rocks and, thereby, to possibly extend the area prospective for such deposits. Till geochemistry, and biostratigraphic programs were integrated with the bedrock and surficial mapping to support and augment the scientific results and maximize logistical efficiency.

The Central Foreland region is rich in oil and natural gas potential. Exploration and development activities in the area were accelerating. These activities had to respect environmental sensitivities, such as slope stability concerns, other land use options and the unusually large and diverse populations of indigenous animals. The availability of up to date detailed geological mapping, both on the surface and in the subsurface was, therefore, provided an important aid to resource management decisions in the region, such as opening of land for hydrocarbon exploitation, or its removal for protected status.

Project Delivery

The Central Foreland NATMAP project was led by the GSC and jointly conducted by GSC and the government geoscience agencies of B.C., Yukon and NWT. During the period from 1998 to 2003, the project benefited from the participation and diverse expertise of over 200 researchers and students from institutions across Canada as well as Russia, Britain and the USA. Government funding included Natural Resources Canada (GSC), Indian and Northern Affairs Canada and the governments of Alberta, B.C., Yukon and the Northwest Territories, and financial and in-kind support was provided by 21 corporate partners and consultants, and 12 universities.

The principal aims of the project were the production of an extensive suite of regional bedrock and surficial geology maps. The former document the surface expression of dramatic changes in stratigraphy, sedimentary environments, paleogeography and structural style at depth, all critical for assessing and exploiting the region’s hydrocarbon resources. The surficial geology studies, documenting landforms and glacier and lake deposits, are important because they identify terrain types, gravel sources and landslide hazards and provide the geoscience knowledge critical for road, bridge and pipeline locations. As of mid-2006, the project had published 70 surficial and bedrock geology maps at 1:50,000, 1:100,000 and 1:250,000 scales, with approximately 8 others nearing release. Many of these new maps were also released as GIS data sets on CD-ROM.

Rapid release of data and interpretations was a key goal of the project. Digital compilation and production enabled the project to release Open File maps within weeks of returning from the field. Some 270 presentations at national and international meetings, and over 100 more at annual NATMAP workshops provided a further avenue for rapid technology transfer to users. Also, more than 40 short Current Research style reports quickly put significant new interpretations into the public domain. These were followed up by over 40 formal synthesis publications, including two dedicated Special Issues of the Journal of Canadian Petroleum Geology, the primary source of published geoscientific data for the Canadian petroleum industry.

An important component of the project was the training of young geoscientists. Dozens of university students and young professionals starting out in the petroleum industry worked with and were formally mentored by experienced scientists from the participating geoscience agencies. This was partly reflected in the production of 11 theses and 3 post-doctoral fellowships.

The Central Foreland project addressed several key hypotheses by defining and comparing the geology of the Trutch-Toad River map areas in the south and the Fort Liard-La Biche River areas to the north. It had been recognized previously that the size of sedimentary basins and the style of their later deformation changed abruptly near the B.C. - NWT boundary. A crustal-scale transition reflecting a regional change in the geometry of earlier continental rifting was hypothesized as the cause. A second key hypothesis was that the formation of the Rocky Mountains in northern B.C. involved reactivation of Precambrian basement on steep faults (thick-skinned style), in contrast to the structural style farther south where large, far-travelled thrust sheets are characteristic (thin-skinned style). Both hypotheses profoundly influence models of basin evolution, the conditions for resource generation, and the formation of hydrocarbon traps.

Scientific Results

Scientific advances revealed through new maps, publications and presentations provided new ideas to help focus exploration strategies and spur future research.

Economic Implications

- The extensive new geoscientific knowledge base created by the project has contributed to documented resource exploration expenditures on the order of $400 million and the drilling of 48 new wells, including 17 successful gas producers, between 1998 and 2006.

- The new public domain geoscience knowledge has reduced petroleum exploration cost and improved exploration focus worth at least $1 million.

- Better understanding of sedimentary depositional systems and facies associations has led to improved regional stratigraphic correlations, and distribution of potential hydrocarbon source rocks and reservoirs; higher resolution of the region's thermal evolution has led to improved models of the time-temperature evolution in the thermal kitchen where hydrocarbons are produced; improved resolution of structural inheritance in influencing younger deformation styles has led to better models of hydrocarbon trapping systems. Hydrocarbon source, reservoir, generation and trapping are the four essential components of a basin model for hydrocarbon exploration. The Central Foreland project reduced uncertainty in all four components, which lead to reduced risk, increased success rates and reduced cumulative environmental impacts throughout the project area.

- The release of new data that suggests significant hydrocarbon prospectivity in deep Devonian targets beneath the Cordilleran Foreland has been followed up by a B.C. Government report, extensively citing Central Foreland products, that expands on the prospectivity of this untested target. (Production in the region was sourced from shallower Carboniferous and Triassic targets.).

- The Robb Lake MVT deposit, the largest of a suite of sediment-hosted lead-zinc deposits in the central Cordilleran Foreland, is now known to result from a large-scale hydrothermal event of Late Devonian or Early Carboniferous age, as distinct from much later Cordilleran hydrothermal systems. This new knowledge improves the focus of MVT exploration throughout the region.

- Detailed mapping in western La Biche River (Yukon) has led to additional follow-up work in adjacent Coal River, a poorly known part of Selwyn Basin. This work has significantly extended the prospective area for Sedex type base metal deposits in both map areas.

Environmental Implications

Geochemical studies revealed that numerous small streams emanating in springs within the Mattson Formation are too acidic to drink. The acidity is attributed to a natural phenomenon - the dissolution by groundwater of the naturally occurring iron-sulphide mineral, pyrite, to form sulphuric acid. This finding alone will have little direct impact on the local community. It does, however, provide important baseline information on the natural acid drainage of the area, to be taken into account when granting land use or resource development permits and the attached requirements for environmental impact mitigation or subsequent site reclamation. The area affected by this natural acid drainage is believed to extend into the proposed Nahanni National Park reserve expansion area and may impact on existing mineral exploration activities there.

In response to long standing community concerns about recent changes in Fisherman Lake and a suspicion that these changes were related to hydrocarbon exploration and development over the past 40 years, the project undertook a pilot study of gas seeps and water chemistry in the lake. Fisherman Lake, near Fort Liard, is a traditional summer camp site for the local community and the home of several families year round. Many community members are reluctant to eat fish from the lake, fearing that it may be contaminated. Analyses of the isotopic composition of the gas showed that it is naturally occurring biogenic gas produced by the decay of vegetation in the lake bed; and the changes are part of a natural process called eutrophication. The study recommended that further analyses be undertaken to broaden the scope of the sampling, and to determine the timing of these chemical changes using siliceous diatoms recovered in lake sediment samples. A follow-up study is currently underway at Queen's University.

Landslides are an important local hazard for community developments such as roads, pipelines and petroleum drill pads, particularly in the Liard, Kotaneelee and La Biche ranges, where ongoing exploration and development activities are regularly disrupted by slope failures. During landslide mapping, it was recognized that certain bedrock units were more likely associated with large landslides than others. Taking advantage of digital map compilation, a new map product for areas affected by extensive landslides was developed, showing bedrock geology with landslides superimposed. Such maps are particularly useful for engineers and planners engaged in siting excavations and foundations where landslides might cause structural failure.

New surficial and bedrock geological maps and reports of the Fort Liard and La Biche River map areas have been used extensively in the ongoing MERA process for the proposed expansion to Nahanni National Park Reserve. The proposal includes areas covered by the new mapping.

Recognized Impacts

The intent of government geoscience agencies is to have their new geoscience knowledge contribute in a significant way to the nation's economic development while minimizing environmental degradation. The direct impact of geological mapping, however, is usually difficult to quantify. Resource exploration responds to a complex mix of factors, such as commodity prices, refining capacity, regulatory framework, First Nations land claims and recent discoveries in the area. Also, approximately two-thirds of petroleum industry managers are reluctant to formally acknowledge external sources, or influences, of the information they consult. Thus, any direct links between the Central Foreland NATMAP results and exploration levels and successes is incomplete. Nonetheless, the following impacts have been documented by industry and attributed to the new geoscience knowledge produced by the project.

