Pioneering Geology in the Canadian Cordillera

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PIONEERING GEOLOGY IN THE CANADIAN CORDILLERA

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INTRODUCTION

The collection of papers compiled in this volume was presented at a symposium of the Pacific Section of the Geological Association of Canada, entitled *The Earth Before Us - Pioneering Geology in the Canadian Cordillera*, in March of 1991. As a result of interest generated by the symposium, the publication of these papers was undertaken by the British Columbia Geological Survey Branch in co-operation with the Geological Association of Canada. The papers focus on early geoscience studies in the Canadian Cordillera and events leading to the present status of geologic activities in the region. The Canadian Cordillera comprises a geologically complex mountainous region composed of five major tectonic belts that extends for more than 1500 kilometres through British Columbia and Yukon Territory. Past governments and industry have endeavored to understand the geology of this land mass in order to develop the region and locate mineral and petroleum resources. From gold rushes, mining, petroleum exploration, and marine discoveries to engineering endeavors and earthquake studies, each was an integral part of unlocking the Cordilleran puzzle. The following papers discuss how the geological, geophysical and geotechnical aspects of this complex geographical area have been investigated, while disclosing behind-the-scene stories of the people involved.

The papers are written by prominent researchers, many of whom have had direct personal experience in the development of their fields. For example, Atholl Sutherland Brown describes the history of the British Columbia Geological Survey from the unique perspective of a former head of the Geological Division (1974-1984). Similarly, Marilyn Mullan describes the events leading to the establishment of the Britannia mine as a National Historic Site, a process with which she herself was intimately involved. In addition, Chris Yorath and John Wheeler describe activities of the Geological Survey of Canada, an organization with which both writers have long been associated. Chris Yorath also writes from the perspective of author of the recently released book, *Where Terrains Collide* (Yorath, 1991) and coeditor of the Decade of North American Geology volume entitled *Geology of the Cordilleran Orogen in Canada* (Gabrielse and Yorath, 1992). Both these volumes are recommended for further reading, the first for the non-specialist and the second for an excellent technical overview of Cordilleran geology.

The papers are compiled from the personal experiences of the authors, historical documents and information collected from contacts with early researchers, some of whom still continue to have a significant impact on geologic studies in the Cordillera. The first hand accounts of early developments in Cordilleran geology by these researchers are an important contribution to this volume. For example in the field of engineering geology, the personal contributions of Hugh Nasmith and Charlie Ripley are acknowledged and discussed by Doug VanDine in his paper jointly presented with them. Although retired, VanDine's co-authors continue to be involved in professional activities in their field. Similarly, John Wheeler has continued, in `retirement', to have a significant impact on our understanding of the geology of the Canadian Cordillera, as exemplified by his recently published, monumental compilation maps delineating tectonic assemblages and terranes of the Canadian Cordillera (Wheeler and McFeely, 1991 and Wheeler *et al*., 1991).

Although not intended to be comprehensive, the papers presented here give a broad cross-section of geology in the Canadian Cordillera. The volume begins with a presentation of the vivid history of gold rushes and mining. This colourful discussion of events that put British Columbia `on the map' is presented by Bob Griffin, a researcher with the Royal British Columbia Museum. The evolution of geologic thought by scientists from the Geological Survey of Canada, universities and industry is then discussed by Chris Yorath. Complimentary activities of provincial geologists are described by Atholl Sutherland Brown in his summary of the history of the British Columbia Geological Survey. These papers are followed by accounts of the evolution of research in major geologic fields in the Cordillera including engineering geology, mining, petroleum geology, geophysics, paleontology and marine geology. Each of these areas is discussed separately by well-known specialists. Gary Rogers, a prominent seismologist with the Geological Survey of Canada, discusses the history of earthquake studies in British Columbia. Early mining in British Columbia, as exemplified by the development of a world-class mine at Britannia, is discussed by Marilyn Mullan. Doug VanDine, Hugh Nasmith and Charlie Ripley provide a summary of historical events in engineering geology and Jim Murray and Bill Mathews describe developments in marine geology, the province's newest geological science. Rolf Ludvigsen, an eminent paleontologist well known for his work on the Burgess Shale fauna which is now preserved in a World Heritage

Site, describes developments in paleontology, emphasizing the search for Cambrian and Precambrian fossils. The history of the petroleum industry in the Cordillera is summarized by Nick Wemyss, formerly with the British Columbia Petroleum Geology Branch. The volume concludes with a first-hand account of geologic mapping by the Geological Survey of Canada in the `early days' and a comparison with today by John Wheeler, an eminent Cordilleran geologist.

Due to the growing awareness among geoscientists of the importance of presenting information on geological research to the public, the symposium from which these papers are drawn included a special session geared for a general audience. The session was jointly sponsored by the Pacific Section of the Geological Association of Canada and the Royal British Columbia Museum. During this presentation Bob Griffin described how British Columbia boomed during the search for placer gold in the last half of the 19th century. Robert Turner discussed the dramatic early expansion of railways and other transportation systems in response to mining developments in the province. The Turnagain placer gold nugget, one of the largest known in British Columbia, was on display at the symposium for the first time in more than 50 years and it is now part of a formal exhibit at the Royal British Columbia Museum. The nugget is 1641 grams in weight (52 oz) and is 20 centimetres long. It was discovered in the Turnagain River area in northwest British Columbia in 1937 by Alice and Vern Shea and was purchased that year by the British Columbia government for only $1500. The large number of people attending the symposium illustrates the public interest in the history of geologic developments in the Cordillera and the importance of presenting scientific results at a level that can be appreciated by all.

It is a pleasure to be able to introduce this volume to interested readers. It is hoped that these papers will not only increase our understanding of the history of geologic studies in the Canadian Cordillera but will also highlight the need for geologic research in fields of current importance including: earthquake, landslide and other geologic hazard investigations, environmental studies related to groundwater and other subsurface resources, the preservation of heritage resources and continued economic development in the mineral and petroleum industries.

ACKNOWLEDGMENTS

The original symposium was co-convened by Arlene Collins of the Geological Survey of Canada and her enthusiastic efforts towards gathering the symposium participants and organizing the public and technical presentations is gratefully acknowledged. The preparation and publication costs of this volume have been offset by the British Columbia Ministry of Energy, Mines and Petroleum Resources and particular appreciation is extended to John Newell for editing, and to Brian Grant of the Scientific Review Office for final editing and layout. Not at all least, appreciation is also extended to each of the authors for their personal contributions.

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MINERS AT WORK, A HISTORY OF BRITISH COLUMBIA'S GOLD RUSHES

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ABSTRACT

The search for gold is the single most dramatic event of British Columbia's early history. Although European settlement originally was founded on furs, it was the gold rushes of 1858 through the 1860s that changed the direction of development in this province for considerable time. These gold rushes not only brought a sharp increase in population and wealth but also initiated development of an early infrastructure of roads and services and directly influenced the shape of British Columbia's politics. It has been estimated that between 1860 and 1880 about $35 000 000 worth of gold was extracted from the 130 square kilometres (50 square miles) surrounding Barkerville. Although the later gold rushes were smaller, they also played an important role in our history.

The rush to British Columbia was only one of a series of sudden shifts in population and wealth that resulted from the search for placer gold. California and Australia both attracted hordes of miners in search of riches. This paper places the British Columbia gold rush in a world context; it drew less world attention and was smaller than either the Californian or Australian rushes. The discussion then follows, in some detail, the progress of the early miners up the Fraser River in 1858, past Hill's Bar, reputedly the richest bar in North America, and on into the Cariboo and Barkerville in the 1860s. Particular attention will be paid to the interaction of the government and the miners, especially as highlighted by the Ned McGowan incident of 1859 and the Grouse Creek war of 1867. An examination will also be made of the life of the miners and the conditions under which they worked, as well as the wealth they extracted. A brief look at some highlights of other British Columbia gold rushes, starting with Rock Creek in 1860 and ending with Atlin in 1898, will also be presented.

INTRODUCTION

One of the most exciting historical events in British Columbia was the gold rush up the Fraser River into the Cariboo to Barkerville. This portion of our history has aroused more interest than almost any other episode and much has been written about it. These events certainly had a greater impact on post-contact British Columbia, than any other event that took place in such a short period of time. The Fraser River and Cariboo gold rushes, however, are only part of the full picture of the search for placer gold in the province and while this paper mainly focuses on them it also touches on other rushes.

19TH CENTURY GOLD RUSHES

Miners have been preoccupied with gold for centuries. The 19th century introduced new elements into this quest. Several gold discoveries early in the century, especially in Brazil and Siberia, focused attention on the availability of placer gold. No stampede developed to Brazil or Siberia, such as happened with the discovery of gold in California, since both of these discoveries were too distant and under strict government control. A great deal of the work in Brazil, for instance, was carried out by slave labour. As well, world communication and transportation networks had not quite reached the necessary plateau for such a mass movement of people. These factors came together in 1848 and 1849 to spark the greatest gold rush the world has seen, the one to California. Over 100 000 people are estimated to have been in the gold fields by 1852 (British Columbia at its peak probably had no more then 20 000 miners). In California between 1848 and 1860, an estimated $639 billion in gold was discovered while in British Columbia between 1858 and 1949 an estimated $93 million worth of gold was recovered. In 1859 the California goldfields produced over $44 million in gold, while British Columbia production in 1860 amounted to over $2 million. Even though the accuracy of both figures is somewhat suspect, the difference is so great that any errors are not significant. Nor does this detract from the importance of the gold rush to British Columbia and its impact on this territory, but rather illustrates the difference between the two areas and why many prospectors saw and portrayed the British Columbia goldfields as a humbug and false trail.

It was also in California that the techniques of gold mining were refined. Most of those eager prospectors who flocked to California had no idea of how to look for gold and the Sierra Nevada was their training ground. Miners, or those who had learned from the Californians, seemed to be always available thereafter to set newcomers straight. Most of the techniques had originated centuries before, but knowledge of them was not widespread – from gold panning to rockers to sluices, all were learned and relearned during the California Rush.

In the 1850s another substantial rush developed, this time to Australia. In 1851, it is reported that about half the male population of South Australia had departed for the goldfields. Although numerous 49er's (participants in the early California rush) went to Australia, even more prospectors arrived from England. It is worth noting as well that the Australian discoveries were made by an Australian who had gone to California in the search for gold. He remembered seeing similar areas in Australia and returned home to make the first Australian discovery.

FRASER RIVER GOLD RUSH

Gold was still being found in California at the time of the gold rush to British Columbia, but much of the easy digging was gone and many miners were seeking new sources of wealth. Gold had been reported earlier in British Columbia, around Fort Kamloops in the early 1850s, for instance. Rumors of gold found on the Thompson River by natives aroused interest in California and when the S.S. Otter arrived in San Francisco in February of 1858 carrying some of this gold, the rush was on. James Moore, one of the first miners to reach the Fraser River, was attending a fire department meeting in San Francisco when he first heard the news. He and others were dispatched to British Columbia to report on the situation. Miners soon flocked to Victoria on their way to the Fraser River.

Moore's group, the first miners on the Fraser River, bypassed Victoria and went through Whatcom and Point Roberts to reach the Fraser in March of 1858. His company had camped for the night at Fort Hope and then moved on in the morning, stopping for a midday meal on a bar about 2.5 kilometres below Yale (about 21 kilometres from Hope). T.H. Hill thought he noticed colours and washed a pan of gravel discovering one of the richest river bars in the world. During Hill's Bar's peak production, each miner averaged about 50 cents a pan day; over $2 million in gold was recovered. (Values of gold are somewhat difficult to determine and convert but are given in this paper in the value of the day; the $2 million from Hill's bar, at about $20 per ounce (31.1 grams), would equal about $35 million, at $350 per ounce today). Hill's Bar was also the site of another incident which will be referred to later. A few bars below Hope were also mined in early 1858. Gold in paying quantities was found at Fargo's Bar about 5 kilometres above Sumas and before the end of 1858 miners had worked their way a considerable distance up river. At least seven bars below Hope were mined, between Hope and Yale there were at least 26 bars and between Yale and Lytton another 40. The gold-bearing sand and gravel in these bars varied considerably but at Hill's Bar it was said to be 2 metres deep, 60 metres wide and cover the whole bar, a distance of about 0.8 kilometre. Mr Winston, so it is recorded, took about 23 kilograms of gold from the bar between December 1858 and April 1859; at times they reportedly obtained about 1.5 kilograms (50 ounces) a day and when running the sluices day and night, up to 2.5 kilograms (70 or 80 ounces). It was quite a sight. Alfred Waddington reported seeing 800 rockers at work between Hope and Yale, while Governor James Douglas, in November 1858, thought there were about 10 000 miners at work above Murderer's Bar which was located just below Hope (Howay, 1914, p. 41).

CARIBOO GOLD RUSH

These miners were often footloose and early in 1858, at least one adventurer, Aaron Post, had worked his way as far as the Chilcotin River, testing and trying every bar and reportedly finding gold in most of them. The gold hunters were moving into the upper Fraser by early in 1859. After reaching the mouth of the Quesnel River in May of 1859, prospectors continued up both the Quesnel and the Fraser, finding rich diggings. The advances away from the Fraser found the richer strikes to lure the miners ever on. On the Horsefly River for instance, five men with two rockers, took out about 3.1 kilograms (101 ounces) in one week, some areas reported earnings of $200 per day per man. Incentives such as this spurred prospectors onward and soon they were trying the most inhospitable of places. In 1860 Doc Keithley, George Weaver and their companions found Keithley Creek and adjoining streams, and finally in 1861 William Deitz and his partners crossed over Agnes Mountain and discovered Williams Creek, the richest of the rich Cariboo streams.

At first Williams Creek gave no sign of its great wealth, and was called for a time Humbug Creek, but late in 1861 Mr. Abbott decided to penetrate the hard blue clay over which they had been mining [at a depth between 8 and 12 feet (2.4 - 3.7 m)]. Under this clay was the real wealth of Williams Creek. Working alone (his partner had gone for supplies) Abbott retrieved about 1.5 kilograms (50 ounces) in 48 hours. The claim, with three men, produced at least 3.5 kilograms (120 ounces) per day and probably more, with an estimated total production of $150 000, though this is certainly low. Many of the miners were very reluctant to reveal how much gold was recovered by their efforts and so estimates are very inaccurate.

These were difficult workings, hard to get to and difficult to work (Figure 1). Some went to a depth of over 24 metres (80 feet) and had to be continually pumped to reduce the water (Figure 2). Supplies were expensive and winters harsh. When compared to the diggings in California it was misery. Nor did the large tract of ground exist as in California, the Cariboo goldfields covering a comparatively small area.

One of the worst problems was travelling to and from the goldfields. The early trek through the Fraser Canyon was formidable. On one occasion when Governor James Douglas queried Gold Commissioner George Cox as to why he had not collected licence fees on his journey, Cox replied:

With perpendicular ascents and dangerous descents my eyes and thoughts were wholly engrossed with the safety of my life, more especially when

Figure 1. Miners, ground sluicing on the "Ne'er do well" claim, Grouse Creek, 1867 or 1868. (British Columbia Archives and Records Service, HP765).

Figure 2. Sheepshead claim on Williams Creek in 1867 or 1868. (British Columbia Archives and Records Service, HP 5189).

mountain and overhangs the river.(George Cox to Jame *crawling along the edge, paths ... are only a few inches in width and ... form the trail along the sides of this lofty* s Douglas, 6 April 1859, see Howay, 1926, p. 101).

Even after conditions had somewhat improved, the trek remained arduous. In 1862, W. Champness ventured up to the Cariboo to try his hand at mining. He did not have great success but he did leave us an interesting account of his adventure. After what he felt was a trying journey to Williams Lake, well over one half the trip, he recorded:

Miners returning from the Cariboo diggings...after hearing the complaints of our travelling difficulties thus far, only laughed at us saying, "You've not even reached the bad tracks yet." And we soon had reason to believe them: Our horses were often plunged up to the belly in swamps and mud. British Columbia is truly a horse-killing country. At times we dragged our burdens heavily up steep and forested mountains. Then, again, we frequently met with rapid and steep streams, where in the absence of bridges, we had to wade or otherwise attempt - often at the risk of life and limb (Champness, 1972, p. 61).

Upon completion of the Cariboo Road in 1863, the trip became easier and faster than in previous years and included way-side houses (Figure 3). The journey, however, remained strenuous and it was not until 1865 that a wagon road finally reached Barkerville. Even with its final completion, the average stage time from Yale to Barkerville was still four days (Howay, 1914, p. 131).

Figure 3. "A way-side house", 1862, from Cheadle (1971). (British Columbia Archives and Records Service, HP 74431).

Travel was not only very difficult but conditions on reaching the mines were often not much better:

Hundreds, after working like slaves, and expending all their little capital, have had to retrace their weary way down to the coast, with scarcely rags enough to cover them, obliged to tie bits of sacking around their bleeding feet, and to sell their blankets for a very little bread. Truly, the numbers of these poor broken-down fellows, with their pale, pinched faces and tattered rags, eloquent of hunger and poverty, were enough to dishearten all of us together; for hundreds of such passed us during our journey, in parties of from two to a score. (Champness, 1972, pp. 61-62).

Nor did this situation improve with the better access by road. Alexander Allan found conditions just as bad in 1868 as Champness had found in 1862.

I know that in gold country such as this people generally suppose that a man cannot help but make money and have plenty of it always at command but a *more mistaken idea was never entertained. There are it is true many who have made and are now making their fortunes, but it is also true that the far greater number rank as unfortunates, those whose lot it may not be believed but it is only too true is worse than the most miserable and poverty stricken person in the old country*(Bescoby, 1932, p. 48).

Along Williams Creek, the richest of the gold areas, four small communities grew. Richfield was the earliest, and it became the government centre, but was soon eclipsed in size and importance by Barkerville (Figure 4). Further down the creek from Barkerville was Camerontown, and Marysville below it. None of these towns were far apart.

Figure 4. Barkerville in 1865. (British Columbia Archives and Record Service, HP 93780).

William Cheadle visited Williams Creek in 1863 prior to the establishment of Marysville:

At dusk we arrived at Richfield, the first part where gold was struck on this creek, & it was quite dark before we reached Cameron Town below, passing thro' Barkerville or Middle Town. The whole 3 towns extending almost continuously down the creek for a mile & containing about 60 or 70 houses a piece. This spring there were only 3 or 4 houses at Cameron Town! Our path was a difficult one over endless sluices, flumes & ditches, across icy planks & logs, all getting tumbles, gumboots being very treacherous. (Cheadle, 1971, p. 249).

Despite the hardship and the many who were unsuccessful, these were rich claims. In 1862 Thomas Elwyn, Gold Commissioner at Richfield wrote to Governor Douglas:

The yield of gold on this creek [Williams] is something almost incredible...Cunningham & Company have been working their claims for the past six weeks, and for the last thirty days have been taking out gold at the rate of three thousand dollars every twenty four hours...Steel & Co have been engaged for the last ten days in making a flume but during the previous three weeks their claims yielded two hundred ounces [~100 kgs] a day. These figures are so startling that I would be afraid to put them on paper, in a report for His Excellency's information were I not on the spot and know them to be the exact truth (Akrigg and Akrigg, 1977, p. 240).

Such views are as typical as those expressed by the many disheartened miners. There is no doubt that many returned poorer than they arrived with only a few finding great wealth, but there is also no doubt that some did find such wealth. As the Reverend Edward White wrote in 1861:

The bags of [gold] dust which are now coming down, confound and strike dum[b] every person who has dared call Fraser River gold mines a humbug. If I had time and space I would fill sheets with the reports of lucky ones. I could give you a long list of those who went up last spring with hardly enough to pay their expenses to Cariboo, and are now returning with $5 000 to $20 000 each. (Christian Guardian, 4 Dec. 1861, p. 192, cited by Akrigg and Akrigg, 1977, p. 235).

The early hustle and bustle had slowed considerably by 1865, even though a lot of gold was still being taken from the ground at numerous mines (Figure 5). Few new discoveries were made and the gold was getting harder and harder to get. As hydraulic operations started, water wheels, pumps and other devices became needed accessories to gold mining. It was no longer a game for the individual miner.

Figure 5. Williams Creek from Black Jack Canyon, 1868. (British Columbia Archives and Records Service, HP 13188).

Barkerville in 1862 was a city of tents but by 1863 wooden houses began appearing. A continuous complaint was that the roadway was always dirty and never repaired. In the fire of September 16th, 1868 about 116 buildings were destroyed, but the town was reportedly built larger and better and included three gas lights, one each in front of the two banks and the Hudson's Bay Company store. Prior to the fire (Figure 6), Barkerville had a variety of merchants and other enterprises with most of the buildings being businesses and included 20 general stores, 18 saloons, 8 boarding houses, with only 2 private residences listed as destroyed by the fire. Even though the peak of the gold rush had passed, rebuilding Barkerville proceeded quickly; 41 merchants reestablished themselves in 1868, by 1869 there were 76 and 98 in 1871 (Bescoby, 1932, p. 2).

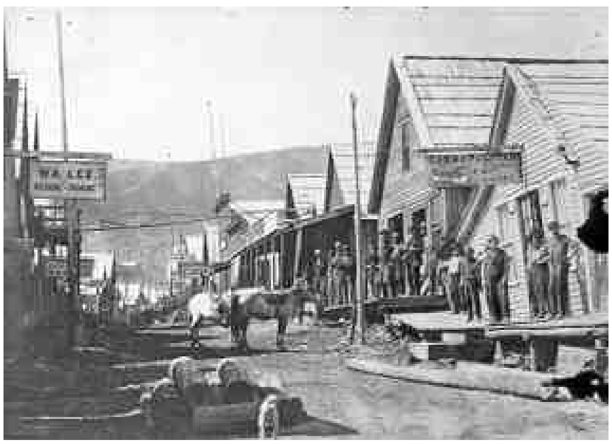

Figure 6. Barkerville prior to the fire of 1868. (British Columbia Archives and Records Service, HP 10111)

Camerontown and Marysville, each about 1.5 kilometres apart, were located between Barkerville and what is now Wells. Marysville was largely residential but some businesses and other facilities were set up in Camerontown, such as the hospital in 1864. Other communities grew up on some of the surrounding streams and in the gulches. Some of these earlier small communities were Grouse Creek, Keithley and Van Winkle, initially considered as the main centre for the area. Some of the others included Antler in 1863 which had seven merchants. Centreville was established in 1867 and by May 1868 had 100 dwellings. Felixville sprang up at the head of Conklin Gulch in 1869 and Gladstoneville at the mouth of Chisholm Creek in 1870. The buildings were often rough, though lumber was available from several small sawmills. The cabins the miners lived in were generally one room affairs, made of log with a single window and single door, a stone fireplace and a mud floor; some of the larger companies built bigger buildings (Bescoby, 1932, p. 4).

LAW AND ORDER

There was general agreement among the pioneers that lawlessness played little part in the mining community, in general it was a pretty safe place. Thomas Hammett commented that *Respect for Law and order was always a marked feature of life in Cariboo.... The strict enforcement of the laws scared away the `bad men' who used to give a bad name to mining camps on the other side of the line..*.(Bescoby, 1932, p. 31). James Douglas wrote to Newcastle at the Colonial Office in 1863 that *unanimity and good feeling prevail among the miners on Williams Creek and both the Upper and Lower Towns have been perfectly quiet, and free from disturbance.* (Bescoby, 1932, p. 32). The local paper, the Sentinel, reported only a few crimes: a burglary Aug 26, 1865 of a merchant, for instance, or the bar-room fight in 1866 which was reported as generally friendly in nature. Between 1866-71 only 135 criminal cases were heard and of the 25 in 1868, two were felonies, six thefts and the rest drunkenness.

There were only two recorded instances of individuals who could be considered habitual criminals. One was Jesse Pierce. He is first noted in 1864 when he was in court over a mining dispute. In 1865 he was charged with supplying liquor illegally to native women in Lorings saloon in Camerontown and in 1868 he squabbled with James Knight at Mosquito Creek. He was wounded, but his adversary Knight was let off as the wounding was considered accidental. In September 1868 Pierce was in a fight in the Arcade saloon in Barkerville, and in March 1869 he assaulted William Phillips at Mosquito Creek, who died as a result. Pierce was imprisoned but escaped and in September 1869 was declared an outlaw. As far as I am aware he was not recaptured. Another individual, William Williams, also had a long list of offenses but these two men are the only two so recorded (Bescoby, 1932, p. 37).

Two incidents especially stand out in the story of law and order during the gold rush. The first occurred in 1858 at Hill's Bar. When the miners flocked to British Columbia in 1858, James Douglas acted speedily toward taking control of the situation and protecting the realm for the British Government. He adapted procedures used in the Australian rushes and appointed Gold Commissioners who would act as general government representatives, though their main concern was to enforce the mining regulations. Douglas proclaimed that *The Gold Commissioner alone without a jury shall be the sole judge of law and fact.*(Bescoby, 1932, p. 9). Unfortunately some of his first choices of employees were not the best.

On Christmas day in 1858, a Hill's Bar miner committed assault in Yale. Captain Whannell, the Gold Commissioner at Yale, sent out a constable with a warrant to Hill's Bar where the criminal was residing. George Perrier, the Hill's Bar Gold Commissioner refused to recognize the warrant and even issued a warrant for the arrest of the victim in Yale. Whannell than arrested Perrier's constable when he arrived in Yale to serve the warrant. A posse was organized under Ned McGowan, who had a notorious reputation. They proceeded to Yale, released the constable and arrested Whannell, who Perrier then arraigned and fined for contempt of court. Accusations flew to Victoria and Douglas immediately dispatched Colonel Moody with Judge Begbie and marines to the scene. McGowan was fined for his part and Perrier and his constable dismissed. (This is a much abbreviated version of the story, for more information, see Akrigg and Akrigg, 1977, pp. 146-154). These first government representatives seem to have been an unsatisfactory group, especially Perrier, Whannell and Richard Hicks. Hicks was *deficient in nerve for the position he holds*, so Begbie wrote to Douglas in early 1859,*I cannot get anyone to speak up for him. Even Mr. Edward McGowan who does him the honour of preferring him to Capt. Whannell alleges his reason to be because he prefers dealing with a knave rather then a fool.* (Matthew Baillie Begbie to James Douglas, 1 Feb. 1859, 14 Jan. 1859, Colonial Correspondence, F142a, Provincial Archives and Records Service). By the end of 1859, they were largely replaced with a new group of more competent men, many of whom had served in organizations such as the Irish Constabulary; Peter O'Reilly, being one example. Not that they were all without blemish. Andrew Elliott was temporarily removed while Douglas had his books and transactions audited. All was found in order, merely in great disarray and after a reprimand, Elliott was reinstated. (C.S. Young to Andrew C. Elliott, 6 June 1862, Colonial Correspondence, Provincial Archives and Records Service).

The second incident is the Grouse Creek war of 1867. In 1864 the Gold Commissioner Peter O'Reilly granted the rights to a certain portion of land on Grouse Creek to the Grouse Creek Bedrock Flume Company of Victoria, for ten years, provided it fulfilled all conditions of the Gold Fields Act. The Grouse Creek Company ran out of money and left the site apparently abandoned in 1866. The local Canadian Company applied for rights over the supposed abandoned claim and these were granted by the Gold Commissioner, Warner Spalding. Some months later the Grouse Creek Company renegotiated with the Crown, through Spalding, for its rights to the claim and they were reinstated. The Canadian Company of course objected and the case returned to Miners Court under Spalding who, not unsurprisingly, found for the Grouse Creek Company. The Canadians refused to move. After further exchanges, the district magistrate finally requested the marines. Instead, Governor Seymour arrived and persuaded the Canadian Company to leave the ground, evidently with the promise of a new trial. A few of the company were arrested but spent an agreeable time in jail as, *their sympathizers supplied them with bountiful grog; [and] what with games and songs, interspersed occasionally with a derisive hoot at the officials, they were the jolliest convicts ever seen.*(British Colonist, September 9, 1867, cited by Tina Lo, A Delicate Game: The Meaning of Law on Grouse Creek, paper presented at British Columbia Studies, 1990). Joseph Needham (Figure 7), Vancouver Island's Chief Justice, decided in favour of the Grouse Creek Company and this was finally accepted by the Canadian Company. Both of these, so-called wars, were tests of the local justice system and little violence accompanied the incidents. What they did do was bring to a crisis point certain problems which needed resolution; the replacement of incompetent Gold Commissioners and some changes and clarifications to the method of dispute resolution, as well as clarification of the limits of government authority and the extent to which the government was prepared to go to protect its authority.

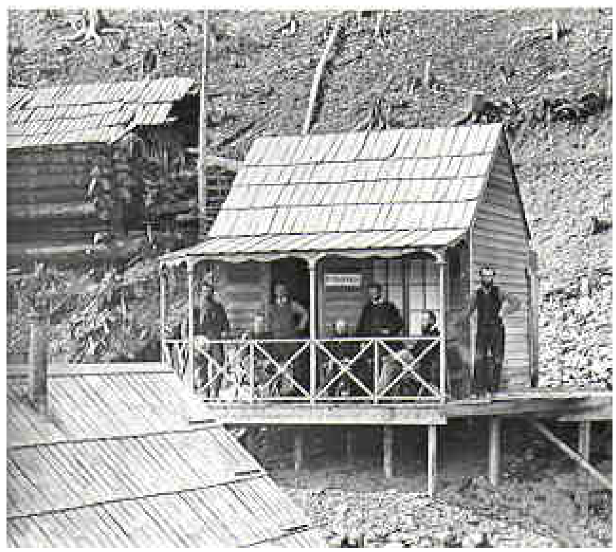

Figure 7. Judge Needham and party at Dr. Carrall's, 1867. (British Columbia Archives and Records Service, HP 4359).

OTHER BRITISH COLUMBIA GOLD RUSHES

Although the Fraser River and the Cariboo gold rushes are the most dramatic of the gold rushes they were not the only such episodes. Even in 1859 many of the miners were leaving the dwindling bars of the lower Fraser and some headed for a new strike in the Boundary Country at Rock Creek. Charles Wilson, an officer on the boundary survey described this community in 1860:

The Town or rather, I beg its pardon, city has sprung up like a mushroom, there are about 350 inhabitants, miners, gamblers, sharpers,... Pikes, Yankees, Loafers... There are a good many substantial *log buildings, stores, gambling houses, grog shops, butcher shops, etc...* (Wilson, 1970, p. 126).

This was one of the wilder communities and reportedly needed to be straightened out by Gold Commissioner, Judge Cox, though according to Wilson, "the miners have behaved very well." (Wilson, 1970, p. 126). Mining lasted at Rock Creek for about three years with an estimated $250 000 worth of gold recovered.

In 1863 a small flood of miners occupied the Wild Horse Creek area in the Kootenays, so named when the first miners to the area saw a wild horse near the mouth and followed it up the creek. This was a rough and ready camp, which was portrayed as, *a horde of outlaw gamblers, murderers and out of a job desperados*. The miners, however, immediately established a miners' court system and elected a sheriff while awaiting the arrival of a Gold Commissioner to handle legal matters (Christian,1967, p. 29).

The main feud seems to have been between the early and late arrivals over accessibility to the better claims. When a brawl erupted, one Tommy Walker shot off Yeast Powder Bill Burmeister's thumb. Bill, not taking this lightly, shot Walker dead. A miners' jury acquitted Bill. Gold Commissioner Haynes arrived one week later, investigated and gave the same verdict.

The main town was Fisherville which was described in 1864 as a queer place and thoroughly a "mining camp"... all sorts of log huts, shake houses, split timber huts, bark huts ... men lounging about — others playing cards — others drunk — miners rocking and sluicing — pack trains commencing — altogether a motley vagabond crew in the midst of a lively and exciting scene (Birch Diary, 1864, British Columbia Archives).

When Gold Commissioner Peter O'Reilly arrived in 1865 he found Wild Horse very similar to other mining areas he had served at:

Glad to see many old faces from the Cariboo who gave me a hearty welcome. The town is like all the mining villages I have yet seen, therefore nothing very attractive, the mines of course I don't as yet know anything about but the country if I may judge by the little I saw of it on the my way in is a vast improvement on Cariboo as is the climate from all I have heard.(Peter O'Reilly to Caroline, May 18th, 1865, O'Reilly Collection, British Columbia Archives).

In 1864 about 2300 were mining in the area but this boom quickly died with about 450 remaining in 1866.There were small rushes to many different streams such as to Leech River near Victoria in 1864 and to many areas of southern British Columbia, but in the late 1860s most of the excitement moved north, to Omineca in 1869, Cassiar in 1873 and finally Atlin in 1898. The trek of miners to the north was smaller than the rush to the Cariboo. In the Omineca, Germansen Creek became the focus of the search with the rush peaking in 1871. In 1872 only two creeks, Germansen and Manson were being worked and in 1874 the rush had dwindled to about 60 claims being worked by some 80 miners. The Cassiar rush peaked in 1876 with about 2000 miners working the area. Some were rich creeks, the Dease River, for instance, yielded nearly $1.5 million in gold, but neither the Omineca nor the Cassiar possessed the wealth of either the Cariboo or of the later strikes around Atlin (Howay, 1914, pp. 266-272).

Figure 8.Atlin in 1899. (Royal British Columbia Museum photo)

The Atlin gold rush occurred at the same time as the much more spectacular rush to the Klondike and so has been somewhat overshadowed, but it was a substantial gold find. Miners were able to trek down from the Yukon to the newly formed community of Atlin (Figure 8) or stop on their way north. In late 1898, over 3000 miners were working the streams around Atlin (Figure 9). Production in 1898 was estimated at more than 100 kilograms (3750 ounces) of gold, valued at $75 000. By 1899 about 12 440 kilograms (400 000 ounces) of gold, with a value of $8 000 000, had been produced. Between 1898 and 1949 over $22.5 million in gold was recovered from these creeks.

The search for placer gold did not end with the spectacular and often shortlived rushes. In 1889 the Gold Commissioner John Bowron recorded that *Williams Creek with its tributaries, worked for nearly thirty years still yields more gold then any other creek in the Province.*(British Columbia Department of Mines, Annual Report, 1889, p. 273). All these areas, plus many others, continued to be worked once the main rush had passed them by and miners still continue to find gold in most of the early gold areas as well as making new discoveries. One of the largest nuggets found in British Columbia, weighing about 1617 grams (52 ounces), was discovered in 1937 on Alice Shea Creek. Gold was only found in that area, for the first time in 1932.

Figure 9. Mining on Spruce Creek, near Atlin in 1903. (BC Archives & Records Service, HP 72954)

PLACER MINING IN THE EARLY 1900s

A brief look at some of the major placer mining operations just after the turn of the century shows that although many small operations continued into the 1900s, the industry underwent a transformation which included an increasing dependence on hydraulic mining methods. The hydraulic operation was first introduced in 1860s. A monitor directs a high pressure stream of water to wash the gravel down to the sluice box for the recovery of gold (Figure 10). Tremendous amounts of gravel and earth could be moved by this means. The largest of these developments were in the Cariboo and the Atlin areas with some renewed interest in Cassiar and Omineca.

The largest of the these operations was in the Cariboo. Miners had realized by 1900 that much of the wealth of Cariboo gold remained locked in the deep gravels of the streams and gulches. Cutting below the old surface workings on the South Fork of the Quesnel River, near Quesnel Forks, the Consolidated Cariboo Hydraulic Mining Company produced a gigantic pit at Bullion. In 1900, for instance, the company moved nearly 2 million cubic yards (over 1.5 million cubic metres) of gravel and recovered 20 470.91 troy ounces (636.7 kilograms) of gold (Anonymous, 1901a). Even though it was by far the largest, Consolidated Cariboo was not the only player. Many of the longer worked creeks continued to be mined using both older and slower techniques as well as hydraulic methods. The Forest Rose property on Williams Creek, for instance, was first developed in the 1860s with the owners first using hydraulic methods in 1876. It remained in continuous operation until 1900. On Grouse Creek, the Waverly Hydraulic Company started work in 1880 and remained in operation for some years after 1900. Discoveries in the Horsefly area in 1901 were thought to be the precursor of developments that would bring the

Figure 10. Consolidated Cariboo Hydraulic Mining Company's 15-centimetre (6 inch) monitor in 1896. (British Columbia Archives and Records Service, HP 99924).

Cariboo to world attention as had events in 1862 (Anonymous, 1901b). Certainly some new excitement was generated, but the deep gravels of the Cariboo required capital and laborious effort to bring them into production.