The project's publications have formed the geological underpinnings that have led to investments in land acquisition and wells drilled valued in hundreds of millions of dollars, and of cost savings and improved exploration focus worth over $1 million. At a typical cost of $6 to $12 million each, 48 new wells have been drilled to date in, or within a few kilometres of, areas newly mapped in the project; implying a direct influence on expenditures on the order of $400 million.

- "Maps from the NATMAP Foreland project have been an integral part of Burlington Resources technical analysis of the Trutch and adjacent areas of the foothills.... The above work has formed the geological underpinning to justify recent expenditures at BC land sales. These expenditures have totalled greater than $25 Million .... during the course of the mapping." (Burlington Resources, March 2001)

- "The Besa-Prophet area (NE BC) was open for oil and gas land postings in 2002. Six 50,000 scale sheets mapped during the NATMAP project covered this area. For industry to have mapped this area it would have taken months of field work over several field seasons, and likely the work would not have covered an entire sheet. Even partial coverage would cost us close to $500,000." (AEC, Dec 2001)

- Gulf Oil stated that the surface maps published by the NATMAP team provided an essential base to begin subsurface exploration and that this level of mapping would take a resource company years to complete at a cost of hundreds of thousands of dollars

- Nexen reported that the new detailed maps within the LaBiche River and Fort Liard areas helped with analysis of prospective structures in the Liard, Kotaneelee and La Biche Ranges. Collection of these data by the company on its own would have involved expenditures of at least $250,000

- The Pink Mountain map sheet in the southern Trutch area was used by AEC in its seismic interpretation of lands it held at the time of release.

Conclusions

The many new maps and reports of the Central Foreland NATMAP Project provided the essential geoscience groundwork to better understand the stratigraphic history and structural evolution of the northeastern BC - southern Territories region. In fulfilling its NATMAP goals, this field-based bedrock and surficial mapping project

- supported Canada’s hydrocarbon and mineral industries by directly influencing their economic activities, measured in hundreds of millions of dollars, that resulted in successful natural gas developments within and adjacent to the project area;

- successfully collaborated with industry, academia and other government geoscience agencies to promote efficient technology transfer of much new geoscientific knowledge;

- fostered and enhanced the training of dozens of Canadian geoscience students and young professionals; and

- contributed significantly to the development and application of digital databases, map production technologies and GIS products in the GSC.

Appendix IV – Beaufort-Mackenzie Research Project (2000-2013)

Beaufort-Mackenzie Research Project (2000-2013)

BEAUFORT MACKENZIE BASIN RESEARCH PROPOSAL

Introduction

The simultaneous coincidence of (1) the settlement of many native land claims in the Mackenzie Delta area and commensurate offerings of blocks of land for exploration, (2) reasonable and apparently stable prices for natural gas, (3) a high and increasing demand for natural gas, (4) decreasing natural gas production volumes from western Canada, and (5) the positive attitude toward the construction of a gas pipeline from the Delta to Alberta has resulted in a dramatic increase in the interest in exploration in the southern, largely onshore, portion of the Mackenzie Delta. Recent land sales have been won by companies that do not have a long history of operation in this area and thus there is a high demand for both existing geoscience data (generated largely by the Geological Survey of Canada during the 1970's and 1980's) and interpretation expertise (embodied in a number of GSC-Calgary researchers) as well as new research directed specifically at the refining the biostratigraphic picture, building temperature, pressure and hydrocarbon generation history models, and developing new and enhancing old migration and entrapment models for natural gas over a geographic area generally focused on the southern Mackenzie Delta.

Overall Proposal

The Geological Survey of Canada Calgary (Drs. Dale Issler, Dave McNeil, Lloyd Snowdon and Vern Stasiuk) propose to undertake a cost-shared three year research project in the southern portion of the Beaufort-Mackenzie Basin. This research will be directed at (1) assembling existing biostratigraphic, pressure-temperature, and organic petrographic and geochemical data into a single, coherent set; (2) generating new analytical results where gaps exist and samples are, or will become, available within the new round of exploration, and (3) providing interpretations of those data within a comprehensive technical report which addresses the immediate exploration and development opportunities and problems.

The research will be undertaken in three parallel streams:

(A) Biostratigraphy, using microfossils and palynomorphs to refine the Tertiary framework and establish the Pre-Tertiary biostratigraphic framework within the subsurface of the southern Beaufort-Mackenzie Basin;

(B) Pressure-temperature studies of the Beaufort-Mackenzie Basin to identify the pressure histories associated with currently known hydrocarbon bearing zones and the development of petrophysical log-

based pressure prediction models and apatite fission track constrained thermal history models; and
(C) Integrated models of hydrocarbon generation, expulsion, migration and entrapment based on Rock-Eval/TOC and petrographic data along with biomarker analyses of reservoired hydrocarbons and extracts from potential source rocks.

Biostratigraphy Research in the Beaufort-Mackenzie Basin

Tertiary Biostratigraphy

The biostratigraphic framework for the Tertiary of the Beaufort-Mackenzie Basin (BMB) has been established using microfossils (foraminifera) and palynomorphs (pollen, spores, dinoflagellates). Foraminiferal zones and taxa have been documented by McNeil (1989, 1996b,c, and 1997) and McNeil and Birchard (1989). Palynological zonations and illustrations were documented by Norris (1986, 1997) and McIntyre (1996c). Previous work has established a reliable framework for correlating depositional sequences and interpreting subsurface sections in the BMB, but parts of the Tertiary section, such as the offshore Eocene and Paleocene remain largely unstudied and poorly known, despite having high hydrocarbon potential. A coordinated micropaleontological and palynological study of the strata is proposed to increase biostratigraphic resolution through the Paleocene and Eocene. Micropaleontological research would be carried out at GSC. Palynological research would be carried out by post-doctoral research or by private consultants.

Pre-Tertiary Biostratigraphy

Pre-Tertiary biostratigraphy in the Beaufort-Mackenzie Basin has received less attention than the overlying Tertiary section. Very little published work exists for the subsurface section mainly underneath the Mackenzie Delta. McNeil (1996a, 1997) has completed some taxonomic and biostratigraphic work on the Upper Cretaceous. McIntyre (1996a,b) has summarized the palynofloras through the Cretaceous in general. The bulk of the published work has been based on outcrop sections to the west and east of the Mackenzie Delta. This includes foraminiferal work on the Jurassic Husky Formation (Hedinger, 1993), the Hauterivian-Barremian Mount Goodenough Formation (Fowler and Braun, 1993), and the Upper Cretaceous Smoking Hills/Mason River formations (McIntyre, 1974). As in the Tertiary, a coordinated micropaleontological-palynological research initiative is proposed to refine and apply existing biostratigraphic zonations into the subsurface. Given the complex structural history (break-up unconformity) within the Lower Cretaceous and the existence of important source rocks (Upper Jurassic and Upper Cretaceous), biostratigraphic control would seem to be an essential exploration tool in the pre-Tertiary section.

Micropaleontological research would be carried out primarily at GSC-Calgary with possible input by consultants or post-doctoral research.

Pressure-Temperature Research in the Beaufort-Mackenzie Basin

Executive Summary

We propose to undertake quantitative basin studies, at the Calgary division of the Geological Survey of Canada, in support of renewed hydrocarbon exploration in the Beaufort-Mackenzie Basin (BMB). The BMB has experienced a complex tectonic history with multiple phases of folding, faulting and uplift which led to the development of significant regional unconformities and structural traps for hydrocarbons. In addition, extreme variations in surface temperature and sediment accumulation rate, and the widespread occurrence of overpressured sediments further complicate the basin history. Many aspects of the regional geology are well understood for the BMB but little is known concerning its thermal, burial, erosional and fluid flow history. The fluid pressure regime is a direct function of the basin plumbing system and it strongly influences hydrocarbon migration and accumulation. Therefore, improved knowledge of the basin pressure system should aid in assessing hydrocarbon prospectivity. Furthermore, overpressures are a potential drilling hazard and methods for predicting their distribution are desirable from a safety viewpoint.