Consolidated Cariboo's Bullion mine, on which development had started in 1894, was to remain the largest of the producing mines. The company operations in 1903 included 34 placer mining leases covering about 25 000 acres. They employed about 120 men and had 53 kilometres of canals, three main reservoirs, two secondary reservoirs and a main sluice at the Number 1 pit 365 metres (1200 feet) long. Despite recovering slightly over $1 million between 1894 and 1902 the company still had not made a profit. During that period it was estimated that about 4.5 million cubic metres (6 million cubic yards) of gravel had been washed and that about another 380 million cubic metres (500 million cubic yards) remained (Watson, 1903). Over 9 million cubic metres (12 million cubic yards) had been worked by 1905 and the company claimed to be making 19 cents to the cubic metre (25 cents to the yard) but later estimates were about 7.5 cents to the cubic metre(10 cents per yard). Consolidated Cariboo lost money and the pit, 0.8 kilometre in length, was closed. Reopened in later years, Bullion Placers Limited finally closed the pit in 1942 (Lay, 1935).

In the Atlin, Cassiar and Omineca areas hydraulic mining emerged about the same time. Five hydraulic operations were working creeks near Atlin in 1900, while several large companies were also operating in the Omineca. The Cassiar, in 1894, *was slumbering after the great excitement of 1872*. In 1900, a hydraulic operation commenced on Thibert Creek and although it remained the only operation until 1904 when the Berry Creek Company started, gold production grew in importance over the next decades. Hydraulic mining, in this fashion, is no longer legal in British Columbia.

CONCLUSION

The story of placer mining in British Columbia is far from finished. New discoveries are made every year and considerable quantities of gold are still found. The placer gold mining industry has changed from its early origins. Although some methods have been discarded and others introduced, the gold pan is still commonly used for testing small gold finds and the sluice box remains the primary means of separating gold from its associated gravel. The attraction of wealth is only part of the incentive to the gold miner, for the romance of the search for gold has cast its lure widely.

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THE CANADIAN CORDILLERA A HISTORY OF WHO, WHAT AND WHEN

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ABSTRACT

From the time when Sir John Richardson made the first truly scientific observations on the geology of the Franklin Mountains in 1825 to the imminent publication of the Decade of North American Geology volume, Geology of the Cordilleran Orogen in Canada (Gabrielse and Yorath, 1992), the history of geoscience in the Cordillera can be divided into three stages of unequal length. The first interval, lasting for about 100 years, was one of simply trying to determine what was there. The epic canoe, foot and horse traverses of Hector, Dawson, McConnell, Selwyn, Daly and many others, together with early mineral exploration in the Yukon, Cariboo, Atlin and Kootenay districts gradually led to a comprehension of our geological inventory. The discovery of oil beneath the plains of Leduc, Alberta in 1947 resulted in extensive exploration by petroleum companies throughout the Rockies and Mackenzie Mountains. Coal and base metal mines added considerably to the economy of British Columbia as did the Department of Geology at the University of British Columbia whose outstanding and memorable staff supplied the Cordillera with an incredible array of talent. This first stage ended in 1959 when Bill White of the University of British Columbia published his benchmark paper entitled Cordilleran Tectonics in British Columbia, the first attempt at a regional synthesis of much of the Cordillera invoking classical geosyncline and orogenesis theory (White, 1959).

The second stage began with the development of modern plate tectonic theory and the widespread use of helicopters to conduct regional reconnaissance mapping which had begun during the mid-1950s. The publication of Raff and Mason's famous map (Raff and Mason, 1961), together with Fred Vine's and Drum Mathews' attempts to explain it and thus give validity to the hypotheses of sea-floor-spreading and plate tectonics as formulated by Harry Hess, allowed the Cordillera to be viewed in a totally different way (Vine and Mathews, 1963). Regional helicopter reconnaissance surveys such as Operations Stikine, Mackenzie, Liard, Nahanni, Porcupine and Bow-Athabasca added vastly to our knowledge of the orogen and permitted the second synthesis to be published by Jim Monger, Jack Souther and Hu Gabrielse (Monger et al., 1972). Using the new dogma, the architecture of its five morphogeological belts as previously defined by John Wheeler and Atholl Sutherland Brown, was characterized in terms of assemblages of oceanic rocks, each a response to the several processes embodied in Hess' ideas.

Perhaps as a reflection of the mobilist versus stabilist arguments that characterized the initial stages of the plate tectonics revolution, the third stage, towards the end of which we currently find ourselves, is a time of reassessment. During the past two decades the formulation of the terrane concept and proposals for their large-scale translations have led to differences in championed tectonic histories between proponents of precise measurement and experimentation, and those who prefer geological inference based on stratigraphic and structural field observations. To the extent that the answers will undoubtedly be found by each of these approaches, and not necessarily by compromise, we must await the post Decade of North American Geology years to witness the next chapter in the developmental history of geoscientific ideas in the Canadian Cordillera.

EARLY GEOLOGIC OBSERVATIONS IN THE CANADIAN CORDILLERA

Apart from casual observations made during early marine explorations along our coast, such as those of Cook and Bodega y Quadra in the latter part of the 18th century, the first specifically geoscientific observations recorded in the Canadian Cordillera were those of Alexander Mackenzie. During his return trip in 1789 up the river that bears his name, near the modern community of Fort Norman he noted *several smokes along the shore and experienced a very sulphurous smell and at length discovered that the whole bank was on fire for a very considerable distance.* He concluded that *it proved to be a coal mine,to which the fire had communicated from an old indian encampment*. Some 36 years later, John Richardson in the company of John Franklin's second overland expedition to the polar sea, recorded observations at the same locality and noted T*he pipe-clay, when taken newly from the bed, is soft and plastic, has little grittiness, and when chewed for a little time, a somewhat unctuous but not unpleasant taste.* The locality comprises a series of bocannes within Early Tertiary alluvial fan deposits that include lignite and pyroclastics. To my knowledge Richardson's comment is the first and only attempt to introduce volcanic ash into western diet.

Serious geological observations began in 1857 when James Hector, a physician and naturalist attached to the first CPR route expedition led by Captain John Palliser, made observations on the stratigraphy of the southern Rockies and recorded the first observations of coal deposits on Vancouver Island. Systematic geological surveys began in the 1870s with the work of Selwyn, Dawson, McConnell and James Richardson. Particularly noteworthy was the work of George Dawson whose perceptions on the natural history and ethnography of southern British Columbia, the Yukon and Queen Charlotte Islands were such as to cause many of today's field geologists to still sense his presence, half expecting to see his smiling happy face peering over our shoulders to get a glimpse of their field notes.

Comprehensive studies of the Cordillera began in the 1880s by Dawson and McConnell. The latter's geological cross-section of the Rockies became a standard reference, and the McConnell fault, one of the great thrust faults of the southeastern Rockies was subsequently named for him. A far-ranging reconnaissance journey by these two men in 1887 and 1888 provided the initial geological information on the northern Cordillera, including much of northern British Columbia and the Yukon where the respect and affection of the people for George Dawson is expressed in the name of one of its most important communities. Work in the Cariboo region in the 1880s by Amos Bowman set the foundation for subsequent mapping in a geologically complex area where, 20 years previously, a major gold rush spurred efforts of the McDonald government to persuade this distant territory to join our ever quarrelling confederation.

In the late 1890s much geological survey activity arose from mineral exploration in the Klondike, elsewhere throughout the Yukon and in the Atlin and Kootenay districts of British Columbia. Names such as Joseph Keele, W.W. Leech and J.C. Gwillim made lasting contributions, some of which were superceeded only three decades ago. Also important was D.B. Dowling's published monograph of the coal-bearing formations of the Rockies, a work that remained the principal reference for many years.

EARLY TWENTIETH CENTURY INVESTIGATIONS

Two investigations in southern British Columbia during the early years of the 20th century were notable in relationship to modern tectonic concepts. The first was R.A. Daly's International Boundary Survey during which he recognized the fundamental division of the Cordillera into an eastern part dominated by sedimentary rocks and a western part containing abundant volcanic, plutonic and metamorphic rocks. Similar surveys some three decades earlier across the American Cordillera by Clarence King and John Wesley Powell had recognized the same fundamental divisions, thus allowing for J.D. Dana's miogeosyncline and eugeosyncline hypotheses to be applied to the North American Cordillera. The other survey was C.W. Drysdale's study of the Kootenay region from which he proposed that the various types of mineral deposits were related to differences among terranes encompassing different hostrocks.

Between 1910 and 1915 mapping in the southern Cordillera was conducted by many geologists who, in later years, were to attain international recognition as university researchers and teachers, men such as N.L. Bowen, author of the Bowen reaction series of igneous petrogenesis, R.A. Daly who went to Harvard, and A.M. Bateman who, while at Yale University, wrote his famous textbook on economic geology which became the standard text for many years. Two frequent visitors of note were C.D. Walcott and C.H. Clapp. The former drew attention to the remarkably well preserved, soft-bodied fauna in the Lower Cambrian Burgess shale near Field in the southern Rockies, a locality which has since been designated as a World Heritage site by the United Nations. The latter conducted several seasons of fieldwork on southern Vancouver Island and was the first to define the basic stratigraphic and tectonic elements of the southern Insular Belt.

INFLUENCES OF MINERAL AND HYDROCARBON EXPLORATION

Investigations of mineral districts and hydrocarbon resources have provided much of the focus for Cordilleran exploration. Regional studies in the Stikine region by F.A. Kerr were supported by student assistants who themselves made significant contributions to Canadian geology, people such as Cliff Lord and Stu Holland, the former becoming Chief Geologist of the Geological Survey of Canada (GSC) in the early 1960s and the latter, Chief Geologist of the British Columbia Survey at the end of that decade. In the north, W.E. Cockfield carried out diverse studies in the Yukon, mainly in mineral districts such as Keno Hill and Galena Hill.

After 1930 H.S. Bostock became the best-known geologist in the Yukon as a consequence of his extensive mapping program, his reports on the mineral industry and through his contacts with mining and exploration personnel. He greatly advanced our knowledge of the physiography and physiographic development of the northern Cordillera and his maps and reports continue to serve as valuable guides to placer and lode exploration.

One of the most interesting examples of integrated industry and government exploration took place during the early stages of the Second World War in the Mackenzie and Franklin Mountains region of the Northwest Territories. In recognition of the strategic importance of the Norman Wells oil field which had been discovered and developed during the 1920s, in early 1942 a cooperative exploration and development project, called the CANOL Project, to increase the known limited reserves was undertaken by the Geological Survey of Canada and the United States Navy under the direction of the late Ted Link of Imperial Oil.Although the threat to American coastal oil supplies was abrogated during the first week of June of the same year at the Battle of Midway, the project went ahead and produced forty reports, several maps and at least one vast fortune as a consequence of the cost - plus 20 per cent construction of the CANOL pipeline from Norman Wells to Fairbanks, Alaska.

In 1947 oil was discovered beneath the plains of Leduc Alberta and a year later the blowout of Atlantic No. 3 announced that Canada was to enter the oil business. The Geological Survey and several oil companies intensified exploration in the Rockies during which Digby McLaren and Helen Belyea established stratigraphic and biostratigraphic correlations between the exposed Upper Devonian reefs in the mountains with their producing equivalents in the subsurface of the plains. At the same time structural, stratigraphic and biostratigraphic studies were conducted by Con Hague, Frank McLearn and Bob Douglas, the latter chosen to be the editor of the 1970 edition of Geology and Economic Minerals of Canada. It was these studies in the Foreland Belt that provided the impetus for the large, helicopter-supported reconnaissance mapping projects undertaken by petroleum companies and the GSC in the late 1950s and 1960s.

Construction of the Alaska Highway and the CANOL Pipeline and road to Fairbanks in the early 1940s provided access to the Mackenzie, Selwyn, Pelly, Cassiar and northern Rocky Mountains for E.D. Kindle, Con Hague, M.Y. Williams and Cliff Lord. A reconnaissance study of the northern Rockies and Cassiars by Mat Hedley and Stu Holland of the British Columbia Survey emphasized the profound lithological discordance between the two areas and illustrated the great areal extent of Mesozoic granitic rocks in the Cassiars. In 1943, K. de P. Watson and Bill Mathews, working with the same organization, conducted a study of the Tuya-Teslin area of northwestern British Columbia where their observations of the Pliocene and Pleistocene volcanic rocks led to Bill's characterization of `tuyas' as flat-topped volcanic edifices erupted into lakes thawed from glacial ice by the heat of the ice-covered volcano. Detailed structural studies in the southern Omineca Belt by Mat Hedley and Jim Fyles led to the recognition of large recumbent folds involving the entire regional stratigraphic assemblage, the first of such structures to be recognized west of the Foreland Belt.

THE UNIVERSITY OF BRITISH COLUMBIA

The influence on Cordilleran geological research and mineral exploration by The University of British Columbia during the first half of the 20th century was considerable. Following the appointment of R.W. Brock, formerly Director of the Geological Survey of Canada, in 1914 as Dean of Applied Science, many outstanding teachers and researchers joined the Department of Geology. These included M.Y. Williams as professor of paleontology and Henry Gunning, one of the greatest professors of economic geology of his time. Later, teachers such as Bob Thompson, Harry Warren, Bill Mathews, Ken McTaggart and Vladmir Okulitch taught a variety of students who, during the years between 1945 and 1950 included Hu Gabrielse, John Wheeler, Dick Campbell, Jim Aitken, Atholl Sutherland Brown, Hugh Nasmith, Jim and John Fyles, Jim Roddick, Owen Hughes, Bill Poole and many others, all of whom became variously notorious throughout the Canadian geoscientific community.

MID-TWENTIETH CENTURY INVESTIGATIONS

The late 1940s and early 1950s saw a great increase in the number of field parties including those led by Stu Holland in the Cariboos and Jack Armstrong, Cliff Lord and Fred Roots in the Omineca Mountains. In addition to Armstrong's and J.S. Grey's discovery of the Pinchi Lake mercury deposits, Jack Armstrong was the first to attempt correlation of stratigraphic assemblages throughout the full length of the Intermontane Belt.

REGIONAL MAPPING AND DEVELOPMENTS IN PLATE TECTONICS

The 1950s saw a new era of mapping when pack-horses and canoes were replaced by helicopters.Several major oil companies carried out regional helicopter-supported reconnaissance projects throughout the entire length of the Foreland Belt. At the same time the GSC began several projects in western Canada, one of the largest being Operation Stikine which, in 1956, covered six 1:250 000-scale map areas and employed eight staff members, forty-five support staff, three pack-horse groups, two helicopters and several fixed-wing aircraft.

The British Columbia Survey continued its detailed studies of mineral districts but also conducted investigations of regional scope. The work of Gerry Henderson in the Stanford Range of the Rockies in the early 1950s resulted in the first clear picture of stratigraphy and structure in the westernmost part of the southern Foreland Belt. Gerry went on to become one of Canada's foremost petroleum geologists, President of Chevron Standard Ltd and ultimately executive director of Canada's LITHOPROBE project. Geoff Leech, in a study of the Shulaps ultramafic body, recognized the importance of the Yalakom fault, later seen to be one of the most important terrane-bounding faults in the Cordillera.

The first century of Cordilleran geology ended in 1959 with publication of Bill White's benchmark paper entitled *Cordilleran Tectonics in British Columbia* (White, 1959). This was the first regional synthesis of Cordilleran geology and the first attempt to outline its complete evolution. Naturally it was based upon classical geosynclinal and stabilist hypotheses which remained essentially unassailed until August of 1961 when, in the Bulletin of the Geological Society of America, Arthur Raff and Ronald Mason published their famous magnetic anomaly map of the Juan de Fuca Plate (Raff and Mason, 1961).

The early years of the second century of Cordilleran geology were crowded with many exciting events. Although the stage had been set for the onslaught of the mobilist hypothesis in 1956, when Ted Irving and Keith Runcorn independently published two important papers confirming the theory of continental drift, it was not until the years between 1963 and 1965 when Fred Vine, Drummond Mathews, Larry Morely, Andre Larochelle and John Tuzo Wilson explained the origin of the magnetic signature of the ocean floors and provided the interpretive support for the brilliantly intuitive ideas of sea-floor spreading and plate tectonics that had been proposed by Harry Hess of Princeton University at the beginning of the decade.

Meanwhile, back in the Canadian Cordillera life went on. Atholl Sutherland Brown completed his work on the geology and mineral deposits of the Queen Charlotte Islands and to the south, Jan Muller was well along in his mapping of Vancouver Island. Helicopter-supported reconnaissance operations such as Bow-Athabasca led by Ray Price in the southern Rockies, and Operation Norman led by Jim Aitken in the District of Mackenzie essentially completed the reconnaissance mapping and establishment of the basic geological framework of the Cordillera as described in 1970 by the 5th Edition of Geology and Economic Minerals of Canada, edited by Bob Douglas.

The realization of the basic geological framework of the Cordillera was much enhanced in the mid-1960s with the near simultaneous recognition of its five-belt architecture by John Wheeler and Atholl Sutherland Brown. Without this fundamentally simple architectural model which arose from some 100 years of mapping, the current concepts about which we are arguing today could not have been developed. Moreover, were it not for the work of some remarkable paleontologists such as George Jeletzky, Hans Freebold, Tim Tozer and Howard Tipper, the understanding of this architecture would not have been achieved.

DEVELOPMENTS IN GEOPHYSICS

Geophysical studies in the Canadian Cordillera were slow to develop. Although the first seismograph was established in Victoria in 1898 it was not until the early 1960s when other types of geophysical studies began. Indeed, possibly the loneliest geoscientist in Canada for almost a decade was Bill Milne, who moved behind the Tweed Curtain in the early 1950s to be Canada's Dr. Earthquake on the west coast, and who later fathered the tumultuous birth of the Pacific Geoscience Centre in 1978.

In 1966 a prize-winning paper entitled *Structure, Seismic Data and Orogenic Evolution of the Southern Canadian Rocky Mountains* was published in the Bulletin of Canadian Petroleum Geology by Bert Bally, Pete Gordy and Gordon Stewart, all of Shell Canada Resources Ltd. (Bally *et al*., 1966). Although it had been intuitively suggested two years previously in a structure cross-section compiled by Bob McCrossan, in that paper interpreted seismic sections and supporting well data clearly showed that the characteristic thrust faults of the Foreland Belt flattened at depth to form a regional décollement above the Precambrian crystalline basement. The necessary corollary to this observation was that the strata of the miogeocline had been detached from their basement and moved hundreds of kilometres eastwards. What caused the shortening was not to become clearly evident until a decade later.

RECENT GEOLOGIC INVESTIGATIONS: 1970 TO THE PRESENT

In 1970, a paper describing the second attempt at a synthesis of Cordilleran geology was presented at the Geological Society of America meeting in Washington D.C. by Jim Monger, Jack Souther and Hu Gabrielse. This synthesis, published in 1972, was based upon plate tectonic principles wherein four of the five belts were shown to have developed through the superpositional accumulation of oceanic assemblages such as oceanic crust and island arcs (Monger *et al*., 1972). Although each succession was thought to have developed in response to oceanic tectonic processes such as subduction, the concept of crustal mobilism and the realization of the significance of the many prominent northwesterly trending faults was to wait yet more years, in spite of the fact that in the following year, Jim Monger and Charlie Ross published their now classic paper on the Tethyan fusulinacean faunas of the Intermontane Belt.

Meanwhile, along the shores of Buttle Lake on Vancouver Island, Ted Irving and Ray Yole were drilling holes in the Upper Triassic oceanic lavas of the Karmutsen Formation. The calculated paleopole was found to be substantially discordant, from which they suggested that Vancouver Island was allochthonous, a conclusion in support of Tim Tozer's earlier suggestion that the Triassic ammonites from this formation were near equatorial in paleoclimate latitude.

Although all found these results interesting, many tended to drift along, arriving at eight, departing at five, as though careless of the approaching bandwagon that was hurtling down Pender Street toward the Tower of the Sun [*Ed. note: the GSC Cordilleran Division is currently housed in the Sun Tower building*]. An exception was the tireless Dick Armstrong who continued to amass the enormous volume of geochronologic and isotopic data that was soon to become so fundamental to the understanding of the tectonic development of our beloved mountains. The 706 line became a household word. Continental crust, oceanic crust, depleted mantle, calcalkaline, tholeiitic, MORBs and a host of other acronyms punctuated our language, which somehow had become disorganized and in need of an idea. That idea came in November of 1977 with the unfortunate name of Wrangellia.

Although Jim Monger currently prefers the term accretionary complexes, it has been and is `terranes' that continues to focus much of our attention. Big and small, fat and thin, suspect or tectonostratigraphic, they continue to tantalize us in much the same way as does the elusive Universal Theory linking the four fundamental forces of nature. From where have they come? How far have they moved? When and how did they collide with ancestral North America? Only interim answers are being proposed, some more forcefully than others. Tilt versus translation, Middle Jurassic and mid-Cretaceous versus Eocene: these and other differences will long continue to drive the body of Cordilleran geoscience and ever provide us with the reasons for our next field season and the necessity of further syntheses beyond the Decade of North American Geology (Gabrielse and Yorath, 1992).

CONCLUSION

In conclusion I paraphrase from the opening paragraph of a recently published book (Yorath, 1991).

The people of the Cordillera are my heroes. Collectively they form a cult. Their language is expressed in contractions, is often metaphoric, and, to the uninitiated, utterly unintelligible. Their altars are rocks, their season is summer and their children tend to have birthdays in June. What distinguishes them from most others is their consuming passion for what they do. They long for summer when the mountains will ring with the blows of their hammers, when helicopters will carry them through the sky. They will gaze from windswept peaks and see continents in collision, entire oceans created and destroyed. They will lose themselves in time.

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THE MINERAL SURVEY - CORDILLERAN CINDERELLA

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ABSTRACT

The British Columbia Geological Survey has a long distinguished history dedicated to aiding the discovery and development of the mineral resources of the province. Nevertheless compared to its civil sisters, the British Columbia Forest Service or the Geological Survey of Canada, it has aspects of a Cinderella - poorly clothed and poorly recognized.

Elements of the British Columbia Geological Survey existed in the Colonial era - the government assayer and analyst appointed in 1859 was the first member of the survey, the Vancouver Island geological expedition of 1864-65, a precursor; the Annual Report, starting in 1874, was the first publication. The birth of the actual predecessor of the survey can be followed through five different organizations with differing names and expanding roles, but with the same principal mandate - to forward mineral affairs and to do it cheaply. These stages are the Bureau of Mines, the Mineral Survey, the Mineralogical Branch, the Geological Division and the BC Geological Survey. There is considerable correlation between the changes in organization, nomenclature and expansion of roles with the incumbency of the various Chief Geologists.

The era of the Bureau of Mines, 1895-1917, was one of heroic exploratory expeditions by the Provincial Mineralogists, first W.A. Carlyle and then W. Fleet Robertson. The latter was in office from 1898 to 1925. In addition, they created the format of future Annual Reports and rigorous mineral statistics. The Mineral Survey, 1917-1937, was a cumbersome administrative organization of six Resident Engineers who nominally reported to the Minister but worked for the Provincial Mineralogist. The period saw a considerable expansion of property examination, monitoring of industry and aid to explorers. J.D. Galloway was the Provincial Mineralogist during most of this period.

The Mineralogical Branch era extended from 1937 to 1966 with first J.F. Walker, then P.B. Freeland and finally H. Sargent as Chief. Walker was an innovator who reorganized, reoriented and centralized the survey, continuing these functions from above as Deputy Minister. He instituted geological surveys of mineralized terrains as well as studies of strategic commodities.

The Geological Division era, 1966 to 1984, saw considerable expansion in roles to parallel in a small way the great expansion and modernization of the exploration industry. Under M.S. Hedley, S.S. Holland and A. Sutherland Brown many resource functions were introduced, district geologist positions created and regional geochemical surveys started.

The present era of the GSB started in 1984 under W.R. Smyth with considerable expansion occurring initially under a Federal-Provincial Mineral Development Agreement. Quadrangle mapping became a principal focus of a broad expansion. The search for the golden shoe goes on.

INTRODUCTION

The British Columbia Geological Survey has a long distinguished history dedicated to aiding the discovery and development of the mineral resources of the province. Nevertheless compared to its civil sisters, the British Columbia Forest Service or the Geological Survey of Canada, it has aspects of a Cinderella - poorly clothed and poorly recognized.

Elements of the British Columbia Geological Survey existed in the Colonial era. *Trade follows the flag but the flag follows the pick*, hence a need for aspects of a geological survey was felt when the gold rush and the discovery of coal catapulted the territory toward colonial and then provincial status. The attitudes of the Hudson's Bay Company against colonization were shredded by their own actions; news of the sale in San Francisco of gold bought by the company from natives in the Interior triggered the rush. After attending to law and order and land tenure, the new Colonial government slowly assembled the pieces to form a survey. This started in 1859 with the appointment of a government assayer and analyst. Other actions included the Vancouver Island exploratory expedition of 1864-65 under Dr. Robert Brown, the institution of the Annual Report of the new Minister of Mines in 1874, a first technical publication, and the appointment of a series of mining and geological consultants. Other important factors in the prehistory of the survey included the assignment of jurisdiction over land and minerals to the provinces by the British North America Act of 1867 and the terms of Union of British Columbia in 1871 which charged the federal government with the costs of geological survey. In spite of the latter, the province shared, with the Geological Survey of Canada, the costs of Amos Bowman's geological survey of the Cariboo goldfields and published his hardrock economic geology report.

DEVELOPMENT OF THE BRITISH COLUMBIA GEOLOGICAL SURVEY

The British Columbia Geological Survey can be followed from its formal birth in 1895 through five different organizations with differing names and expanding roles but with the same principal mandate - to forward mineral affairs and to do it cheaply. These stages were: the Bureau of Mines, the Mineral Survey, the Mineralogical Branch, the Geological Division and the BC Geological Survey. There is a considerable correlation between changes in organization and nomenclature and the expansion of roles with the incumbency the various Chief Geologists during the century of the survey's existence (Figure 11).

THE BUREAU OF MINES

The era of the Bureau of Mines, 1895-1917, was one of heroic exploratory expeditions by the first three Provincial Mineralogists, William A. Carlyle, W. Fleet Robertson, and John D. Galloway. These three are shown together in Figure 12 on the steps of the Bureau office in the remaining Birdcage Building built in 1858 by the first Colonial Governor, Sir James Douglas.

The occasion was Fleet Robertson's retirement and the return of Carlyle to Victoria in 1925. Carlyle was the innovator who set up the system including mining, geological and exploration articles as well as rigorous statistical records of the mining industry in the Annual Report. This report was unrivalled in usefulness by publications of other provinces or State surveys. Unfortunately Carlyle moved on to an international career as mine manager and consultant after only three years. Happily he was succeeded by another capable man, W. Fleet Robertson, who was Provincial Mineralogist from 1898 to 1925. In his early years he explored the north with great vigour to evaluate its mineral potential, travelling by pack string, canoe and on foot in a remarkable series of journeys. In his later years this affable man kept to his office but his deputy, Jack Galloway, carried on the field tradition with a more rigorous geological and property evaluation approach.

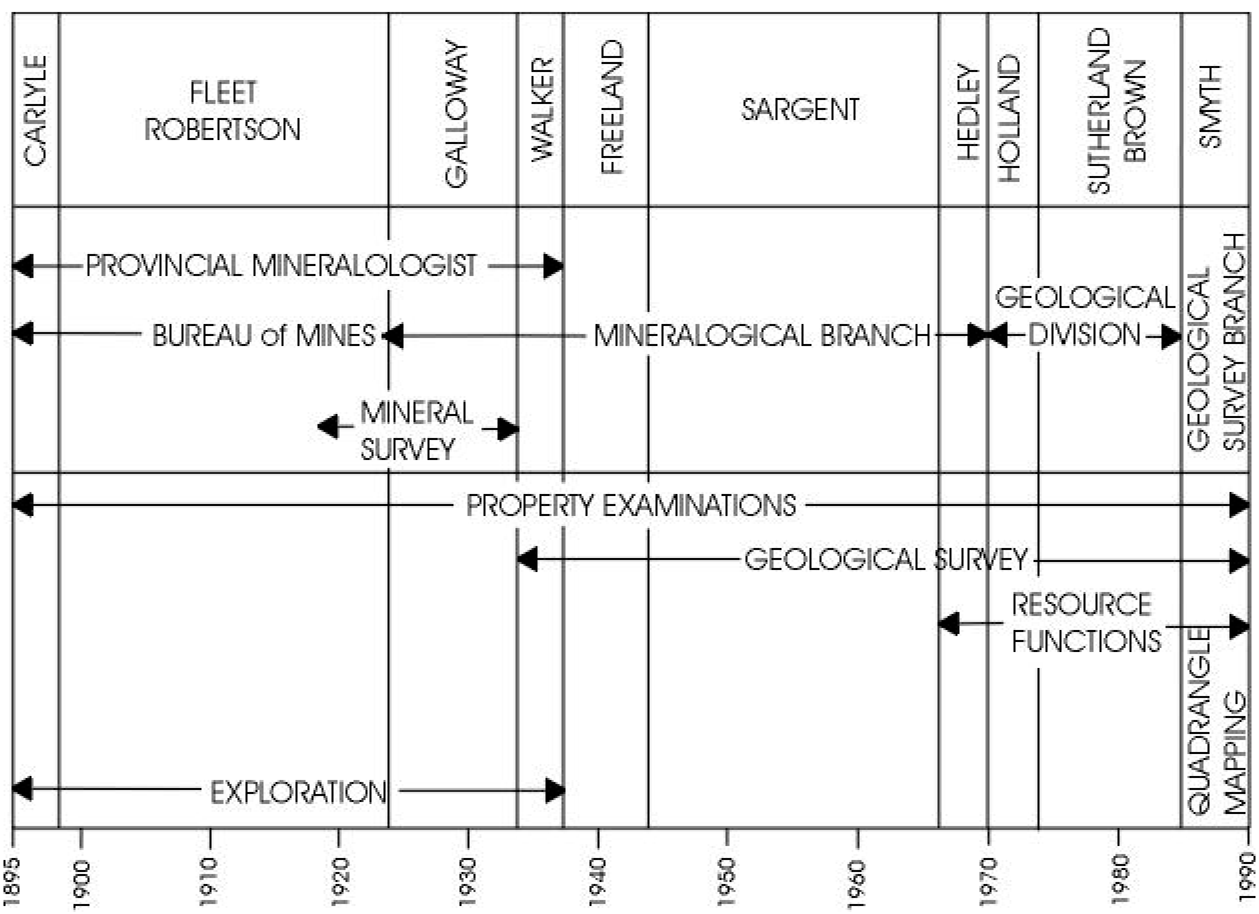

Figure 11. Table showing the relationship in time between the succession of Chief Geologists of the British Columbia Geological Survey, the nomenclature applied, and the main programs conducted.

Figure 12. The first three Provincial Mineralogists: William A. Carlyle (right) the first; W. Fleet Robertson (centre), the second, and John D. Galloway (left) the third. They are photographed in 1925 standing on the steps of the last of the Birdcage Buildings that housed the survey for many years.

THE MINERAL SURVEY

The Mineral Survey era, 1917-1937, was initially productive but its cumbersome administrative organization designed by the Minister and his cronies eventually spelled its demise. There were two parallel units, the continuing Bureau of six civil servants and the Mineral Survey of six Resident Engineers distributed around the province. These engineers and geologists reported to the Minister on contract but in most ways worked for the Provincial Mineralogist. Figure 13 shows the Minister, Deputy Minister, Provincial Mineralogist and five of the Resident Engineers in their prime, on the steps of the Legislature in 1929. This period saw a considerable expansion of property examination, monitoring of industry and aid to explorers. Galloway, Provincial Mineralogist for most of the era, was a tough-minded and competent mining geologist but eventually he left in 1934 to go consulting.

THE MINERALOGICAL BRANCH

The Mineralogical Branch era extended from 1937 to 1966 with first John F. Walker, then P. B. Freeland and finally Hartley Sargent as Chief.Walker, the last Provincial Mineralogist, was the cocky innovator who reoriented, reorganized, restaffed and centralized the survey, continuing these functions from above as he moved to Deputy Minister in three years. He created a small organization that was dedicated to detailed geological surveys of mineralized terrains as well as studies of strategic commodities (Figure 14).


Figure 13. The Resident Engineers of the Mineral Survey on the steps of the Legislature in 1929 with their Minister (with cane), Deputy Minister (with the long stemmed carnation), and the Provincial Mineralogist, John D. Galloway (far right).

Freeland for six years and Sargent for twenty-three oversaw this program of perceptive mapping with only minor changes. The conceptual thinking and planning was mostly the product of Matthew S. Hedley's and Stuart S. Holland's minds. The mineralized terrains of the province were tackled one after another with a similar method; initial probes outlined the problems and the area that needed to be mapped, followed by work from unaltered periphery to mineralized centre and, finally, study of the mines and mineralization. These techniques were successful but the staff of only ten field geologists was too small to cope with the demand for data as the exploration industry of the Cordillera exploded and modernized in the 1960s.

THE GEOLOGICAL DIVISION

The Geological Division era, 1966 to 1984, was one of only modest growth but considerable expansion in roles, a pale reflection of industry's parallel development. The staff grew steadily (Figure 15) reaching 63 employees and contractors in 1981 before being reduced to 50 during the recession of 1982-84. During this period mapping capability, if anything, contracted as the survey scrambled to start the many resource functions needed by a contemporary agency. Under Hedley, Holland and then Atholl Sutherland Brown, any growth was channelled toward instituting programs of district geologists, mineral inventory, land-use appraisals and regional geochemical surveys. It was also an era when political impacts occurred, even to the working level, as the survey was caught in a bitter conflict between the government and industry over

Figure 14. Half the field staff of the Mineralogical Branch photographed in Sooke in 1953. From the left they are Stuart S. Holland, G.G.L. Henderson, W.R. Bacon, J.T. Fyles and J.W. McCammon.

Figure 15. Most of the professional staff of the Geological Division outside one of the houses they occupied in 1977. Deputy Minister James T. Fyles fourth from the right below and Atholl Sutherland Brown, Chief Geologist, at the top right.

taxation and concepts of government's role in mineral resources. Scientifically the survey showed its flexible capability as it swung its small field research efforts from porphyries to uranium and coal and on to massive sulphides and epithermal gold.

THE BC GEOLOGICAL SURVEY

The present era, the Geological Survey Branch, started in 1984 under W.R. (Ron) Smyth (Figure 16) with a considerable expansion that occurred initially under a five-year Federal-Provincial Mineral Development Agreement, the first British Columbia enjoyed. This was followed by a recommendation of the Mining Industry Task Force, set up by the provincial Government in 1986, that the Geological Survey be expanded as a necessary aid to the exploration industry. Many aspects neglected previously were thus given priority such as nonmetallic resources and upgrading the mineral inventory but the principal focus of the expansion was the initiation of 1 to 50 000-scale quadrangle geological mapping. This program, like the earlier mapping programs, is directed toward mineralized or potentially mineralized areas, but mapping is carried to quadrangle boundaries and less emphasis is placed on mineral deposit research. Although recognition for the Cinderella survey appears at hand, the search for the golden slipper goes on.

Figure 16. The Geological Survey Branch in the rotunda of the Legislature in 1989 with Ron Smyth, Chief Geologist, with the striped tie near the centre of the front row. It looks like Cinderella's coming-out party.

THE EMERGENCE OF ENGINEERING GEOLOGY IN BRITISH COLUMBIA "AN ENGINEERING GEOLOGIST KNOWS A DAM SITE BETTER"!

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ABSTRACT

Engineering geology is a subdiscipline of geology. Engineering geologists apply geological principles of rock, soil and groundwater to the appropriate location, design and construction of a wide variety of engineering structures, and to the assessment and design of mitigative measures for a wide variety of natural and man-made hazards. The types of projects with which engineering geologists are involved are quite different from those carried out by traditional geologists. It follows, therefore, that the aptitudes of engineering geologists and the approaches used in their investigations also differ from those of traditional geologists.

Based on this thesis, the development of engineering geology in British Columbia can be divided roughly into three phases. Up to 1920, geology was not consciously considered in the engineering projects in the province. Between 1920 and 1945, when geological input was required or requested for an engineering project, it was usually supplied by traditional geologists. After 1945, trained and experienced engineering geologists began to practice in the province and began their involvement with the engineering projects of the day. By the 1960s, engineering geology was well established and a recognized subdiscipline of geology in British Columbia.

INTRODUCTION

This paper deals with the emergence of engineering geology, and hence emphasizes developments prior to 1960. What is the significance of the sub-title? We'll let you be the judge.