A significant research program would be established at GSC-Calgary with joint funding from the GSC (salaries and overhead costs of full-time employees) and an industry consortium (costs for specialized analyses and salaries for a contract worker assigned to the project). Additional funds may become available from other government sources as well. The proposed research would address key questions concerning hydrocarbon generation, migration and accumulation at the basin scale and it would involve the compilation, interpretation and modelling of new and existing multi-parameter data sets. The exact scope and cost of the study are yet to be determined and they are dependent on the level of input and participation by members of the consortium. However, it is anticipated that an amount on the order of $70k per year for three years would be required to accomplish many of the objectives outlined in this proposal. Some non-exclusive research possibilities include

- analysis of hydrocarbon-bearing zones with respect to pressure distributions within the BMB
- acquisition and modelling of paleotemperature and thermochronological data
- quantitative pressure prediction using well log data
- pressure history modelling

Work would begin as soon as possible following the establishment of priority research objectives in consultation with participants in the consortium. All consortium participants would have access to data, interpretations and technical reports that are generated as a result of this research. The data and interpretations will remain confidential for a period of one year after the formal presentation of research results to consortium members. This confidentiality requirement excludes relevant unpublished data and interpretations resulting from previous government-funded research. At the end of the confidentiality period, results will be available for presentation at conferences and for publication in scientific journals and GSC publications.

Geological Background

The Beaufort-Mackenzie Basin (Figure 1 and Table 1) is an underexplored frontier basin with proven hydrocarbon potential. Current ideas favour its origin as a rifted margin. Early to mid Cretaceous rifting and post-rift thermal subsidence of the lithosphere created accommodation space for Upper Cretaceous to Recent sediments which accumulated as a series of northward prograding deltaic complexes. Sandstones and shales of the Upper Cretaceous-Cenozoic sedimentary wedge are underlain by differentially eroded Mesozoic and Paleozoic clastic and carbonate rocks in onshore regions of the basin and by modified continental to oceanic crust in areas farther offshore. The area is structurally complex, with faulting and folding related to initiation and reactivation of Cretaceous rift-related structures, multiple phases of Tertiary compression in the western part of the basin and syn-sedimentary growth faulting which accompanied deltaic deposition. Superimposed on this structural fabric are zones of undercompacted, overpressured strata, permafrost and gas hydrate of laterally varying thickness

Organic Geochemistry Research in the Beaufort-Mackenzie Basin

Initial research objectives – Tertiary

The current state of knowledge for Mackenzie Delta oil-source rock systems is highly variable. A considerable amount of work has been done on Tertiary systems in the northern part of the Delta and on the late Cretaceous (Smoking Hills/Boundary Creek) source rock around the southern rim of the present shoreline. At present there are two petroleum generation models (resinite hypothesis of Snowdon, and the northward increasing oil generation potential of the Richards Formation of McCaffrey et al., 1994). One objective of the current research would be to critically examine these hypotheses and try to resolve if either, both or neither of these models is the most appropriate. The work plan would include bulk and biomarker geochemical analyses, along with a detailed petrology study of the organic matter facies in various potential source units. Resolving this question will help to construct geological models useful for the prediction of oil versus gas and to potentially identify optimum source facies within the Tertiary.

A second component of research on the Tertiary will be to resolve which of the existing discoveries have been derived from the Eocene (Richards) source rock and which have been derived from the Paleocene. While there is a consensus that the Adlartok discovery has been derived from a Paleocene source while most of the other Tertiary oils, condensates and gases have been derived from an Eocene source, there are questions about which source has been responsible for the Niglintgak discovery and to what extent the Paleocene source is likely to be the dominant contributor to reserves in the western part of the Delta. Systematic, detailed biological marker work following that of Brooks, Curiale and McCaffrey will resolve these issues.

Once the source rock picture has been clarified through various correlation techniques and a review of the heat flow and thermal evolution picture has been completed, hydrocarbon generation models will be constructed using the Platte River 1D software (BasinMod) and constrained by all of the available thermal maturity data from both rocks and oils. These models will be useful for identifying the ages of structures most likely to contain hydrocarbons and potentially which styles of traps will preferentially contain oil versus gas. The characterization of source rocks with respect to natural gas generation will be accomplished by applying the best available models for gas generation directly from kerogen and from oil cracking. Gas generation kinetics and kinetic oil stability at high temperatures are areas of active research in a number of labs around the world and efforts will be made to ensure that current literature and conference presentations are incorporated into the interpretation of gas generation.

Initial Research Objectives – pre-Tertiary

The gas, condensate and oil discoveries made in the Parsons, Siku, Kamik area have been ascribed a Husky Formation source (Langhus, 1980), but this has been done largely without any supporting evidence. Geochemical analysis of the Husky, McGuire, Permian and other potential source units older than the Smoking Hills/Boundary Creek interval was initiated in the 1980's but the interpretations were not completed before the GSC research program in this area was terminated. If additional discoveries are to be made in the southern part of the Delta, one or more of these units will almost certainly have to be an effective source. Identification of that source, determination of the evolution of thermal maturity in conjunction with the development and timing of structural trapping configurations will significantly reduce exploration risk and enhance the scope of potential exploration targets. Within the context of this research initiative, additional samples of various potential source units will be identified through screening with Rock-Eval/TOC analyses and petroleum source potential further examined using bitumen extraction, fractionation and analysis using GC and GC-

MS. The chemical characteristics will be used to identify genetic families of oils and condensates and correlate these with one or more of the potential source rocks. The existing library of data will be augmented through the analysis of new discoveries leading to a rapid understanding of the source of those new discoveries. Petrographic analyses will also provide present thermal maturity constraints which will be especially important for the stratigraphic sections presently at high levels of thermal maturity, where Rock-Eval/TOC is a much less sensitive tool.

Platte River BasinMod numerical models will be used to assemble the existing and newly generated data in this area and as a tool to determine the most likely timing of hydrocarbon generation and direction of migration.

Appendix V – Geological Survey of Canada (Calgary)

(circca 2001)

Geological Survey of Canada (Calgary) - circa 2001

Wriiten by G. Smith for the Division's first Internet website

It is presented here as a snapshot of the organization at that time

Who are we?

The Geological Survey of Canada (Calgary) is a division of the Geological Survey of Canada (GSC) established in 1967 in response to an increasing demand by government and industry for geological information about the energy-rich regions of western and northern Canada. We have become an important source of information and expertise on the geology, geochemistry, geophysics and resource potential of the sedimentary basins in western and northern Canada, which contain most of Canada's known oil, natural gas and coal resources, as well as important deposits of minerals. We are also the Geological Survey of Canada's national centre for research in paleontology, coal and organic geochemistry.

What do we do?

We conduct studies designed to describe and explain the depositional and deformational histories of sedimentary basins. These studies help us understand the basins and the mineral and energy resources within them. Research results are published as reports and geological maps. This information is fundamental to:

- Exploring and developing mineral and energy resources
- Formulating government policies
- Managing responsibly the land surface and underlying nonrenewable resources

We have specialists in most of the main geoscience subdisciplines, highly qualified research support staff, sophisticated analytical and data processing equipment, and extensive geoscience archives.

Our location in University Research Park adjacent to The University of Calgary, along with our proximity to a large population of petroleum and coal industry geoscientists, stimulates constructive collaboration and exchange of information.

Our scientists are prominent in the international geoscience community and work closely with provincial and territorial government agencies.

RESEARCH AND EXERTISE

Most of our research focuses on sedimentary basins - low areas in the Earth's surface in which sediments accumulate. The sediments may be derived from:

- rock fragments (clastic sediments) transported by wind or water some distance from their place of origin (e.g. precursors of sandstone, siltstone and shale)
- precipitation from aqueous solution (e.g. precursors of limestone and dolomite)
- evaporation of saline solutions (e.g. precursors of gypsum and potash)
- plant debris (e.g. precursors of coal)
- animal organisms (e.g. precursors of reef rock and petroleum)

Following deposition and burial, sediments undergo physical and chemical changes over time. Differing types of sediment, depositional processes and physical and chemical environments are responsible for the types of rocks, fluids and gases that subsequently form.