What is engineering geology? There are many definitions and the following is a hybrid of a number of these:

Engineering geology is a branch of geology that applies geological principles of rock, soil and groundwater to the appropriate location, design and construction of a wide variety of engineering structures, and to the assessment of, and design of mitigative measures for, a wide variety of natural and man-made hazards.

Some disagree that engineering geology is a branch of geology; rather it is the application of all branches of geology to the practical problems of engineering. Usually an engineering geologist is a generalist as opposed to a specialist, uses existing geological maps as opposed to creating new ones, predicts how things will behave in the future as opposed to how they were formed in the past, tends to be a pessimist as opposed to an optimist, is a bearer of bad news as opposed to a bearer of good news, and is paid accordingly!

ORIGINS OF GEOLOGY AND ENGINEERING GEOLOGY

Modern geology had its beginnings in the late 1700s and early 1800s, for example, in the works of Hutton, Werner and Lyell. The first geological map of England was prepared by William Smith in 1813, who is now known as the father of British geology (Sheppard, 1920 as referred to by Legget and Karrow, 1983). Smith was also the first engineering geologist. With reference to the location and construction of canals in England, he wrote:

The natural order of the various strata will enable the engineer to find the most appropriate materials, choose his location, avoid slippery ground or remedy the evil.

Meanwhile, during the same era, the Spanish, Captain James Cook, Alexander Mackenzie and Simon Fraser were just discovering and exploring the area that is now British Columbia. Of course, native peoples had lived in the area for many thousands of years.

In the late 1800s and early 1900s, engineering geology was developing as a recognized discipline in Europe and the United States. In 1881, Penning's British textbook entitled *Engineering Geology* was published as the first text in the field. In the early 1900s Charles Berkey, an American, was a trained geologist who worked on the water supply for New York City, then later on the Hoover dam and a multitude of other engineering projects. Berkey is considered the first American engineering geologist. In 1914, Ries and Watson published the first edition of their American text entitled *Engineering Geology* and in 1925, Karl Terzaghi, a trained Austrian engineer, published the first text in *Soil Mechanics* (in German). Terzaghi is known as the father of soil mechanics, but also had great interest in geology. In 1929, Redlich, Kampe and Terzaghi, published their text *Engineering Geology* (in German). Later, Terzaghi was to have a very close association with British Columbia.

An event occurred in 1928 that raised the level of awareness of geology in engineering around the world. In the failure of the St. Francis dam in California, 426 lives were lost. From Ransome's 1928 paper in *Economic Geology*:

So far as can be ascertained, no geological examination was made of the dam-site before construction began...The plain lesson of the disaster is that engineers, no matter how extensive their experience in building of dams...cannot safely dispense with the knowledge of the character and structure of the adjacent rocks, such as only an expert and thorough geological examination can provide. (Ransome, 1928)

ORIGINS OF ENGINEERING GEOLOGY IN CANADA

Thomas Roy is considered the first Canadian engineering geologist. In the 1830s and early 1840s, as a civil engineer in Upper Canada (now Ontario), he had a keen interest in, and appreciation of, geology (Legget, 1980). Projects and studies carried out by Roy include: a survey for one of the first railways in Ontario, a proposed theory for the raised beaches around Lake Ontario, a stratigraphic section for a portion of southern Ontario, a study for the improvement of Toronto's harbour, a similar study for improved navigation on the upper Ottawa River and a pamphlet on the principles and practices of road building in Canada. Today the Engineering Geology Division of the Canadian Geotechnical Society presents an annual award named after him.

The year 1842 was the beginning of the Geological Survey of Canada (GSC), but for many years its work was restricted to bedrock mapping in eastern Canada. In late 1800s and early 1900s, geologists from the GSC started to take an interest in engineering (Scott, 1979). In 1873, the GSC bought a steam-driven diamond drill to locate various construction materials to *extend and hasten the exploration and survey in the North West Territory*. In 1900, H. Ami reported on the geology of the cities of Saint John, Quebec City, Montreal, Ottawa and Toronto. In 1903 he worked on the geology for the foundations of the bridge over the St. Lawrence River at Quebec. In 1904, R.W. Ells wrote about the landslides in the Ottawa Valley–St. Lawrence Lowlands. McConnell and Brock, in 1904, investigated the Frank slide in Alberta, and in 1914 Brock became first Dean of Applied Science at the recently founded University of British Columbia. All this work was done by classical hardrock geologists.

Between the 1850s and 1890s civil engineering began to be taught at a number of eastern Canadian universities including New Brunswick, Toronto, McGill, Ecole Polytechnique, Royal Military College and Queen's. Beginning in the 1870s, McGill, Toronto, Royal Military College, École Polytechnique, Laval and Queen's began teaching geology but it would be more than 50 years before the two disciplines began to integrate.

In 1925, John Allen at the University of Alberta taught the first geology course in Canada specifically designed for civil engineers. In 1927, he wrote the first engineering geology paper to appear in the (Canadian) Engineering Journal, entitled *Geological Aspects of the Spray Lake Water Power Project*. In 1929, he also wrote a discussion in the Engineering Journal entitled, Importance of Geology in Civil Engineering. From that discussion:

The day was coming...when the practicing civil engineer would invariably have the geological problems associated with the particular project on hand investigated by one qualified in that profession. (Allen, 1929 as referred to by VanDine, 1987)

In the late 1920s, Robert Legget, a young, energetic British civil engineer, emigrated to Canada to work on a hydro development in northern Ontario. In the early 1930s, he took up Allen's cause, and wrote his first paper for the Engineering Journal entitled, *Geology and Civil Engineering: their Relationship with Reference to Canada*. This 12-page paper was expanded by 1939 to become the first Canadian text on the subject, *Geology and Engineering*. It is presently in its 3rd edition entitled *Handbook of Geology in Civil Engineering* (Legget and Karrow, 1983). Legget went on to head the National Research Council, Division of Building Research and become President of the Geological Society of America.

DEVELOPMENT OF ENGINEERING GEOLOGY IN BRITISH COLUMBIA

In 1843, Fort Victoria was established on lower Vancouver Island by the Hudson's Bay Company. It was the first European settlement on the west coast of what was to become British Columbia. The first geological observations in the province were made by Dr. James Hector, a doctor, naturalist and geologist on the Palliser Expedition of 1857-60. In 1871, Selwyn and Richardson conducted the first GSC mapping in the province followed by numerous others.

Early Engineering in British Columbia

Examples of early engineering in British Columbia include several road and railway construction projects. In the 1860s the British Columbia gold rush led to the construction of the Cariboo Road from Yale to Barkerville under the direction of the Royal Engineers (Figure 17). The location and construction of the Canadian Pacific Railway (CPR) through the province took place in the 1870s and 1880s. In the early 1900s the spiral tunnels and the Connaught tunnel were constructed to reduce the grade on the CPR line and the Grand Trunk Pacific and Canadian Northern (now the

Canadian National) railways were constructed through British Columbia (Figure 18).

Figure 17. The only known photograph of the Cariboo Wagon Road under construction, probably taken in 1862 along the Thompson or Fraser River. The exact location and date of the photo are unknown (British Columbia Archives photo 74225).

Figure 18. A Canadian Northern Railway survey party, surveying along the rugged west bank of the Thompson River in 1911 (British Columbia Archives photo 30150).

If you examine the records for these, and most engineering works in Canada in the 1800s and early 1900s, there was very little attention paid to geology in the location, design and construction. For the most part these works were bulled through by civil engineers who were trained, both in school and on the job, to be resourceful and innovative and most of all to get the job done in spite of the geology. In addition, there were few geologists at that time and fewer who were interested in engineering projects.

Early Observations of Landslides in British Columbia

Possibly the first description of a landslide in the province was of the Drynoch landslide, south of Spences Bridge, along the Thompson River. Matthew Begbie, Chief Justice of British Columbia (also known as the Hanging Judge), presented a paper to the Royal Geographic Society in 1871 entitled On the Benches or Terraces of British Columbia. He writes:

In some [areas], the displaced surface seems to have moved painfully and grindingly over the subjacent bed-rock [sic], and the surface is broken into a thousand irregularities ...the mass [Drynoch landslide] looks not unlike an earthen `glacier du Rhin'(Begbie, 1871 as referred to by VanDine, 1983).

In 1877, John Macoun, a naturalist with the GSC, also described Drynoch landslide. H.J. Cambie, a civil engineer, during a survey for the CPR in 1878, was the first engineer to briefly describe the slide and postulate a cause and possible solution. Cambie's report is possibly the first engineering geology report on a natural hazard in the province.

In 1897 Robert Stanton, a British civil engineer, wrote a thorough 18-page paper (plus 3 drawings) entitled *The Great Land-slides on the Canadian Pacific Railway in British Columbia* which was presented to, and published by, the (British) Institution of Civil Engineers. This paper on landslides in glaciolacustrine silts along the Thompson River is the first major paper related to engineering geology in the province. Stanton described the slides, the bedrock and surficial geology, climatic conditions and postulated probable causes. For example:

"In considering the real nature and causes of the slides, the solid geology does not have so important a bearing on the matter as the present position and condition of the superficial or drift deposits due to the glaciers, which now partially cover, and at one time largely covered, the interior country" (Stanton, 1897).

Engineering Geology in British Columbia 1920 to 1945

In 1921, Geological Engineering began at the University of British Columbia (UBC), but only geology related to mining and petroleum geology, not civil engineering, was taught. Between 1920 and 1945, British Columbia was beginning to develop and a few larger engineering projects were under construction. In 1919, when the Department of Public Works wanted to improve navigation in the Fraser River delta, W.A. Johnson of the GSC carried out a geological investigation to *determine by what engineering methods the navigable part of the river might be improved*(Johnson, 1921). This is possibly the first geological investigation for an engineering project in the province.

Victor Dolmage, a hardrock mining geologist with the GSC, was Chief of the British Columbia division from 1922-1929, and mapped the bedrock geology of many parts of the province. In 1927, he started his involvement in engineering geology by carrying out geological mapping of the tunnel on Mission Mountain as part of the first Bridge River Project for British Columbia Electric Railway Company. In 1929, he began private consulting as a mining geologist and taught on a part time basis at UBC in the Geological Engineering program. One of his students was Dr. Jack Armstrong (referred to later). In 1930, Dolmage provided geological input for the Cleveland dam site on the Capilano River and for the First Narrows pressure tunnel for the Greater Vancouver Water and Sewage Board (Dolmage, unpublished). Although not trained as such, Victor Dolmage can be considered the first engineering geologist in British Columbia.

Other geologists who also contributed to some engineering projects during this period were D.F. (Cap) Kidd and H.C. Gunning, also both originally with the GSC. Kidd left the survey to form his own practice, while Gunning went to teach at UBC and later become Department Head of Geological Sciences and Dean of Applied Science. The volume of their work in engineering and geology is minor compared with Dolmage.

1945 to 1960

The early post-World War II years were a boom period in British Columbia. A host of dams, pulp and paper mills, tunnels and large plants were conceived, designed and constructed. While still consulting as a mining geologist (until 1955), Dolmage was involved in many of these major projects including a number for British Columbia Electric (later British Columbia Hydro) such as the Bridge River Powerhouse, Wahleach power project, Cheakamus power project, Jordan River project and the W.A.C. Bennett dam (Figure 19). He also worked on most of the water tunnels in the Vancouver area for the Greater Vancouver Water and Sewage Board and assessed the geology of most proposed dam sites along the coast for Alcan, including the 14.5-kilometre Kemano tunnel.

Figure 19. Victor Dolmage inspecting dinosaur tracks near Portage Mountain dam (now W.A.C. Bennett dam).

By 1955, Dolmage was doing engineering geology work almost exclusively under the company name of Dolmage, Mason and Stewart. This included the demolition of Ripple Rock in Seymour Narrows for Canada Public Works in 1957, at the time the largest ever non-nuclear blast. A paper on that project, published in the Bulletin of the Canadian Institute of Mining and Metallurgy, won the Leonard Gold Medal. It is interesting to note that of all the hydro-related work that Dolmage did, he did none in the Strathcona Park area (John Hart and Strathcona dams) out of principle, feeling that the park should not be developed. In 1950, in the first volume of the British Columbia Professional Engineer, Dolmage contributed a paper entitled *Geological Examination of a Dam Site*.

In the 1930s and 1940s, Karl Terzaghi was a Professor of the Practice of Civil Engineering at Harvard. The only course he taught was Engineering Geology. In 1945, Terzaghi was brought to the west coast, initially in Washington but later in British Columbia, by H.A. Simons as a review consultant for soil mechanics in relation to pulp and paper mills at Port Alberni, Campbell River, Nanaimo, Crofton and Castlegar. Later, for British Columbia Electric and Alcan, Terzaghi worked closely with Dolmage on numerous sites: Mission dam, Daisy Lake dam and Cheakamus power project (located on landslide debris). He also carried out assignments for Pacific Great Eastern Railway (now British Columbia Rail), Greater Vancouver Water District and for Alaska Pine and Cellulose at Woodfibre (on a submarine landslide). These are all classic, one-of-a-kind projects (Figure 20).

Figure 20. Karl Terzaghi (centre) inspecting construction of Deas Island Tunnel (now George Massey Tunnel).

Although trained as a mechanical engineer, Terzaghi had a very strong leaning towards geology.

"He never gave a lecture in soil mechanics. They were always lectures in geology, geomorphology, and how they related to a problem, to which...some...soil mechanics had an application. He was a geologist at heart although he was an engineer's engineer at the same time. But he always regarded soil mechanics as a branch of engineering geology which in turn was a branch of geology." (Peck as referred to by Legget, 1979)

"Every civil engineer is engaged in experimental geology..." (Terzaghi, 1953 as referred to by Legget, 1979)

In Terzaghi's lectures and writings he often referred to his projects and experience in British Columbia. He had a great influence on engineering geology in the province and upon his death in 1963, British Columbia Hydro renamed Mission dam, Terzaghi dam.

In 1951, Charlie Ripley, a relatively young soil mechanics engineer, with an undergraduate degree from the University of Alberta and a graduate degree from Harvard (under Terzaghi), moved to British Columbia from the prairies and started one of the first soil mechanics consulting firms in the province, Ripley and Associates, now known as Klohn Leonoff. Over the next few years Ripley worked closely with both Dolmage and Terzaghi on numerous large engineering projects. Under that tutelage he learned the value of geology in engineering projects, a lesson remembered throughout his career and passed along to his colleagues.

In the early 1950s, the British Columbia Department of Mines was the only provincial department to have any geologists on staff but they were all hardrock geologists working on mining-related projects. There was a need to provide advice on civil engineering and groundwater problems to other departments including Highways, Agriculture, Water Resources and Public Works. Consequently, Hugh Nasmith, a University of British Columbia graduate in Geological Engineering, with post graduate training in Engineering Geology from the University of Washington, was hired. He was the first trained engineering geologist to work in the province and for the province. Nasmith was involved in numerous projects from the early 1950s to 1958 when he left the department and joined R.C. Thurber and Associates, now Thurber Engineering Limited, where he continued that involvement.

In this same time period other geologists and engineering geologists came on the scene. In the late 1940s Jack Armstrong, trained as a hardrock geologist, began mapping the surficial geology of Vancouver and the Fraser Lowland which led to the publication of a GSC Paper entitled *Environmental and Engineering Applications of the Surficial Geology of the Fraser Lowland, British Columbia* (Armstrong, 1983).

Doug Campbell, another classically trained geologist, was introduced to engineering geology by Dolmage. In the late 1950s he became involved in geological investigations for the W.A.C. Bennett dam. Jack Mollard, a Regina-based engineering geologist, introduced air-photo interpretation to geology and engineering in the province in the late 1950s, while on a project for British Columbia Electric.

At UBC in 1959, an engineering geology program was initiated within the Geological Engineering Program, partially at the insistence of Henry Gunning, then Dean of Applied Science. Bill Mathews recounting the beginning of engineering geology at UBC:

"...a demand has arisen for geologists trained in interpreting the rocks and soil in the vicinity of major construction projects in terms of (1) potential hazards, (2) problems of construction, and (3) sources of raw materials. The geological engineer, soundly trained in both geology and engineering fundamentals, is the man, we believe, best qualified to work closely with the civil

engineer responsible for the execution of this work" (Mathews, 1967).

1960 to Present

Continued growth of the province has generated numerous, large, challenging engineering projects in recent years. There is a continued acceptance of engineering geology.The number of well trained and experienced engineering geologists, including some of the best in the world, has grown. Today engineering geology is practiced in a number of provincial government ministries, Crown corporations, federal government agencies, railways and consulting firms. Although engineering geology has had little impact on bedrock mapping in British Columbia, it has stimulated research in surficial geology, geomorphology, geologic processes, groundwater and environmental work. Today, engineering geologists are involved in a wide spectrum of projects, of which dams are a major area because *engineering geologists know a dam site better*!

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BRITANNIA - THE STORY OF A BRITISH COLUMBIA MINE - FROM MINING RESOURCE TO HERITAGE RESOURCE

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British Columbia Museum of Mining, Britannia Beach, B.C.

ABSTRACT

Mining has played a major role in the economic development of British Columbia, a province whose growth has been dependent on its natural resources. Like most early mineral discoveries, the Britannia orebody (located on the east side of Howe Sound north of Vancouver) was found by chance, by a medical doctor prospecting for gold in 1888. From this early discovery, the Britannia Mining and Smelting Company Ltd. developed the property which was to become a leader in British Columbia mineral production. In the 1920s, it was the largest copper producer in the British Empire. It operated for 70 years, produced over 52 million tonnes of ore and employed approximately 60 000 people representing 50 nationalities. The ore was milled at Britannia and the concentrates were shipped to smelters at Crofton on Vancouver Island, Tacoma in Washington State and one as far away as Japan.

Much of the success of the Britannia mines has been credited to their long-term ownership by the Howe Sound Company. However, it was sold in 1963 to Anaconda (Canada) Ltd. Its future looked bright, but it fell victim to a recession and in 1974 the mine was shut down.

Although Britannia was a company town, the community developed a life of its own in the picturesque Howe Sound setting. In 1967, a Centennial committee was formed and commissioned a history of the mine. The committee restructured in 1971 to form the Britannia Beach Historical Society. The society's goals were to preserve the site and establish an outdoor museum. With the assistance of Anaconda and the British Columbia mining community, it opened the British Columbia Museum of Mining to the public in 1975.

Since 1975, the museum has continued to refine and develop its public programs. It has acquired ownership of approximately 16 hectares (40 acres) of land and 22 buildings, including the Britannia concentrator (the mill building). In 1988, the Historic Sites and Monuments Board of Canada recognized the Britannia mines' substantial contribution to the development of Canada's economy by designating the mill a National Historic Site.

The society recently produced a business plan entitled The Britannia Opportunity. The vision is to develop the overall theme of A Day in the Life of a Coastal Resource Community through the rehabilitation and expansion of the museum and the National Historic Site. This will include the development of a town centre at Britannia Beach.

The story of the Britannia mines can be seen as a model for early 20th century hardrock mine development. Likewise the plan for the preservation of that heritage, The Britannia Opportunity, can be seen as a model for future heritage development in Canada.

INTRODUCTION

The Britannia copper orebodies have a well documented history. Doctor A. A. Forbes, a medical doctor who was prospecting for gold, is credited with their 1888 discovery. Development of the mines was at first slow, but by the 1920s and early 1930s, the Britannia operation had become the largest producer of Copper in the British Empire. Almost 70 years of operations produced more than fifty million tonnes of ore from a volcanic massive sulphide deposit. From the 53 630 983 tonnes of ore mined, 15 299 kilograms (492 968 ounces) of gold, 180 438 kilograms (5 814 026 ounces) of silver, 516 743 031 kilograms (1 139 223 376 pounds) of copper, 15 563 083 kilograms (34 310 727 pounds) of lead, 125 291 323 kilograms (276 220 086 pounds) of zinc, and 444 806 kilograms (980 630 pounds) of cadmium were extracted.

When the mine finally closed in 1974, the legacy of its heritage was already well established by the community of Britannia Beach. A history book, *Britannia - The Story of a Mine* (Ramsey, 1967), had been written and the Britannia Beach Historical Society was three years old.The society's main aim was to preserve the history of mining in British Columbia, with the goal to establish the British Columbia Museum of Mining at Britannia Beach.

LOCATION

The Britannia mines are located approximately 51.5 kilometres (32 miles) north of Vancouver on the eastern shore of Howe Sound. Although for the first 50 years of its existence access was only by water, Britannia is now easily accessible both by rail and road (Figure 21). The Sea-to-Sky Highway (#99) runs right through Britannia on its way to the world-class ski resorts at Whistler and Blackcomb mountains.

DISCOVERY AND EARLY HISTORY

In June 1792, Captain George Vancouver was the first European to venture into Howe Sound. The expedition is documented in his diary which mentions an encounter with natives whom he described as skilled traders. Vancouver noted that they possessed copper ornaments and showed a preference for any metal objects which they could obtain by barter (Vancouver, 1984).

Figure 21. Location and access map of the Britannia Beach mining area.

It was not until 1859 that the name Britannia was given to the range of mountains on the eastern shore of Howe Sound by a surveyor, George Henry Richards, Captain of the S.S. Plumper. He named the range in honour of the old warship of the British Royal Navy which had participated bravely in several famous sea battles including the Battle of Trafalgar.

A year before the naming of the Britannia Mountains, gold was discovered in the gravels of the Fraser River approximately 150 kilometres upriver from its mouth.This discovery precipitated the famous 1858 Fraser River gold rush. Over the next 40 years, thousands of prospectors and adventurers were lured to the West Coast. Howe Sound was not overlooked in this search for riches. The Britannia area was already known by the natives as a source for red ochre which they used as a pigment in their paint and dyes. Their long-term presence in this area has been documented by petroglyphs which were discovered by the Geological Survey of Canada just north of Furry Creek on the east shoreline of Howe Sound. Red ochre is an oxidation product of iron in the sulphide ores. It is also a visible indicator of some of the valuable minerals sought after by prospectors.It is usually referred to as a gossan.

A sample of mineralized rock and legends of the red ochre brought Doctor A.A. Forbes to Britannia in 1888. Employed by the federal government to care for the local native people who had survived a devastating smallpox epidemic, he was a medical doctor who lived on the west side of Howe Sound. Apart from being a medical doctor, he had nurtured keen interests in chemistry and prospecting which he pursued in his spare time. When a fisherman by the name of Granger showed him a sample of rock containing copper minerals, Doctor Forbes offered to hire him to lead him to its source.Granger wanted money for a boat so he agreed, and the two went to Britannia on a prospecting expedition. After a disappointing two-day search, they were returning home when Doctor Forbes shot a buck deer. In its death throws, it uncovered mineralized rock. After some testing, Doctor Forbes was satisfied with his discovery. As promised, he paid Granger who then bought his boat and left for Alaska. Doctor Forbes worked his prospect off and on for ten years, but eventually became distracted with other more accessible prospects.

In 1898, Oliver Furry, a trapper, was encouraged by some furriers to stake five mineral claims in the area of Britannia. It is unclear how he knew about Doctor Forbes' workings although it is likely he either stumbled across them while tending his traps, or observed Doctor Forbes coming and going from the property.Regardless, Furry's five claims would become known as the Britannia Group. One of them was the famous Jane.

BUSINESS ORGANIZATION AND EARLY DEVELOPMENT

Control over the claims passed in quick succession to a firm of Victoria fur buyers and then to a group of Vancouver businessmen who formed the Britannia Syndicate. Local interest did not really take hold until 1901 when George Robinson, a mining engineer from Butte, Montana, visited the property. Upon inspection, he concluded that it was well situated for a mining operation. The orebodies were only 5 kilometres from tidewater on the east side of Howe Sound and 50 kilometres by water from the fast-growing city of Vancouver which could provide the necessary services and work force. There were magnificent stands of timber in the area for construction and an ample water supply for power and other uses.

Figure 22. The Jane Basin mine site, circa 1915.

The Britannia group of claims had been staked by various interests. They included four adjoining claims: the Jane, the Bluff, the Fairview and the Empress. Estimates of ore potential were between 1 and 3 million tonnes. In spite of these favourable indications, Robinson knew from experience that considerable development work was necessary before the mine could move into production. This would require a major influx of capital and the establishment of a business structure. With the assistance of Grant B. Schley, head of a New York banking establishment, control of the Britannia Syndicate was secured and the Honourable Edgar Dewdney, former Lieutenant-Governor of British Columbia and famous builder of the Dewdney Trail, was appointed President. The Howe Sound Company was established to serve as a holding company for the operation which later became known as the Britannia Mining and Smelting Company. Much of the future success of the operation has been credited to the long term ownership of the mines by the Howe Sound Company.

In 1903, an infusion of capital enabled Robinson to carry out his plan. At the Jane Basin where the mine was located, new adits were driven and service buildings were built (Figure 22). Families moved in and the Jane community was established. To transport ore down the mountain to the shore, an aerial tramway, 5 kilometres long was constructed in two sections. The original concentrator, Mill Number 1 (with a processing capacity of 200 tons of ore per day) was constructed at Britannia Beach. Transportation facilities were also built and a community which serviced the mine and the mill was growing. In 1905, the first ore was produced and shipped to the Crofton smelter on Vancouver Island owned by Howe Sound Company.

George Robinson, whose drive, determination and influence had brought the mine into production, died suddenly in 1906. Meanwhile world copper prices had declined and there were problems separating the ore. During this trying period, Mr. R.H. Leach controlled the operation. Though we know very little about Mr. Leach, we gain a very good insight into the social history of the period through the eyes of Harriet Backus, the wife of assayer George Backus who had been hired to solve the mineral separation problems. In her book Tomboy Bride she describes in great detail her visit through the mill, the luxury of her home and the company store, the pretty cottages, the school and the hospital (Backus, 1969). As well, she entertains us with details about the employees of mixed racial backgrounds who comprised the Britannia work force (Figure 23).

Figure 23. Early Britannia children, circa 1914 (Vancouver Public Library photo number 7532)

MOODIE ERA

In 1912, the operation was given a major boost by G.B. Schley who never lost sight of Robinson's dream.Although he never visited Britannia, he had great faith in the property. To replace Leach, he hired Canadian J.W.D. Moodie, a demanding but skillful mining man.Moodie was given full authority and approximately $5 million capital to revamp every aspect of the operation. Over the next eight years, he was highly successful, launching Britannia into the ranks of world copper producers (Figure 24).


Figure 24. Britannia Beach, circa 1916.

By this time, the mining operation had been expanded to over 600 employees, but the high-grade ore had been mined out. There was still an abundance of low grade deposits so the key to expansion was improvement in the transportation system and the construction of a new, more efficient mill.

Mill Number 2, a gravity mill, was constructed to take advantage of a newly patented flotation process to treat the low-grade ore. The Crofton smelter had become obsolete. It became economically feasible to ship the concentrates to Tacoma, Washington. To improve the transportation system, a new network of haulage tunnels was driven to connect with the orebodies. A switchback rail line and an incline were also constructed to replace the inefficient aerial tram and horse trail.Production increased tenfold, from 200 tons per day to 2000.

Although this was a highly productive period for the operation, several tragedies rocked the Britannia operation. The worst of these occurred on March 21st, 1915 when an avalanche struck the Jane operation killing more than 50 people. Moodie himself experienced a personal tragedy when his wife died giving birth to their fourth child.

In the wake of the Jane avalanche, immediate plans were implemented to construct a new and safer community at the *Tunnel Camp* which later became known as *The Townsite* or *Mount Sheer*. It soon developed into a self-contained community and friendly rivalries were to spring up between it and the service community at the Beach.

In 1918, the world-wide `flu' epidemic ravaged both tightly knit communities. All efforts concentrated on nursing the sick. Yip Bing, the Chinese boy who worked in the store, earned himself the nickname of Dr. Y.B. as he helped care for the sick by delivering pots of soup from his hand cart. Moodie's oldest daughter and his sister (who had come from eastern Canada to care for his motherless children) were both victims of the epidemic. Then G.B. Schley died.An old friend of Moodie's, he had been a long and faithful supporter of the Britannia dream. Schley was replaced by his son, Evander, who was not a friend of Moodie's. Evander ordered a tightening up of the operation and recalled Moodie to home office in New York. Moodie resigned in 1920 missing the next two disasters.

On March 7th, 1921, Mill Number 2 burned to the ground. Then just seven months later, on Sunday October 28th, during a period of heavy rain, Britannia Creek flooded its banks and swept through the unsuspecting community. The town was reduced to a mass of wreckage and tangled debris. Thirty-seven people were killed and many more were injured.

BROWNING ERA

For the next 25 years, the Britannia operation was under the direction of C.P. Browning. He had worked under Moodie's direction since first coming to Britannia in 1913 as a graduate of the Columbia School of Mines. A school friend of E.V. Schley's from Columbia, he had risen dramatically through the hierarchy of the Howe Sound Company. He lived at the *Townsite* with his wife Mary, a Vassar graduate, and their family.They were well liked by the townspeople and many of the conflicts which existed in the community were resolved as a result of Browning's enlightened style of management.

Although it was the momentum resulting from Moodie's drive and determination which successfully brought Britannia into its period of peak productivity, it was the Browning era of social concern and changes in the community which made Britannia a model company town. The company store was reorganized as a cooperative. Community clubs were organized at the Beach and Townsite. Popular events such as the Beach's May 24th crowning of the the Copper Queen and Townsite's July 1st Mining Games became annual traditions. These special events were enthusiastically organized and looked forward to with great anticipation by the whole community.

Following the fire and the flood, a new mill had to be constructed and the Beach community had to be rebuilt. All of Browning's skills were put to the test. It was under his direction that the million dollar Number 3 Mill (which still stands today) was constructed. Designed on similar lines to the Number 2 gravity fed mill, it was nevertheless refined and improved. Instead of timbers, it was built out of steel on a cement foundation.A.C. Munroe, the mill superintendent in 1922, proudly announced that it was processing 2400 tonnes of ore per day.

Figure 25. Early miners, circa 1927: at peak production the mine had more than 1000 people on the payroll.

The transportation system was also upgraded so that an underground rail system replaced the clumsy surface one. With ore now transported to the mill by gravity directly from the far reaches of the mine, Moodie's vision of 1914 had finally been realized.

Britannia mines reached peak production in 1929 when the mill treated more than 6300 tonnes per day (Figure 25). More than a thousand people were on the payroll and the value of the stock jumped from $3 to $8 per share. Britannia attracted world-wide attention and became recognized as the British Empire's largest copper producer (Figure 26).

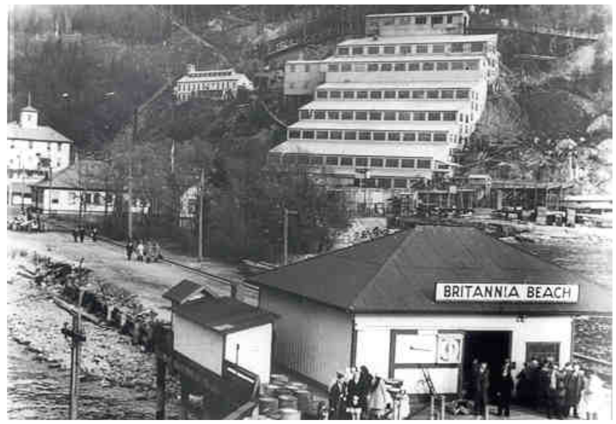

Figure 26. Britannia mine, circa 1948: a world class copper producer.

Although the onset of the Great Depression in the 1930s signalled a downturn in the fortunes of the mine, Browning pulled the operation through the decade by cutting production and diversifying the minerals extraction. Gold, silver and pyrite became important byproducts. By 1938, Britannia was again one of the largest producing mines in British Columbia as it geared up to produce minerals for World War II.

Labour relations, which had generally been very good under Browning's direction, became an issue in the post-war period as general labour unrest throughout British Columbia precipitated Britannia's first organized strike in 1946. Browning finally retired two years later in 1948. It was the end of an era which had begun in 1913.

PERIOD OF DECLINE

By the late 1950s, new open-pit mines in Merritt and on Vancouver Island had eclipsed the glory which was once Britannia's.When the price of copper fell in 1957, competition became difficult. The mine closed and went into liquidation, and the assets were taken over by the Howe Sound Company. Ironically, this was the hundredth anniversary of British Columbia's becoming a Crown Colony, a political move which had been enacted mainly in recognition of the territory's considerable potential for mineral resource development.

Metal markets strengthened in 1958 and the mine reopened, albeit on a reduced scale. All operations were consolidated at the Beach, and the townsite of Mount Sheer was abandoned. Those buildings which could be salvaged were relocated to the Beach. The rest were eventually destroyed.

In 1963, the future of the mine once again appeared secure when the Anaconda Mining Company purchased the property for $5 million cash. Anaconda's intention was to use Britannia as a base for its exploration program throughout western Canada. It was an old mine but as long as the price of copper was strong, it was a viable operation. The end finally came in 1974 (Figure 27). Anaconda closed the mine due to rapidly rising costs, increased taxation and growing competition in the marketplace.

Figure 27. The last shift, 1974.

This was not, however, the end of the Britannia community. Although a company town, it had developed a life of its own in its picturesque Howe Sound setting. A Centennial Committee had been formed in 1967 to celebrate the Canadian Centennial. Part of the committee's program was the commissioning of a history book on the story of the Britannia mines. It was written by the famous historian, Bruce Ramsey (Ramsey, 1967). Barney Greenlee, the mine manager, also planted the seed to establish a museum on the Britannia site.

BRITANNIA BEACH HISTORICAL SOCIETY (BRITISH COLUMBIA MUSEUM OF MINING)

In 1971, when the British Columbia centennial plans were being formulated, it was decided to formally organize an historical society. The Britannia Beach Historical Society was duly registered. Its primary purpose was to establish a museum of mining which would collect and display artifacts, pursue research, demonstrate mining techniques, and promote interest in mining activities throughout the province of British Columbia.

The immediate goal was to open the museum. In order to achieve this, the membership had to be expanded beyond the citizens of Britannia Beach to include a broad representation of the mining community. The museum's requirements were space for its buildings and a mine tunnel for the planned underground public tours.Working under the leadership of Jack Greenwood, a Vancouver businessman, the society was able to both obtain a government grant to develop the museum infrastructure, and secure from Anaconda a 20-year lease on the land.Working with assistance from Anaconda, the Britannia community, the public sector and the mining community, the British Columbia Museum of Mining opened to the public in 1975 just one year after the mine's closure. The public programs included an underground mine tour with demonstrations of mining machinery, and an interpretation program of British Columbia mining history.

The early success of the museum brought organizational deficiencies into focus. Anaconda had the mine property up for sale and the museum was operating on a short-term lease. Ongoing funding from the public sector was not available and the mining industry, which was suffering through a recession, was reluctant to make a long-term commitment of support. The Britannia community itself was changing as well, and the idea of preserving industrial heritage was new to British Columbia and slow to catch on.

In the face of this, the enthusiastic members of the society persevered and continued to lobby for an extended long-term lease or donation of the museum lands. In 1979, these efforts finally paid off when Anaconda sold the mine property to Copper Beach Estates, a real estate company.One of terms of the transaction was that 16 hectares of land would be held in trust for the Britannia Beach Historical Society, pending subdivision of the property. In 1986, clear title to the museum lands (including 22 buildings and many of the mine records and artifacts), was transferred to the society.

Ownership of the museum lands was now secure but the society was faced with the responsibility of stewardship for the heritage resource and the operation of an outdoor museum in an unincorporated village with few services and a derelict infrastructure. Museum programs required trained staff, and maintenance and service costs were high. There were also tenants who required services as most of the buildings had been leased to generate much-needed income.

Meanwhile, the Department of Highways had announced plans to relocate the Highway 99 route through Britannia, a move which would necessitate the relocation of several museum buildings. Major fund raising became a key issue as did planning, for without an approved master plan, fund raising was next to impossible. Fortunately, there was funding available for planning.As a result, several studies were conducted.

Following is an outline of the planning process which took place:

1980 TIDSA Theme Park Study (Simons Consortium, 1980). Civil Study (Relocation of buildings).
1981 Britannia, the story of a British Columbia mine (Dykes, 1980 and 1981).
1982 Britannia Concentrator Study (Idiens, 1982).
1984/86 Museums Assistance Programme (MAP) & Management Study (Heritas Management Incorporated, 1985).
1986 Land Acquisition - transfer of clear title to the Britannia Beach Historical Society of the Museum Lands.
1987/88 National Historic Site submission (Mullan and Green, 1987) and subsequent designation (Taylor, 1987; Anonymous, 1988).
1988 Heritage Trust Britannia Mining Village Feasibility Study (Bezanson, 1988).
1989 Landmark Program Application.
1990 Britannia Opportunity - Long Range Plan. Prelude to the Britannia Opportunity - Business Plan (Mullan, 1990).
1991 British Columbia Provincial Landmark Designation.