Sources of primary information for our research are:

- bedrock exposures
- subsurface cores and cuttings
- borehole geophysical logs
- seismic surveys
- potential field surveys such as aeromagnetic and gravity
- remote sensing such as LANDSAT and RADARSAT

We have experts in the following geoscience disciplines:

- Sedimentary basin analysis
- Sequence stratigraphy
- Paleontology
- Geological mapping
- Structural geology and tectonics
- Seismic processing and interpretation
- Geochemistry
- Sedimentary and organic petrology
- Petroleum, coal and coalbed methane resource assessment
- Geoscience technology development

We have scientists who are experts in the geosciences of the following areas of Canada:

- Western Canada Sedimentary Basin
- Northern Mainland and Mackenzie Delta - Beaufort Sea
- Arctic Islands
- Cordillera and west coast
- Appalachia and east coast
- Central Canada cratonic basins

Sedimentary basin analysis

Basin analysis involves making an interpretation of the formation, evolution, architecture and fill of a sedimentary basin by examining geological variables associated with the basin.

Basin analysis provides a foundation for extrapolating known information into unknown regions in order to predict the nature of the basin where evidence is not available. This can assist the exploration and development of energy, mineral and other resources (e.g. water, brines, etc.) that may occur within sedimentary basins.

A basin model is built on a framework of geological surfaces that are correlated within the basin. This stratigraphic framework can be expressed in terms of rock type (lithostratigraphy), fossil content (biostratigraphy), age (chronostratigraphy), or rock properties such as seismic velocity (seismic stratigraphy). A geological map is a representation of correlated surfaces.

Expertise in basin analysis

- Benoit Beauchamp (Upper Paleozoic, Arctic Islands)
- Mike Cecile (Lower Paleozoic, Northern Mainland)
- Keith Dewing (Carbonate stratigraphy, Arctic Islands)
- Jim Dixon (Cretaceous-Tertiary, Mackenzie Delta - Triassic, Western Canada Sedimentary Basin)
- Ashton Embry (Mesozoic, Arctic Islands)
- Tony Hamblin (Cretaceous, Western Canada Sedimentary Basin; Paleozoic, central and eastern Canada)
- Chris Harrison (Lower Paleozoic, Arctic Islands)
- Robert MacNaughton (Neoproterozoic and Lower Paleozoic, Northern Mainland; basal Paleozoic, eastern Ontario)
- Dave McNeil (Mesozoic and Cenozoic microfossils)
- Dave Morrow (Lower Paleozoic, Northern Mainland)
- Godfrey Nowlan (Late Precambrian-Silurian stratigraphy and conodonts)
- Kirk Osadetz (Paleozoic, Williston Basin)

- Terry Poulton (Jurassic biostratigraphy, stratigraphy and molluscan paleontology)
- Barry Richards (Upper Paleozoic, Western Canada Sedimentary Basin and Northern Mainland)
- Arthur Sweet (Cretaceous-Tertiary stratigraphy and nonmarine palynology)
- John Utting (Late Paleozoic & Triassic biostratigraphy and palynology)
- Jack Wendte (Devonian, Western Canada Sedimentary Basin)

Emeritus researchers

- Roger Macqueen
- Jack McMillan
- Ray Thorsteinsson (Lower Paleozoic, Arctic Islands)

Sequence stratigraphy

Sequence stratigraphy is the study of rock relationships within time-equivalent depositional successions bounded by surfaces of erosion or nondeposition. An interruption in sedimentation (discontinuity) is commonly accompanied by a period of erosion that can cause a significant gap in the rock record (unconformity). In sequence stratigraphy, unconformities define the ends of depositional sequences and the beginnings of new sequences.

Sequence stratigraphy can be used as a lithological predictor and as a tool for unraveling basin-fill history. High resolution sequence stratigraphy is useful in petroleum reservoir correlation and modeling.

Expertise in sequence stratigraphy

- Benoit Beauchamp (Upper Paleozoic)
- Jim Dixon (Mesozoic, Tertiary)
- Ashton Embry (Mesozoic)
- Tony Hamblin (Cretaceous)
- Robert MacNaughton (Neoproterozoic, Lower Paleozoic)
- Dave Morrow (Lower Paleozoic)
- Dave McNeil (Mesozoic and Cenozoic microfossils)
- Barry Richards (Upper Paleozoic)
- Arthur Sweet (Cretaceous-Tertiary stratigraphy and nonmarine palynology)
- Jack Wendte (Devonian)

Paleontology

Paleontology is the study of life of past geological times based on the examination of fossil remains of plants and animals. Biostratigraphy is the part of paleontology that relates to the conditions and order of deposition of sedimentary rocks.

Information derived from the study of the evolution of important fossil groups is used to develop and modify the standard geological time scale for intercontinental correlation. This scale is the geological clock that records when geological events occurred. The study of fossils also leads to an understanding of ancient depositional environments. Examinations of the physical and chemical changes that fossils undergo over time can provide insight into the changing physical and chemical characteristics of sedimentary environments over time.

Paleontology research at GSC-Calgary focuses mainly on microfossils (primarily conodonts and foraminifera) and palynomorphs (pollens and spores). We are responsible for the national collection of invertebrate and plant fossils. These fossils are systematically documented, stored and preserved in archives for future research, referencing, teaching and display.

Laboratories

- Conodont laboratory
- Foraminiferal laboratory
- Palynology laboratory

Expertise in paleontology

- Keith Dewing (Carbonate stratigraphy, Arctic Islands)
- Sandy McCracken (Lower Paleozoic and Devonian conodont microfossils)
- Robert MacNaughton (Neoproterozoic and Paleozoic trace fossils)
- Dave McNeil (Mesozoic and Cenozoic microfossils)
- Godfrey Nowlan (Lower Paleozoic and Precambrian microfossils)
- Terry Poulton (Jurassic molluscan fossils)
- Barry Richards (Carboniferous stratigraphy and sedimentology, W. Canada)
- Arthur Sweet (Mesozoic and Cenozoic nonmarine palynology)
- John Utting (Upper Paleozoic and Triassic palynology)
- James White (Mesozoic and Cenozoic palynology)

Emeritus researchers

- Wayne Bamber (Paleozoic corals)
- Ramakant Kalgutkar (fungal palynology)
- Walter Nassichuk (Late Paleozoic ammonoids)
- Alan Pedder (Devonian coral fossils)

- Tom Uyeno (Devonian conodont microfossils)
- Ray Thorsteinsson (Silurian-Devonian ostracoderm fish)

Visiting Scientists

- Brian Norford (Early Paleozoic, macrofossils)
- Jan Jansonius (palynology)

Geological mapping

A geological map is a graphic representation of selected geological features within a desired surface or subsurface area. The relative position and size of each feature on the map corresponds to its correct geographic situation according to an established scale and projection. Commonly, geological features can't be measured continuously over large areas, so their delineation is inferred or interpreted using available evidence. Surface geological features may be traceable in bedrock outcroppings (ground surveys), from air photographs (photogeological reconnaissance) and/or from satellite images. In the subsurface, geological features may be traceable in boreholes using cores, cuttings and/or geophysical logs. Geophysical surveys like those that measure the Earth's magnetic, gravity or seismic properties provide information that helps delineate geological features in the subsurface.

Geological maps describe the distribution of geological features within a landmass. Information from surface mapping is commonly used to postulate the distribution of geological features in the subsurface. The resulting hypothetical model can provide the basis for exploring the landmass in search of its resources.

Expertise in geological mapping

- Mike Cecile (Northeastern British Columbia and Mackenzie Mountains)
- Karen Fallas (Northeastern British Columbia and Mackenzie Mountains)
- Chris Harrison (Arctic Islands)
- Larry Lane (Northern Yukon and northeastern and southeastern British Columbia)
- Edward Little (Surficial materials - eastern Arctic Mainland, Baffin Island, southern Alberta, central British Columbia)
- Robert MacNaughton (Northern Cordillera)
- Margot McMechan (Southern Rocky Mountains and foothills)
- Glen Stockmal (Southern Rocky Mountain Foothills - northeastern British Columbia; western Newfoundland)

Emeritus researchers

- Don Cook (Mackenzie Mountains)

Structural geology and tectonics

Over time, rock masses are subjected to a variety of forces in the Earth's crust (i.e. tectonic forces) that can cause them to deform. The delineation, description and analysis of deformed rock structures is known collectively as structural geology.