CONCLUSION

As the Britannia business plan is developed, the museum programs will focus on the major theme of *A Day in the Life of a Coastal Resource Community*. Visitors will also have the opportunity to trace the evolution of the industry. The process which began with prospectors and miners operating with limited technical knowledge of the earth before them has evolved to the current generation of industrial technical experts who have not only the potential to unlock the secrets of our earth, but also the responsibility to use these valuable treasures wisely.

Even today, we have photo documentation available to illustrate how the Britannia orebodies were deposited. Modern display techniques can visualize the complex nature of ore deposits and consequently focus on the importance of continuing with research and the processes of mine development. What better place for individuals to make these discoveries than at an historic site such as Britannia where past, present and future are all on display? It is a combination not often found in this rapidly changing world. The evolutionary process continues at Britannia Beach which is still a living community of approximately 400 people. The once-great mining resource is now a unique industrial heritage resource with significant potential for development as a world class mining museum integrated with a living heritage site which will continue to grow as a residential community and a major tourist attraction (Figures 28a and 28b).

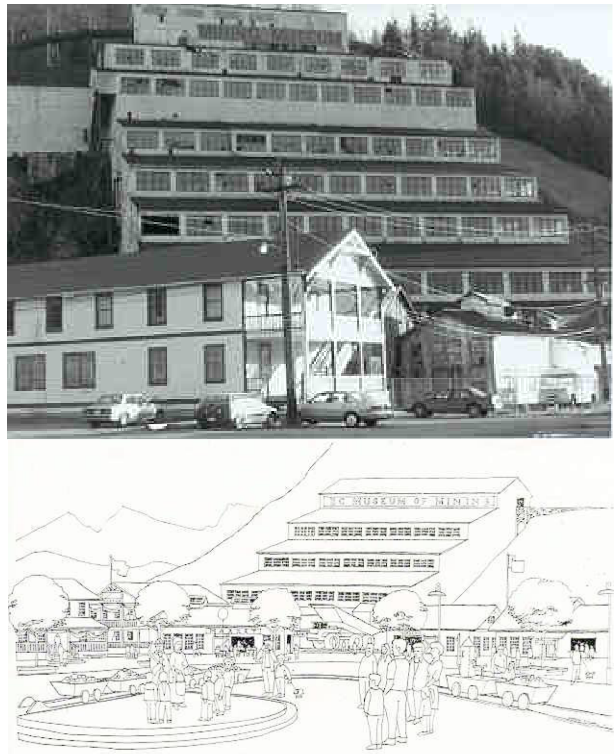

Figure 28. The British Columbia Museum of Mining: (top) museum entry, gift shop and administrative office in foreground with Mill Number 3 as it is today in the background; (bottom) possible future developments.

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BRITISH COLUMBIA’S HYDROCARBON HUNT; "THE HOLE STORY"

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ABSTRACT

The oil and gas hunt in British Columbia has had a colourful, turbulent passage dating back to 1875 when the Dominion Geological Survey’s Selwyn and Dawson noted the hydrocarbon potential in the Peace River area. Oil, tar and gas seeps had been recorded across the province from the Queen Charlotte Islands in the west, to the Fraser Delta in the south, the Kootenay-Flathead valley in the east and to the Peace River valley in the north. Drilling commenced in the 1890s with simple cable-tool rigs. The first commercial natural gas discovery was made in 1922, with a bang! The physical constraints of muskeg and mountains made progress slow and hardship a constant companion to the field parties, seismic crews, drillers and pipeliners. Simple shallow exploration for natural gas steadily evolved to deeper targets of oil, gas and even carbon dioxide, at depths up to 4500 metres. Half a billion barrels and 20 trillion cubic feet of natural gas were found, all in the northeast British Columbia basin. The other interior and offshore basins remain under explored and encouraging. Emerging technologies and new concepts in these historical basins may soon dramatically alter the face of oil and gas production in British Columbia.

INTRODUCTION

Imagine being on a roller coaster ride except... you can’t see where you are going, you lose half your cars when you hit the bottom, the power that runs the ride gets shut off without notice, and the cost of the ride changes with each turn. Welcome to the story of oil and gas in British Columbia!

British Columbia disguises its complex past. Changing sea levels, shifting crust, creation and destruction of volcanic island arcs and interior basins, mountain building, erosion, wide temperature variations and, last but not least, several major glacial periods, have sculpted a geological paradise. This paper discusses events, within this complex Cordilleran setting, that relate to hydrocarbon development, with particular emphasis on the eastern side of British Columbia.

Our interest in energy sources has always been linked to demand. Throughout this paper reference is made to economic conditions which have influenced the geological pursuit of hydrocarbons.

GEOLOGY

The western Canadian sedimentary basin contains all of the present conventional oil and gas reserves of British Columbia. Half a billion years ago the western coastline of North America was near the present Alberta - British Columbia border. To the east the Canadian Shield remained the core of the continent, eroding and shedding mature sands into Saskatchewan and Alberta. To the west lay British Columbia and the deep blue sea, interrupted by occasional islands and rafted chunks of oceanic crust. From the Devonian time of about 400 million years to the Cretaceous of 65 million years ago this part of British Columbia experienced three broad changes that would shape the present distribution of oil and gas deposits.

Imagine snorkeling in the Caribbean. Now try it in Fort Nelson. It would have seemed very similar in the Devonian and Missippian periods when British Columbia was submerged under a warm and gentle sea. Broad, thick platforms with occasional reefs near basin edges and interior seaways, were built of limestone and dolomite. Many of these porous buildups would later contain the giant gas fields of northern British Columbia.

Now imagine sitting on a beach in the Persian Gulf. It is just like hot, dry Fort St. John, in the Triassic of course. The arid tropical conditions created extensive dune fields spilling out into evaporitic salt flats and deep estuaries. Shorelines in the shallow, warm sea were flooded and exposed repeatedly, forming broad layers of sandstone, carbonate and evaporitic rocks. Algal mats flourished, building layered porous stromatolites that would later contain British Columbia’s largest oil field at Boundary Lake.

Now imagine the Fraser River. You have come up through time to the Cretaceous, to a place with a cool and moist climate, coaly swamps and deep erosion. Abundant rainfall carries a wide range of sediments from the uplifting mountains of the west to a seaway linking the Gulf of Mexico in the south and the Arctic sea in the north. The river and shorelines developed clastic reservoirs which were to be deeply buried and charged with gas from adjacent coal seams. The giant Deep Basin gas fields were created.

British Columbia became higher and drier; mountain building and glacial erosion had almost completely disguised the deeply buried past. Seeps from fractured reservoirs and shallow swamp gas gave the first clues to the potential for hydrocarbons and the search began.

EARLY HISTORY

Surface occurrences of hydrocarbons have been used throughout recorded time. Bitumen pits were used as mortar in the Tower of Babel and King Solomon's temple.Three thousand years ago the Chinese drilled as deep as 600 metres and piped natural gas through bamboo for flares to evaporate salt from brine. The Greeks vanquished an enemy fleet by covering the seas with oil and igniting it. The Persian Gulf recently offered a disturbing repeat of that event. The eternal flame at the shrine of the Oracle of Delphi is a natural gas seep. Burma was digging wells by the 16 century and by the 18th century was producing 45 million litres of oil per year. In the 1700s George Washington's property values were actually enhanced by an oil seep!

A 1917 description by the Imperial Oil Company pictured gasoline as, *a clear nervous liquid which is composed of speed, noise and trouble in equal parts. It is made of kerosene reduced to a more violent stage and supplied to the restless portion of mankind.* These words also summarize the passage of petroleum exploration through history.

THE CANADIAN PICTURE

In 1788 the Canadian explorer Peter Pond recorded that Cree along the Athabasca River used tar to caulk their canoes. But it wasn't until the 1800s that our society began to see oil as anything other than soap-box medicine or a natural curiosity.

The industrial age was limited by poor light, lubricants and power sources. Man had depended on whale, fish and vegetable oils to provide smoky, stinking lamps and rancid lubrication for increasingly important machines. In 1850 a little known Canadian doctor, self-taught chemist and geologist in Nova Scotia, Dr. Abraham Gesner, was the first to distill kerosene from asphalt and coal. Its bright, clean odourless flame quickly lit the public's interest and replaced whale oil in lamps. Within ten years there were seventy plants manufacturing kerosene from coal, and eventually oil, in the United States. Until the mid-1850s the primary source of oil had been natural springs and seeps.

In 1850 a chemist with Canada's Dominion Geological Survey determined that tar from seeps in Ontario could be used to build roads, seal boats and make gas for lighting. In 1854 the Tripp brothers of Enniskillen, Ontario created a company to develop these tar pits; the company 1 000 was registered to produce oils, paints, burning fluids, varnishes and other products.Lack of roads and markets made distribution difficult. Every heavy rain turned the area into a swamp and the gummy beds made drainage slow. Eventually poor fortune forced them to sell the holdings to James Miller Williams. In 1857 Williams built a small refinery. Stagnant, algae-ridden surface water lay almost everywhere on the mucky beds and Williams decided to drill for fresh water. The well hit oil at 20 metres and became North Americas' first oil well. Production sold in Hamilton for 16 cents a gallon (about 4 cents per litre), up to 100 000 gallons (378 500 litres) at a time. Williams was the world's first integrated oil company, exploring, producing, refining and marketing oil as the Canadian Oil Company.

In 1859 Colonel Drakes' well was drilled in Pennsylvania, with massive publicity, which got the Americans into the game and started a boom in growth.By 1863 there were 30 refineries in Ontario but the roller coaster of oil prices began to loom. From $6 a barrel in 1861, it slid to $4 in 1864. Demand boosted prices to $11 in 1865 and new production facilities and the start of huge cartels and monopolies in the United States caused the price to drop to 50 cents in 1867.Some things never change. American producers flooded the markets and kept Canadian producers in Canada.

By 1898 the introduction of the automobile forced the refineries to produce gasoline from kerosene; previously this was considered an unpleasant byproduct of little value. Gasoline was to become the premier force of the industrial revolution for the next 100 years, sending explorers into remote regions of British Columbia in pursuit of this clear, nervous liquid.

BRITISH COLUMBIA STARTS THE GREAT WESTERN BLACK-GOLD RUSH

Ontario's greasy fields around Petrolia must have seemed the centre of Canadian petroleum civilization; the Canadian west was but a remote, little understood collection of regions called the Northwest Territories. In 1870 a Geological Survey report noted oil and gas seeps southwest of Calgary.Then in 1875 Alfred Selwyn, the Director General of the Dominion Geological Survey, led the first geological expedition into British Columbia's Peace River country. He mapped surface outcrops and measured the faults and topography of the foothills. His expedition geologist, George Dawson, described the potential of oil and gas in the area; the information remained buried for several years.

Seeps on the British Columbia - Alberta border in the southeast Flathead Valley (Figure 29) were described in 1874 by the pioneer homesteader John George Kootenai Brown to George Dawson. Kootenai Brown would dip gunny sacks into the seeps at Oil Creekand squeeze the oil into containers to be sold for lamp fuel to nearby ranchers. Farther east in Alberta, the CPR was drilling for water for their steam engines and stumbled upon the huge gas fields of Medicine Hat. The recognition of large amounts of oil and gas in western Canada was gaining speed.

Figure 29. Oil and gas seep in the Kootenay region, southeastern British Columbia.

British Columbia always remained an importer of oil, usually in large wooden barrels from the Standard Oil refinery in Ohio. In the 1890s Imperial Oil had set up a terminal in Vancouver to ship in oil. Union Oil then set up a large tank at Coal Harbour as the sea-going and coastal vessels converted from coal to oil. British Columbia saw its first automobile in 1898, a Stanley Steamer owned by William Henry Armstrong of Vancouver, and the restless portion of mankind was off again.

The southeast part of our province remained actively explored with 40 wells drilled since the 1880s. Another geological survey described additional oil seeps in 1891, with most of the land being leased by 1900. A French text written for the Ministry of Commerce and Industry of France, and translated into English in 1901, describes the oil *as coming from siliceous sandstone, rich in magnesian limestone and which would appear to belong to the Upper Cambrian formation*. This international reference noted the complex relationship of older rocks over younger. The study of this overthrusting would continue even to the present and led to many later finds throughout the foothills in Canada and the United States.The British Columbia Ministry of Mines report of 1904 adds that the seepage is *trifling at present, but that the great mass of conformably bedded deposit was in place and suitable for the retention of oil produced in quantity*.

One of the shows on the Alberta side was drilled and had a rate sworn in an affidavit at 300 barrels of oil per day. The first documented British Columbia well, Akamina #1, was drilled in 1909 to 383 metres (1256 feet), with oil shows at 182 metres (598 feet) and 381 metres (1251 feet). In the prospectus used to raise money to drill this well the promoters quote passages from a classic 1906 study by Sir Boverton Redwood, advisor on world wide petroleum resources to the British Admiralty; *Petroleum occurs in south east Kootenay, near Waterton lake; the product varies from a perfectly liquid pale yellow to an opaque blackish brown oil. Gas exudes with the oil from the joints in the rock and ignites readily on application of a light.* The Kootenay was gaining worldwide notoriety. Several attempts were made to drill for the expected massive oil field, with wells flowing up to 20 barrels of oil per day, but no commercial wells remain. Wells were all drilled by cable tool which literally dropped a heavy chisel bit on the end of a cable, chipping a hole down through the layers of tight bedrock to the porous reservoir below. The method was dangerous and slow but information on producible zones was visible in the rock chips scooped up to the surface.

By 1908 there were 268 cars in British Columbia, and nearly 6000 by 1914. The first gas station in Canada was opened by Imperial Oil in Vancouver in 1907.By 1936 there were over 2000 outlets in the province producing an enormous demand for refined oil and gasoline. A refinery had been built at Port Moody, and another across the inlet in 1914. It was still cheaper to bring in crude oil from California and Peru than move the Ontario oil to British Columbia.

Fraser Valley exploration for both natural gas fields and potential storage reservoirs has recently spawned a public controversy but the area has had a long history of drilling, speculation, promoters and tantalizing leads. Over the last few millions of years 5 kilometeres of sediments have built up in the Fraser Delta providing many potential productive horizons. In the 1880s the Canadian Pacific Railroad was drilling for coal and had some gas shows near Haney. In 1904 a natural gas well near the mouth of the Fraser River at Steveston was used to light the streets for several years. Drilling occurred over a wide area and up the valley as far as Chilliwack. A hospital in Delta used local natural gas for about six years. Another well was used by a farmer for cooking and heating from 1936 to 1950 but so far no commercial quantities have been found. Geological analysis of the rocks suggest the area should be suitable for clean natural gas but not for oil.Northwest of Bellingham, Washington, gas in sufficient quantity for local domestic use has been obtained from glacial sediments at depths of about 50 metres; this is probably marsh gas from organic decay of swampy materials. Only a handful of deep wells have been drilled in recent history, none commercial. Each new well, instead of extinguishing the exploration interest with its abundant fresh water, lit new fires by calibrating seismic data, identifying reservoir sandstones and providing pressure data, geochemical analysis and depositional history that would help create the next concept.

The earliest studies of the offshore basins were conducted by Geological Survey of Canada scientists, primarily in the Queen Charlotte Islands. James Richardson in 1872 and 1873, and George Dawson in

1878 and 1880 studied the geology, biology and anthropology of the area.

Oil and tar seeps on northern Graham Island were a constant source of interest through the early 1900s. Between 1911 and 1915 drilling was conducted near northwest Graham Island. An early oil-shale pilot plant reported that the black tarry shales could yield about 20 gallons per ton. That's like heating and squeezing a chunk of rock about the size of a refrigerator to collect 100 litres of low-quality oil. Intriguing, but no large plant was built.

THE NEXT BIG LOOP ON THE ROLLER COASTER: TURNER VALLEY

The turning point of Canada's exploration effort came with the discovery in 1914 of the giant gas and oil field at Turner Valley Alberta. The raw-oil produced was so pure it could be pumped directly from the well into cars as gasoline. So great was the excitement that in one 24-hour period more than 500 oil companies were formed and selling shares to cash in on the frenzy. The role of the risk taker has always been a key part in the high stakes game of exploration. In this case most never drilled a well, let alone saw any oil and huge fortunes were won and lost.

Exploration pushed up along the foothills to the northwest, eventually into the Peace River area of British Columbia. In 1917 McLearn, another Geological Survey geologist wrote that *oil and gas may be found in commercial quantities in some of the strata of the Cretaceous*. Geological reconnaissance work by Gwillim, Dressler and Speiker confirmed these opinions and led to the drilling of five shallow holes in the Hudson Hope area near the present Bennett dam site. The information had to be wrestled from the rigours of bitter cold, -40 C weather, deep mucky roads, lack of supplies, money and support, and primitive equipment. The wells were abandoned but did provide enough natural gas to keep the drilling camp in warmth and hot food.

An Imperial Oil discovery at Peace River in 1922 is considered British Columbia's first commercial gas discovery, with rates reported up to 12 million cubic feet (339 600 cubic metres) per day. Blow-out prevention equipment was neither available nor mandatory in those days. A small gas line was rigged up to supply the cookhouse stove, boiler and bunkhouse. A major leak and explosion on Christmas Day 1922 blew the camp down, destroyed all buildings and supplies. Although no lives were lost, a bitter cold sleigh trip to Pouce Coupe was needed to treat the burnt crew.

The provincial government of that time felt the potential resources of northeast British Columbia should only be developed by the government and froze all activity for the next 25 years. The last well drilled by the government in northeast British Columbia was Pine River #1 between 1940 and 1942. It was a difficult well from start to finish; the final line in the well report ends as *well abandoned due to political influence!*Elsewhere technology was making huge strides. Diamond bits made drilling faster and cheaper, cores could be cut providing a better geological picture of the reservoirs, rotary drilling reduced costs and improved safety, nitroglycerine could fracture and stimulate producing zones, hydrogen sulphide was removed to produce safe, usable natural gas and bush planes made the remote wilderness more accessible, all by the mid 1920s. Minor exploration continued in other British Columbia basins for the next two decades but not much happened until 1947.