Structural geology is used to interpret the deformational history of rock masses and the distribution of geological features within them. From this history a framework is provided for extending known information into unknown regions of deformed rock masses. Structural geologists assess the nature of tectonic forces (e.g. origin, magnitude, direction) acting within the Earth's crust.

Expertise in structural geology and tectonics

- Karen Fallas (Northeastern British Columbia and Mackenzie Mountains)
- Chris Harrison (Arctic Islands)
- Larry Lane (Northern Yukon, northeastern British Columbia, northeastern Russia and Arctic tectonics)
- Margot McMechan (Southern Rocky Mountains and Foothills)
- Glen Stockmal (Southern Rocky Mountain Foothills; northeastern British Columbia; western Newfoundland)

Emeritus researcher

- Don Cook (Mackenzie Mountains)

Seismic analysis

'Seismic', is derived from a Greek word, 'seismos' meaning 'shock'. Seismic analysis is the study of the earth's interior by examination of shock waves that have traveled through the subsurface. These shock waves can be either natural or artificial.

Reflection seismic employs artificial energy sources, such as dynamite, to produce the shock waves. Seismic energy travels down through layers of rock, is reflected back to the surface, captured by geophones, and recorded on digital instruments. These data are then processed to produce seismic profiles. The bands of light and dark reveal the attitudes of the reflective rock layers. The vertical axis of the profiles is usually in units of time and shows how long it took for the energy to travel down to the reflector and back to the surface.

Analysis of reflection seismic, especially when combined with exploration drilling, can reveal much about the rocks below the earth's surface. It has become an important tool in petroleum exploration because it permits one to build contour maps of subsurface layers, and to interpret rock types, environments of deposition, and tectonic histories.

Seismic Analysis at GSC-Calgary

We have acquired from the National Energy Board a vast collection of hardcopy and digital reflection data, mostly from Canada's north.

We carry out seismic interpretation primarily to understand the regional geology of Canada's mainland territories and the Arctic. Seismic studies of the Western Canada Sedimentary Basin and the deformed belt are more areally restricted because of a lack of data. Seismic analysis contributes to an understanding of a wide range of geological problems - from the immediate subsurface to the base of the continental crust - and is thus a fundamental component of GSC-Calgary's integrated and multi-disciplinary study of Canada's vast landmass.

Services

GSC-Calgary has an extensive collection of reflection seismic data in hardcopy format covering the sedimentary areas of Canada's north. Digital copies of many of these lines, particularly from the Arctic Islands, have been acquired as well. These data and our facilities are available for collaborative and cost-recovery activities.

Software

We have commercial software for well log analysis, reflection seismic processing, interpretation and mapping.

'LOGM' by GMA International - digital well log processing and interpretation
'STRUCT' by GMA International - 2-D structural seismic modeling
Geoquest 'IES' by Shlumberger - 2-D reflection seismic interpretation
'ProMax' by Landmark Graphics - digital seismic processing
'ZMAP' by Landmark Graphics - base map generation, data gridding and contouring

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Expertise in seismic processing and interpretation

- Tom Brent (Arctic Islands)
- Jim Dietrich (Western Canada Sedimentary Basin; west coast; Beaufort Sea)
- Bernie MacLean (Mainland Northwest Territories and N.E. British Columbia)

Geochemistry (organic and inorganic)

Geochemistry is the study of the distribution and amounts of chemical elements in rocks, minerals, soils, fluids and gases in the Earth. *Organic geochemistry* pertains to the chemistry of carbon - the basic element of all life. *Inorganic geochemistry* pertains to the chemistry of all other elements. Living organisms are the precursors of petroleum and coal (fossil fuels), which are composed mainly of carbon and hydrogen (hydrocarbon molecules).

Geochemists help determine the probability of petroleum reservoirs occurring in sedimentary basins by studying chemical factors affecting the origin, migration and accumulation of hydrocarbons in the basins. They determine the characteristics of porous reservoir rocks by studying chemical alterations such as mineralization processes that occur during rock/water interactions. They determine possible environmental implications associated with the mining and combustion of coals by examining the amounts, distributions and mobilities of elements within coal measures. And they provide insight into the evolution of sedimentary basins by determining the thermal histories of rock units within the basins.

Petroleum forms from the progressive alteration of organic matter to kerogen through biological, chemical and physical processes (diagenesis), and from kerogen to oil and gas through various stages of thermal alteration (catagenesis and metagenesis). Coal is formed from land-derived organic matter (plants). Peat deposits can be coalified by heat and pressure over time following stratigraphic burial. Coalbed methane is a natural gas by-product of coal formation whereby coal is both the source and reservoir rock. The properties of different petroleums and coals can vary significantly depending on the type of original organic precursors, thermal history, and various biological, ecological and geochemical factors.

Laboratories

- Organic geochemistry laboratory
- Inorganic geochemistry laboratory

Expertise in geochemistry

- Martin Fowler (Biological markers - petroleum systems)
- Fari Goodarzi (Organic geochemistry - PAHs, metals - environmental impact)
- Dale Issler (Basin kinetics)
- Maowen Li (Biological markers - petroleum migration odometres)
- Kirk Osadetz (Applied organic geochemistry - thermal geohistory)
- Lavern Stasiuk (Organic macerals and bitumen)

Emeritus

- Lloyd Snowdon (Organic geochemistry - kinetics)

Sedimentary and organic petrology

Sedimentary petrology is the study of the composition, characteristics and origin of sediments and sedimentary rocks. Results from geochemical analyses and microscopic examinations (petrography) are usually integral components of sedimentary petrology research. Sedimentary petrologists determine sediment source (provenance), depositional environment, and/or postdepositional conditions in sedimentary basins over time.

Organic petrology is the study of the composition, characteristics, origin and distribution of carbonaceous remains of plant and animal organisms in rocks. Coal is a rock comprising mainly carbonaceous matter. Carbonaceous matter is an important component of petroleum source rocks and oil shales. Organic petrology provides considerable insight into the orgin and evolution of these and other rocks bearing organic matter. Applications of organic petrology are multi-faceted.

Laboratories

At GSC-Calgary, research in the area of sedimentary and organic petrology is supported by modern analytical facilities pertaining to:

- inorganic geochemistry
- organic petrology
- organic geochemistry

Expertise in sedimentary and organic petrology

- Fari Goodarzi (Organic matter)
- Tony Hamblin (Clastics)
- Dave Morrow (Carbonates)
- Barry Richards (Carbonates)
- Jack Wendte (Carbonates)

Resource assessment

Resource assessments are estimates of the future supply of natural sources of wealth, such as oil, natural gas, coal and coalbed methane. They facilitate long-term public and commercial planning for future supply possibilities and land use options.

Oil and natural gas

> At GSC-Calgary, assessments of petroleum resources (oil and natural gas) are done on a "play" basis. A play refers to a group of petroleum deposits (pools) that share a common history of hydrocarbon generation, migration, reservoir development and trap configuration.

Basin analysis research provides the framework for play definition. By definition, pools in a specific play form a natural geological population characterized by one or more of the following: age, depositional model, geographic distribution, structural style, trapping mechanism, geometry and diagenesis. The petroleum resource potential of a play is estimated using probabilistic methods within the computer-based PETRIMES system developed at GSC-Calgary.

Coal

Assessments of coal resources are done for individual coal deposits using deterministic methods (i.e. not probabilistic) based on estimates of the areal extent and thickness of coal beds. Sophisticated computer-based geological modeling and coal resource estimation systems developed at GSC-Calgary, combined with extensive digital databases of geological information derived from surface and subsurface coalfield surveys, are used to assess Canada's coal resource potential. Geochemical and petrographic information is used to characterize the coals in individual deposits.

Coalbed methane

Assessments of coalbed methane resources are based on theoretical gas capacity estimates of coal beds. This is a function of thermal maturity (coal rank), depth, and ash and moisture contents of the coals. Several factors (e.g. hydrological conditions, permeability, etc.) can affect the actual gas content within coals. Gas content measurements from exploration wells are used to estimate amounts of methane that may remain stored in selected coal beds.

Expertise in resource assessment

- Peter Hannigan (Petroleum)
- Dave Hughes (Coal and coalbed methane)
- Kirk Osadetz (Petroleum)
- Grant Smith (Coal and coalbed methane)

Technology development

We develop new technologies or advance existing technologies to improve the efficiency and integrity of our research. Recent technology developments have been mainly in the areas of:

- geological modeling and visualization software
- resource assessment and database management software
- microscopy and image analysis
- hydrocarbon generation kinetics
- biomarker applications
- petroleum migration indicators

Expertise in geoscience technology development

- Martin Fowler (Biomarker applications)
- Fari Goodarzi (Power plant emission measurements)
- Dave Hughes (Geological modeling and visualization)
- Dale Issler (Basin modeling kinetics - fission tracks)
- Maowen Li (Petroleum migration indicators)
- Ping Tzeng (Petroleum resource assessment)

PETRIMES

PETRIMES, the Petroleum Exploration Resources Evaluation System, is powerful and versatile. With this system, you can manipulate reservoir and well data in a variety of ways, from simple graphic displays to complex and sophisticated statistical analyses that may be used to reveal the hydrocarbon potential of plays, basins, or regions.

PETRIMES is comprehensive and very easy to use. However, before using the system, you should:

- be familiar with well and reservoir data in order to be able to effectively operate the Reservoir and Well Data Base systems
- be experienced in the operation of the KEDIT text editor
- understand the principles, concepts, and statistical assumptions associated with the evaluation procedure (Lee and Wang, 1990)
- be experienced in the use of graphic function

PETRIMES comprises four databases, statistical and graphic computer programs, and a "Manager". The "Manager" communicates between you and the system and is also responsible for output/input between programs.

PETRIMES is capable of performing the following tasks:

- outlining play boundaries, using polygons
- retrieving pools and/or wells for given formations within the polygons
- plotting exploration histories by drill-sequence of wells, according to time series or spatial distributions
- estimating numbers and sizes of undiscovered pools for given plays
- displaying reservoir parameters using various types of plots
- manipulating or mapping reservoir or well parameters
- constructing or estimating various probability distributions for reservoir parameters of specific plays or regions

PETRIMES will operate on a PC, but in order to run it properly in a personal computer environment, you will need an IBM AT or compatible PC computer with DOS 4.0 or higher and a minimum of 8 megabytes of extended memory and 300 megabytes of hard disk space. An enhanced graphic adaptor, EGA or better, and KEDIT text editor are also required.

REGIONAL EXPERTISE

Regional expertise - Western Canada Sedimentary Basin

- Jim Dietrich - Petroleum resource evaluation
- Jim Dixon - Triassic stratigraphy and sedimentology
- Martin Fowler - Petroleum systems - organic geochemistry
- Steve Grasby - Hydrogeology and hydrogeochemistry
- Tony Hamblin - Petroleum geology and resource potential, Cretaceous clastics
- Dale Issler - Quantitative basin analysis
- Dave McNeil - Mesozoic and Tertiary biostratigraphy – forams
- Godfrey Nowlan - Lower Paleozoic stratigraphy and biostratigraphy – conodonts
- Kirk Osadetz - Petroleum geology, Williston Basin
- Terry Poulton - Jurassic biostratigraphy and stratigraphy – molluscs
- Barry Richards - Carboniferous/Permian stratigraphy and sedimentology
- Arthur Sweet - Cretaceous and Tertiary stratigraphy and nonmarine palynology)
- Jack Wendte - Mid to Upper Devonian sedimentology and sequence stratigraphy
- James White - Mesozoic - Cenozoic biostratigraphy and paleoclimatology

Emeritus researchers

- Lloyd Snowdon - Petroleum systems - organic geochemistry

Regional expertise - Northern Mainland and Mackenzie Delta - Beaufort Sea

- Mike Cecile - Paleozoic stratigraphic and structural analysis, Northern Mainland
- Jim Dietrich - Petroleum resource evaluation
- Jim Dixon - Geology, Beaufort-Mackenzie Basin; Cambrian and Cretaceous-Tertiary, mainland NWT
- Larry Lane - Crustal structure and tectonic evolution of northern Yukon and Beaufort Sea region
- Edward Little - Kivalliq Region, Nunavut: drift surveys, ice-sheet dynamics and deglaciation
- Bernie MacLean - Regional seismic interpretation, northern Interior Plains
- Robert MacNaughton - eoproterozoic and Lower Paleozoic stratigraphy
- Dave McNeil - Mesozoic and Tertiary biostratigraphy and stratigraphy – forams
- Dave Morrow - Lower Paleozoic sequence stratigraphy
- Terry Poulton - Jurassic biostratigraphy and stratigraphy – molluscs
- Arthur Sweet - Cretaceous and Tertiary biostratigraphy and nonmarine palynology

Emeritus researchers

- Lloyd Snowdon - Oil source-rock geochemistry
- Don Cook - Stratigraphy and structure, Franklin Mountains and adjacent plains)

Regional expertise - Arctic Islands

- Benoit Beauchamp - Upper Paleozoic, Sverdrup Basin
- Tom Brent - Regional seismic, Sverdrup Basin
- Keith Dewing - Carbonate stratigraphy, Arctic Islands
- Ashton Embry - Mesozoic, Sverdrup Basin, and Arctic Continental Shelf
- Chris Harrison - Structure and tectonics, Franklinian Basin
- Edward Little - Qikqtani Region, Nunavut: drift surveys, ice-sheet dynamics and deglaciation
- Godfrey Nowlan - Biostratigraphy of the Lower Paleozoic
- Terry Poulton - Jurassic biostratigraphy and stratigraphy
- John Utting - Upper Paleozoic and Triassic biostratigraphy and palynology

Emeritus researchers

- Wayne Bamber - Upper Paleozoic stratigraphy - corals)
- Ray Thorsteinsson

Regional expertise - Cordillera and west coast

- Mike Cecile - Central Forelands NATMAP
- Jim Dietrich - Petroleum resource evaluation, intermontane and Pacific Margin basins
- Karen Fallas - Northeastern British Columbia and Mackenzie Mountains
- Larry Lane - Structure and tectonics, northern Cordillera; and Central Forelands NATMAP
- Margot McMechan - Geological studies and mapping, southern Rocky Mountains and Foothills, Bowser Basin
- Dave Morrow - Carbonate reservoirs, northeastern British Columbia
- Terry Poulton - Jurassic biostratigraphy and stratigraphy
- Barry Richards - Carboniferous stratigraphy and sedimentology
- Glen Stockmal - Southeastern Cordillera; and Central Forelands NATMAP

Emeritus researchers

- Wayne Bamber (Upper Paleozoic stratigraphy - corals)
- Don Cook (Stratigraphy and structure)

Regional expertise - Appalachia and east coast

- Martin Fowler - Petroleum systems - organic geochemistry
- Tony Hamblin - Petroleum geology and resource potential; Carboniferous stratigraphy
- Godfrey Nowlan - Biostratigraphy and palegeography of the Appalachian Orogen
- Glen Stockmal - Tectonic setting of hydrocarbon resources
- John Utting - Upper Paleozoic and Triassic biostratigraphy and palynology

LABORATORIES AND FACILITIES

The research at GSC-Calgary is supported by highly qualified technical and administrative support staff, sophisticated analytical and data processing equipment, and extensive geoscience archives of geological samples, databases, maps and reports.

Laboratories

- Organic geochemistry
- Inorganic geochemistry
- Organic petrology
- Palynology
- Foraminifera
- Conodont
- Lapidary facilities

Organic Geochemistry Laboratory

The Organic Geochemistry Laboratory at GSC-Calgary provides analyses of crude oils, potential source rocks and other sediments in support of various GSC programs. In addition, this laboratory carries out research into the kinetics of organic alteration in geological systems.

The laboratory is the GSC's national laboratory for this discipline and is the only one devoted to these types of analyses in Canada. It provides services to universities (through joint support of research students) and industry (usually with Joint Research or Cost Recovery projects), as well as to researchers throughout the Survey.

Our Organic Geochemistry Laboratory is equipped to perform organic geochemical analyses of oils, coals and sediments. Data from these analyses can be used for assessing:

- organic carbon content
- petroleum generation potential
- depositional environment
- maturity
- degree of biodegradation
- oil-oil and oil-source correlations
- direction and relative distance of migration of hydrocarbons
- the simulation (using pyrolysis techniques) and kinetics of oil and gas generation from sediments and coal
- type and origin of hydrocarbon contamination in sediments

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Inorganic Geochemistry Laboratory

The Inorganic Geochemistry Laboratory at GSC-Calgary deals with specific questions concerning the emission and impact of heavy metals and polyaromatic hydrocarbons in Canada. It is a unique within the Federal Government and a vital link between a number of laboratories in GSC, CANMET and Environment Canada. This laboratory:

- advises federal and provincial governments in Canada on environmental issues and maintains a liaison with USGS
- assists Canadian industry in fulfilling their goal of clean and sustainable development of resources
- helps the Canadian public to understand environmental issues
- educates Canadian youth about environmental sciences by collaborating with colleges and universities
- promotes Canadian industry abroad by maintaining a working relationship

Organic Petrology Laboratory

The Organic Petrology Laboratory at GSC-Calgary is committed to leading and supporting public and private scientific investigations relating to exploration and development of natural resources in Canada. The lab is equipped with a range of microscopes enabling petrographic analyses of organic and associated components of oils, coals and potential petroleum source rocks. Data from these analyses can be used for determining:

- Thermal maturity (vitrinite reflectance and fluorescence)
- Organic facies (maceral composition)
- Origin of pyrobitumens (reflectance and classification)
- Homogenization temperatures and salinities of aqueous fluid inclusions
- Gravity of oil inclusions (fluorescence microspectrometry)

Other types of services performed include:

- Particle size and shape analyses, done using an IBAS image analysis system for automated optical microscopy
- 3-dimensional imaging, done using a confocal laser scanning microscope
- High resolution imaging and energy dispersive x-ray analysis, done using a scanning electron microscope with ancillary equipment

Palynology Laboratory

Palynology is the study of organic-walled microfossils (palynomorphs), which includes microscopic reproductive bodies (pollen and spores) of terrestrial plants, and the resting cysts of mostly marine "algae" (dinoflagellates).

Microfossils are captured in sediment during its deposition and are recovered by dissolving the minerals and concentrating the palynomorphs.

The Palynology Laboratory at GSC-Calgary prepares palynomorph samples for the GSC and collaborating paleontologists/biostratigraphers, in order to determine:

- organic maturity of sediments
- age and correlation of strata
- environments of deposition

Foraminiferal Laboratory

The Foraminiferal Laboratory at GSC-Calgary processes sedimentary rocks for foraminifera and other microfossils using mechanical and chemical methods to break down the rock matrix. Foraminifera and other microfossils are used by paleontologists/biostratigraphers to determine:

- geological age
- stratigraphic correlation
- paleoenvironment, paleoecology, and paleogeography
- thermal maturity and burial diagenesis

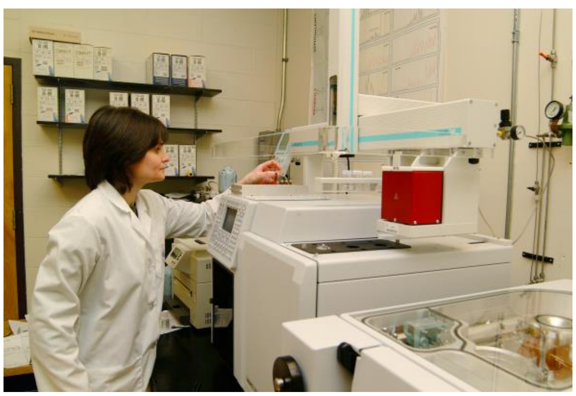
Conodont Laboratory

Conodonts are the microscopic (0.1 - 1 mm), phosphatic remains of a group of primitive chordates. They are mainly tooth-like in shape and functioned as a food-gathering apparatus. They are extinct, having ranged from the Cambrian through the Triassic periods of the Paleozoic Era and early Mesozoic Era (545-210 million years ago) (Geological Time Scale) They evolved rapidly during their history and are especially useful for biostratigraphy (a means of telling the relative age of rock strata).

The Conodont Laboratory at GSC-Calgary extracts conodonts from rocks by acidization and heavy liquid separation, in order to determine the geological age and thermal maturity of samples.

Lapidary Facilities

The lapidary services at GSC-Calgary include the production of fossil and petrographic thin sections, plaster casts of fossils and meteorites and polished rock surfaces.



COLLECTIONS

GSC-Calgary maintains two sample based research collections. Both are available to the public, subject to approval.

- Research collections - Working and reference collections gathered by and tailored to the research objectives of GSC-Calgary.
- National type collection of Canadian fossil invertebrate and plant specimens
- Subsurface core and drill cuttings collection supported by associated drilling documentation.
- Seismic reflection data for Canada's north
- Sedimentary rock units catalogue

Research collection

GSC-Calgary develops and maintains collections of geological materials primarily for scientific research. These collections are gathered through field collection, core/cutting sampling and by donation when a scientifically valuable collection is threatened. The research collections are composed of fossil, rock and mineral specimens, thin and polished sections of rock and fossil materials, photographs and other associated documentation. All specimens are catalogued and maintained using the Sample and Analysis Management System (SAMS).

As custodians of these materials, we ensure their proper storage, preservation and documentation. Although gathered by specific researchers for specific purposes the collections are available as a common resource to all researchers of the GSC as well as outside researchers (subject to the approval of an officer of the GSC).

The research collections are divided into two basic categories:

1. National Type collection of invertebrate and plant fossils (Ottawa) - comprises keys to systems of classification and nomenclature.
2. Working and reference collections (Calgary)

    - The Working Collections are a resource drawn upon by current research projects.
    - The Reference Collections are derived from the working collections and comprise the basis of published scientific interpretation, or represent irreplaceable, scientifically valuable materials.

Canada's National Type Collection of invertebrate and plant fossils

The National Type Collection securely houses the Canadian fossil invertebrate and plant specimens that are illustrated or individually described in publications by GSC and other scientists. The collection is accessible for study to qualified scientists engaged in specific research projects.
Scientists with any organization who describe Canadian fossils are strongly encouraged to deposit
their type specimens within Canada's national facility for secure and accessible storage.

The holdings of the Type Collection up to 1992 (invertebrates) and 1994 (plants) are published by the Geological Survey of Canada:

- "Catalogue of Type Invertebrate Fossils of the Geological Survey of Canada", Volumes I - VIII, by Thomas E. Bolton
- "Catalogue of Types and Figured Specimens of Fossil Plants in the Geological Survey of Canada Collections", 1962 by W.A. Bell, and Volume II, 1994, by Thomas E. Bolton.

Geological core and sample repository

GSC-Calgary maintains a repository of subsurface rock samples (core, cuttings & documentation) derived from petroleum exploration drilling in British Columbia, Alberta, Saskatchewan and the frontier regions of northern Canada and offshore regions of the east and west coasts. Non-confidential samples can be examined by the public (Alberta samples can be examined at the adjacent facilities of the Alberta Government). Samples from the frontier regions are managed by GSC-Calgary on behalf of the Yukon Territorial government.

Repository staff retrieve material for examination and sampling as requested. There are 14 examination booths and seven core tables available for use by internal researchers and the public.

Sampling

Sampling of cores and unwashed cuttings is permitted under strict guidelines, and any resulting thin sections, polished sections and data must be returned at the end of the loan period, when they become part of the Processed Subsurface Collection.

Policy for sampling cores depends on the condition of the core and the requirements of the proposed analysis. The maximum permitted sample volume is one cubic inch per linear foot and no sample may include a significant fraction of the core diameter of any horizon. Under special circumstances, permission may be granted for over-sampling. All requests for sampling that threaten to impair the geological value of the core will be refused.

Requests for cuts of unwashed drill cuttings are on a first-come first-served basis. A maximum of 20g per sample interval is permitted for each procedure.

A maximum of 6-8 grains per vial is allowed for washed cuttings, depending on the volume of material in the vial. The remaining contents of each vial must contain essentially the same proportion of constituents prior to sampling.

All resulting analytical data, petrographic thin sections, recovered macrofossils, microfossils, palynomorph slides and preparations must be returned to the Repository, where they will contribute to the inventory of subsurface material. Any unused core material and other residues or unprocessed material should also be returned. Except under exceptional circumstances, loans are for a period of 6 months.

Anyone wishing to sample well material should address their requests in writing to the Repository Superintendent Richard Fontaine, indicating the purpose of the studies, the volume of material required, and the name and intervals of interest for each well. Permission to over-sample requires explanation of the relevance of the work to the geoscientific community. If permission to sample is received, arrangements for sampling can be made.

Seismic reflection data for Canada's north

We have acquired from the National Energy Board a vast collection of hardcopy and digital reflection data, mostly from Canada's north. (The NEB is the curator of paper copies of any seismic data collected during the course of petroleum exploration in Canada's north. After a period of confidentiality, these data are released to the public. The available data from Canada's western provinces are much less extensive because these jurisdictions have no similar mechanism for data collection.) Our digital seismic data has been either donated by industry or acquired jointly with partners.

Sedimentary rock units catalogue

A catalogue of names of all sedimentary rock units in Canada is maintained by the Paleontology Subdivision of the Geological Survey of Canada, Calgary.

LIBRARY

The Library at GSC-Calgary houses one of the most comprehensive collections of geoscience publications in western Canada. It includes one of the most complete collections of information on the Western Canada Sedimentary Basin, as well as an outstanding selection of sedimentary and petroleum geoscience journals and periodicals.

The Library holds 100,000 volumes and subscribes to 350 serial titles. It is a depository of publications from the Geological Survey of Canada and has substantial holdings from many domestic and foreign geological surveys, notably the U.S. Geological Survey.

Subjects covered in the collection include the geological sciences and related subjects at both the specialized and general levels. Specific subjects include petroleum and coal geology, paleontology, micropaleontology, stratigraphy, structural geology, sedimentary geology, geochemistry, and the geology of the Western Canadian Sedimentary Basin and the Arctic. Russian publications on paleontology form the bulk of the Library's non-English language holdings.

In addition to serving the needs of staff researchers, the Library at GSC-Calgary is open to the public. Everyone, including industry and university geoscientists, students and non-specialists, is welcome.

Our Library works with the Gallagher Library at The University of Calgary to optimize service to the geoscience community in the region. Strong connections are maintained with the NRCan Library - Ottawa (Earth Sciences).

Library users have access to GeoRef, an index to geoscience publications around the world, and GeoScan, an index to Canadian geoscience publications. A reading area and photocopying facilities are available.

Our staff is available for guidance and direction on the use of our library facilities, and are happy to provide Library users with reference services in support of their research.

THINKING GREEN

Those engaged in conducting geological surveys are commonly in situations where they can truly appreciate the value of our pristine natural environment.

In 1991 our concern with matters that contribute to degradation of our natural environment led to a commitment to reduce our consumption of natural resources. Following the earlier successful implementation of a paper conservation and recycling program, we focused attention on our consumption of electricity, natural gas and water.

Our original building facilities, comprising laboratories, offices, project rooms, core and sample repository, library, bookstore and storage space, were built in 1967 to meet our specialized geoscience research requirements. The facilities have since been expanded four times to a total floor space of 18,580 m^2 (200 000 ft^2). The use of electricity, natural gas and water grew as the facilities expanded. By 1990 the 160 employees used 3,475,600 KWh of electricity, 26,000 GJ of natural gas and 42,000 m^3 of treated city water, annually.

The Energy Management Program developed in 1991 was designed to reduce the impact of our operations on the environment, to show responsible use of our natural resources, and to save money. This voluntary initiative resulted in an ongoing process of operational, physical and attitudinal change. In 1995, after several major energy efficiency improvements had been made by on site staff, an energy management service contract was awarded under the Federal Buildings Initiative to further retrofit the building facilities without using our own capital funds.

During the period from 1990 to 1998 conservation measures resulted in a substantial reduction in the use of electricity, natural gas and water, with a commensurate reduction in environmental impact associated with the production and use of these utilities. The functionality and comfort of the facilities have not deteriorated as a result of the changes and in many cases they have improved.

Conservation measures

Type of Utility	**Reduction in 1998 over 1990**	**Total avoided use since 1990**	**Annual Savings in 1998 over 1990**	**Environmental benefits since 1990**
Electrical	42 %	7 500 000 KWh	$83 000	Combined avoidance of 9161 tons of CO_2
Natural Gas	15 %	18 000 GJ	$8 000	91 tons of SO_2 46 tons of NO_X
Water	77 %	182 000 m^3	$31 000	Less water processing, chlorination and sewage treatment

Chronology of activities since 1990 in reducing electricity, natural gas and water consumption	
1990	Peak year of energy and resource consumption. Concerns surface within the organization for the rising cost and impact on the environment. Establishment of paper conservation and recycling program.
1991	An inhouse Ad Hoc Committee on Energy Management is formed to address energy use. Several projects are identified as energy saving opportunities. Installation of time and minimum temperature controls for the air supply to shops.
1992	Replacement and upgrading of 50% of roof area from R 7 to R 22 Internally conducted lighting review and adjustments saving 51,000 Kwh annually. Participation in Alberta's Energy Audit Program. Replacement of original exterior window caulking Installation of two water recirculating chillers to stop the use of city water for laboratory equipment cooling.
1993	Replacement of four main fan motors to high energy efficiency type under the Alberta Power Smart Program. Installation of eight variable speed drives for main fans.
1994	Replacement of 120, 28 year old constant volume air controllers with variable volume air controllers allowing minimizing and adjusting air supply to critical areas during off hours. Initiation of the first energy management service contract for NRCan. Establishment of cardboard recycling program.
1995	Award of energy management service contract to ESCO Landis and Gyr Powers Ltd. (Now Ltd.) under NRCan's Federal Building Initiative. Replacement of all fluorescent lighting to T8 and solid state ballast technology. Installation of 15 variable speed controllers for fume hood exhaust fans. Replacement of all core storage mercury vapour lighting to T8 and solid state ballast technology combined with motion sensors and timed switches. Control of main fans through pressure sensing technology.
1996	Installation of presence sensing flush-o-meters in men's washrooms resulting in 50% reduction of water use. Replacement of one old oversized chiller with 2 smaller and more efficient chillers for west science complex.
1997	Installation of two Low-Nox natural gas burners on two existing hot water boilers as part of NRCan's Greening of Government Initiative.

	Installation of timed lighting control to all hallways Installation of new sequence / load sharing control of two existing hot water boilers Cooling tower vari-drive installation
1998	Replacement of exterior security lighting from mercury vapour to high density sodium lighting. Bookstore chiller, fresh water cooling change to cooling tower re-circulation
1999+	Continuing search for means to reduce consumption of electricity, natural gas and water

Our concerns for environmental matters extend to the use of dual-fuel vehicles that can use both propane and gasoline, and the implementation of a "green procurement" program that places an added value on the selection of environmental-friendly materials. We continue to look for ways to reduce the impact of our operations on the environment. It pays!

EDUCATION AND OUTREACH

Staff at GSC-Calgary actively promote public awareness of science at schools and at various special events. We are the home base for the Calgary Science Network, one of Canada's leading volunteer organizations involved in public awareness of science.

Our scientists visit numerous school classrooms each year to help students and teachers with their science curriculum. In addition to giving presentations and hands-on demonstrations (taking account of age/education levels), we help with the planning and judging of special events such as Science Fairs and Science Olympics. Arrangements for our assistance can be made through the Science Hotline.

During Science and Technology Week (each year in October) we run our Annual Pet Rock and Fossil Clinic. The public is invited to bring in their rocks and fossils and have them identified.

We participate annually in special events such as Hullabaloo, a major family event each May put on by the children's charity "William Roper Hull Home".

The Geological Survey of Canada puts out a wide range of educational materials suitable for teachers, students and those interested in the earth sciences. For example, the beautiful poster Fossils, with an explanatory booklet, helps in learning more about the diversity of life in the fossil record. These and other materials are available at the GSC Bookstore.

Staff of GSC-Calgary are active in scientific and technical societies such as the Canadian Society of Petroleum Geologists and The Geological Association of Canada, among others.

Geoscape Calgary poster

> The Geoscape Calgary poster uses over 30 diagrams, maps, and pictures in an attractive and colourful presentation of Earth materials and processes that have shaped Calgary's geological landscape, or Geoscape.

OIL AND GAS INFORMATION

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