LEDUC REVIVES THE INDUSTRY

Petroleum consumption, particularly gasoline, had soared. Canada's largest company, Imperial Oil, drilled 133 dry holes and had almost given up on finding more oil. The remark often repeated through history was uttered; *all the big finds were gone*. Imperial was experimenting with producing gasoline from natural gas. An expensive, complex process which produced a low quality gasoline but it was thought it may be the only way to stay in the gasoline business. This was in mind in 1947 for the location at Leduc #1 southwest of Edmonton, Imperial's last wildcat drilling program. Nearby were large natural gas fields where Imperial was thinking of a gasoline synthesis project. As many discoveries have shown, serendipity and luck saved the day; the zone was not expected to have oil. Leduc was the largest discovery in 33 years, triggering a boom that would eventually find the bulk of Canada's oil reserves hidden in the deep limestone and dolomite reefs of the Devonian.

At the same time that the lands in British Columbia were opened up to private companies, the Alaska Highway was built allowing access to new areas and more efficient rotary drilling rigs were in use. A major discovery of natural gas was made near Fort St. John in 1948. By 1951 drilling had discovered five new gas fields out of 31 attempts. The Trans-Mountain pipeline was built in 1953 to carry Alberta oil to the coast and refinery capacity doubled. The Westcoast natural gas pipeline was built in 1957. The first British Columbia oil field was found in 1958, the giant Boundary Lake field straddling the border with Alberta. Construction of major refineries at Taylor, near Fort St. John, and Prince George commenced in 1959.Major new discoveries continued with many new oil and gas fields from Fort St. John to Fort Nelson.

Access to the challenging terrain was often limited by weather. The soft muskeg had to be frozen to move equipment, so field seasons were often only two or three months long.River ice bridges had to be made, seismic shot and pipelines laid, all in bitter cold and remote regions. But the big discoveries were being made, from the narrow and long fields riding high on Mississippian faults along the front ranges of the foothills near Chetwynd, to the deep Devonian reefs at Fort Nelson, multilayered and chopped up Triassic oil fields near Fort St. John and gas-filled ancient Cretaceous coastal deposits south of Dawson Creek in the Deep Basin. Half a billion barrels of oil were found and about 20 trillion cubic feet (566 billion cubic metres) of gas, enough gas to supply all of Canada's needs for 10 years. Northeast British Columbia remains the busiest part of the province but other areas are still of interest.

Extensive marine geophysical survey programs were run in offshore British Columbia encouraging Shell to build the world's largest drilling rig in Victoria (Figure 30).Fourteen wells were drilled offshore from 1967 to 1969, with encouraging oil and gas shows but no commercial discoveries. The Queen Charlotte and Tofino basins cover an area about the size of the North Sea, which had 50 dry holes drilled prior to an economic discovery. The entire coast and offshore of British Columbia has had only 13 wells drilled to depths greater than 1000 metres. The small Winona basin at the north end of Vancouver Island has not had a single test.Our Pacific offshore is considered the last great frontier for exploration. It has been closed to drilling by a federal/provincial moratorium since 1972.Until environmental considerations and public concerns are fully satisfied it will likely remain off limits to drilling.

Figure 30. Offshore drilling rig built in Victoria in 1966, then the world's largest. The rig was used to drill 14 offshore wells, all of which were dry.

Vancouver Island has had several shallow wells drilled, from an old well at Muir Creek near Sooke, through one near Saturna, to the coal fields in the north. In 1986, British Petroleum drilled two wells south of Nanaimo to depths of 1.4 and 1.6 kilometres. All were unsuccessful. With the building of the new Vancouver Island pipeline and the interest in methane gas from coal, we may again see geologists on the island exploring for natural gas.

The Flathead Valley has seen occasional revivals as new seismic techniques were used to decipher the complex thrusting and faulting of the rocks, and markets justified the expensive, deep drilling required. Kootenai Brown's oil and gas shows continue to draw attention and now, deep gas, coal-bed gas and carbon dioxide have joined the quest.

The interior basins of Bowser, Nechako, Quesnel and Whitehorse remain remote and little explored. Oil and gas shows have been reported near Quesnel, Horsefly, Hazelton and Burns Lake. Theyare in complex faulted terrain that would suggest the rocks are overmature and reservoirs are poorly sealed.

Work is currently underway by the Geological Survey of Canada and private companies to expand the understanding of these basins. Two wells drilled several years ago in the Nechako basin resulted in minor shows but have not been pursued.

CONCLUSIONS

New technologies may make entire new sources of petroleum available; new drilling and recovery methods, heavy oils, oil shales and methane from coal could double British Columbia's present reserves. The offshore may yet be carefully evaluated and contribute to our energy picture.

The intimate role of energy in our society has generated the need to locate and produce hydrocarbons. Within a short hundred-year history, from Kootenai Brown squeezing gunny sacks to today, Canadians have become the world's largest per capita users of energy. We have nearly a million kilometres of roads paved with asphalt, a cold climate, lots of vehicles and a high standard of living that demands energy-intensive air travel, primary resource production, intensive agriculture and basic creature comforts. The nature of the oil and gas search into the future will be dictated by the markets, economics and lifestyle standards which we set, just like the Chinese thousands of years ago, for ourselves and our children.

From a quotation in the *Story of Oil in British Columbia*, written in 1930 by the Akamina Valley Oil Company,...*From geological information the oil bearing rocks are as thick in British Columbia, if not thicker, than in any other section of the world. This means that the pay formations that will produce the oil should have a longer life because of this greater depth than in other petroliferous areas.* Sixty years ago Akamina may have been ahead of its time. Although its geologists possibly should have referred to natural gas, they were correct, in that great opportunities still exist in the province, born by the courageous, creative restless part of mankind who made the colourful oil and gas story of British Columbia.

THE HISTORY OF EARTHQUAKE STUDIES IN BRITISH COLUMBIA
"From Indian Legend to Satellite Technology"

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ABSTRACT

Earthquakes were part of native life in British Columbia and were recorded in legend. With the coming of the European settlers in the mid-1800s, earthquakes began to be described in newspaper reports. Although sometimes frightening, they did not have much impact on the early communities. The first seismograph in British Columbia, and one of the first routinely operated seismographs in the world, was put into operation in the basement of the customs building in Victoria on September 3, 1898. It was part of the first world-wide network of seismographs. The first seismologist - actually primarily a meteorologist - was Francis Napier Denison.

Large damaging earthquakes, in central Vancouver Island in 1946 (M=7.3) and in Puget Sound (M=7.0) and the Queen Charlotte Islands (M=8.1) in 1949, brought a response from the federal government to undertake earthquake research on the west coast. In the summer of 1951 three sensitive seismographs were set up in Victoria. Research over the following decade delineated the distribution of earthquakes in western Canada and led to the development of Canada's first modern seismic zoning map which was incorporated into the National Building Code of Canada in 1970.

In 1968 the Victoria Geophysical Observatory was formed and earthquake studies expanded to include strong-motion seismology. In 1976 the Pacific Geoscience Centre was created and it moved to a new home at Pat Bay Institute of Ocean Sciences in 1978. Digital recording of earthquakes in the subduction zone region began in 1975 and an effective array to determine earthquake depth in the populated region was in place in 1984. In 1984 detailed seismic monitoring also began in the Queen Charlotte Islands region to assess seismic hazard to potential hydrocarbon extraction. During the 1970s and 1980s much was learned about the seismotectonics of western Canada.

In 1990 a new era in earthquake studies began with the beginning of the modernization of the entire Canadian seismograph network. This will result in the replacement of old photographic and pen-recording instruments with modern digital equipment that will send data to the Pacific Geoscience Centre via satellite.

FIRST EARTHQUAKE RECORDS

The first reported earthquake on the west coast of Canada is recorded in Captain George Vancouver's journal. He wrote that on February 17, 1793 *a very severe shock of an earthquake had been felt at the Spanish settlement at Nootka on the west coast of Vancouver Island*(Vancouver, 1793). Although this is the first documentation of an earthquake in the historical record, earthquakes were part of the native life in British Columbia and were recorded in legend and ceremony. There is an impressive earthquake mask in the collection of the Museum of Anthropology at the University of British Columbia (Cherry, 1971). A dramatic story exists in the verbal history of the Cowichan band of southern Vancouver Island (Maud, 1978). It tells of a great earthquake that occurred in the days before the white man came. It began in the middle of the night and shaking was so severe that it made people sick. It threw down their houses and brought great masses of rock down from the mountains.One village was completely buried beneath a landslide. The people could neither stand nor sit because of the extreme motion of the earth. This vivid description may well have its origin in a great earthquake that occurred on the Cascadia subduction zone about 1700.

EARLY SEISMOGRAPHS AND SEISMOLOGISTS

The first seismograph in British Columbia, and one of the first routinely operating seismographs in the world, was put into operation in the basement of the customs building in Victoria (Figure 31) on September 3, 1898. The seismograph was one of two purchased by the Meteorological Service of Canada, the other was installed in Toronto.The instrument was designed by John Milne, an English scientist, and was the first widely distributed seismograph. The instruments were placed throughout the British Empire under a plan by Milne to study the distribution of the world's earthquakes. By 1910 fifty-two instruments were operating around the world and within a decade, the main features of the seismic geography of the world had been mapped. (The original Victoria seismograph, one of three left in the world, has been restored and is on display at the Pacific Geoscience Centre).

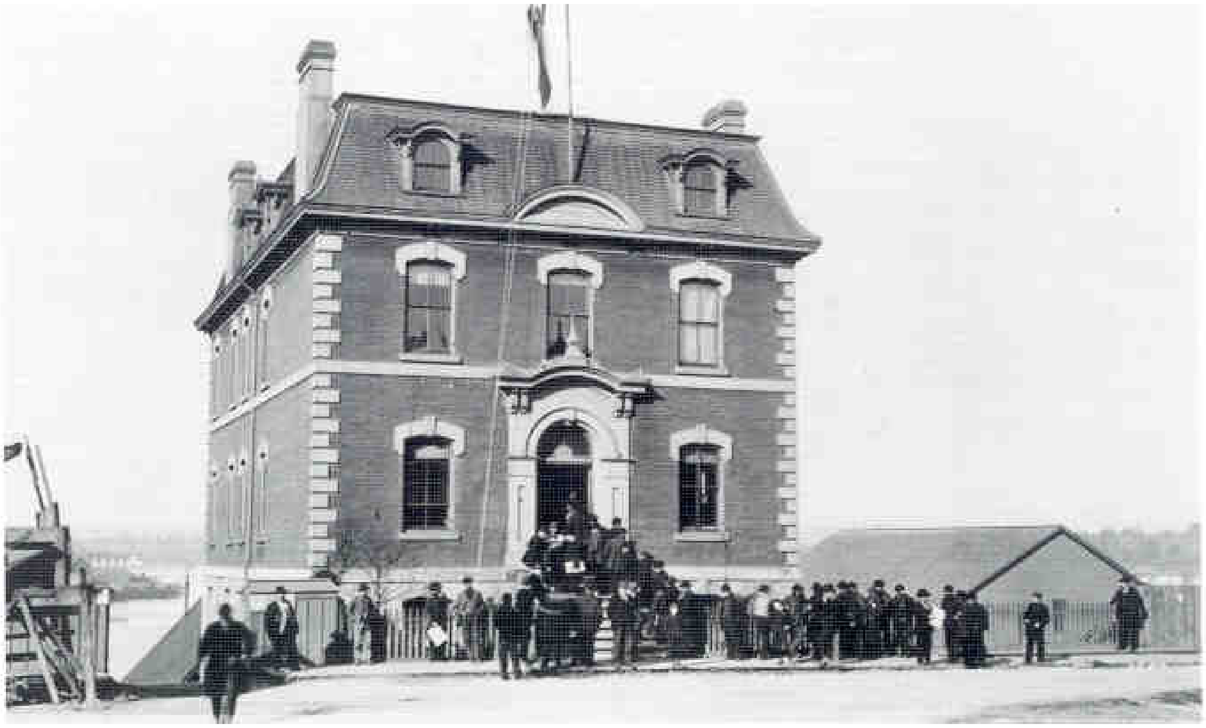

Figure 31. The Victoria Customs House, home of Victoria's first seismograph, circa 1898. The building still stands on the corner of Wharf and Broughton streets. (Photo courtesy of B.C. Archives and Records Service. No. HP71626).

The Milne seismograph was officially under the jurisdiction of Victoria meteorologist Edmund James Reed, but it was Francis Napier Denison, Reed's newly appointed assistant, who took over its maintenance and operation and became Victoria's first seismologist (Figure 32). Although not trained in seismology, Denison designed and built his own seismograph in 1907 and published articles on the large British Columbia earthquakes of 1918 and 1920. In addition he conducted extensive research on local earth tilting, which he thought should be related to earthquake activity – a correct assumption but beyond the capability of the instruments of his day. He also kept a personal scrapbook for over 50 years, saving the newspaper accounts of each earthquake detected at Victoria and any other articles he found to be of particular interest (Denison's scrap books currently reside at the Pacific Geoscience Centre). His weekly science column entitled *Observations in Science* can be found in the Victoria Daily Colonist of 1912.

Denison designed the Gonzales Meteorological Observatory in Victoria (Figure 33) with a specially constructed pier in the basement for the seismographs. In 1914 construction was complete and the Milne instruments were transferred to the new facility. Denison assumed the directorship of the observatory following Edmund Reed's death that same year.A Wiechert 80-kilogram vertical seismograph was added in 1917 and two Milne-Shaw horizontal seismographs in 1922, keeping the seismograph station abreast of advancing technology. Denison continued to operate the seismographs until his retirement in 1936 at age seventy.

Shortly after Denison retired, a shuffle of government departments transferred responsibility for the seismographs from the Meteorological Service to the Dominion Observatory of the Department of Mines and Resources. As a result, in 1939 Victoria's seismographic station made a third move, this time north of Victoria to the Dominion Astrophysical Observatory on Little Saanich Mountain (Figure 34). There the seismographs were under the supervision of astronomer Kenneth O. Wright, who many years later became Director of the Astrophysical Observatory.

A large, damaging earthquake in central Vancouver Island in 1946 (M=7.3) brought a change in focus of earthquake studies on the west coast. E.A. Hodgson, head of the Seismology Division at the Dominion Observatory in Ottawa came to Vancouver Island to investigate. His thorough report on the earthquake (Hodgson, 1946) clearly demonstrated the earthquake hazard on the west coast and he arranged for a modern high-gain seismograph to be

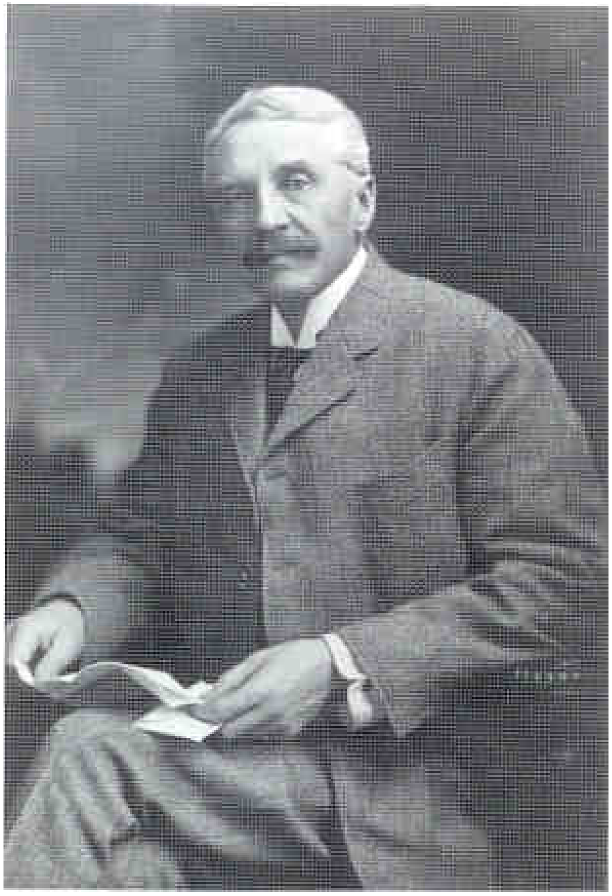

Figure 32. Francis Napier Denison (Victoria's first seismologist) installed the first seismograph in Victoria in 1898. (Photo courtesy of Victoria City Archives. No. 98108-33).

The instrument began routine operation in June 1948.It soon revealed that earthquake activity in the Vancouver Island region was much greater than had been indicated by the previous lower gain instruments.

CONTRIBUTIONS OF W.G. MILNE

In 1949, a damaging earthquake in Puget Sound (M=7.0) and a huge earthquake in the Queen Charlotte Islands (M=8.1) brought a further response. In the summer of 1951 seismologist W.G. Milne (Figure 35) was transferred from Ottawa to the Dominion Astrophysical Observatory and he set up two more sensitive seismographs in Alberni and Horseshoe Bay, just north of Vancouver, forming a triangle to monitor local earthquake activity.

Milne's research during the next two decades focused on delineating the distribution of earthquakes in western Canada and in the process he revealed the coastal and adjacent offshore as the most active regions. He also compiled the first catalogue of historical earthquakes in western Canada. During the 1960s the Canadian seismograph network was expanded to cover

Figure 33. Gonzales Heights Meteorological Observatory, built in 1914. Denison designed the building with living quarters for himself and his wife. Seismographs were located on a concrete pier in the basement.

the whole country with standardized instruments and on the west coast a network of strong-motion seismographs to capture on-scale recording in the epicentral regions of large earthquakes began to be deployed. The Victoria

added to the existing seismographs at the Dominion Astrophysical Observatory to better study earthquakes in the region.

Geophysical Observatory was formed in 1968 as an independent unit and moved to a separate building on the Astrophysical Observatory grounds. Milne's research on seismic hazard led to the development of Canada's first modern seismic zoning map, which was incorporated into the National Building Code of Canada in 1970.

MODERN ADVANCES

During the 1970s significant progress was made determining the depth and focal mechanisms of earthquakes in the coastal region. Earthquakes were found to occur below normal crustal depths in the Vancouver Island region. The new theory of plate tectonics provided a framework to understand the earthquake distribution and the earthquakes provided key information to refine the plate tectonic model. The commencement of digital recording of seismic data began in 1975 and in the same year the first seismic signals from remote stations were telemetered to the Victoria Geophysical Observatory. The mid-1970s also saw the beginning of crustal deformation studies on Vancouver Island to look for crustal motion associated with or preceding earthquakes.In 1976 the Pacific Geoscience Centre was formed, bringing together the Victoria Geophysical Observatory and the west coast marine geology unit of the Geological Survey of

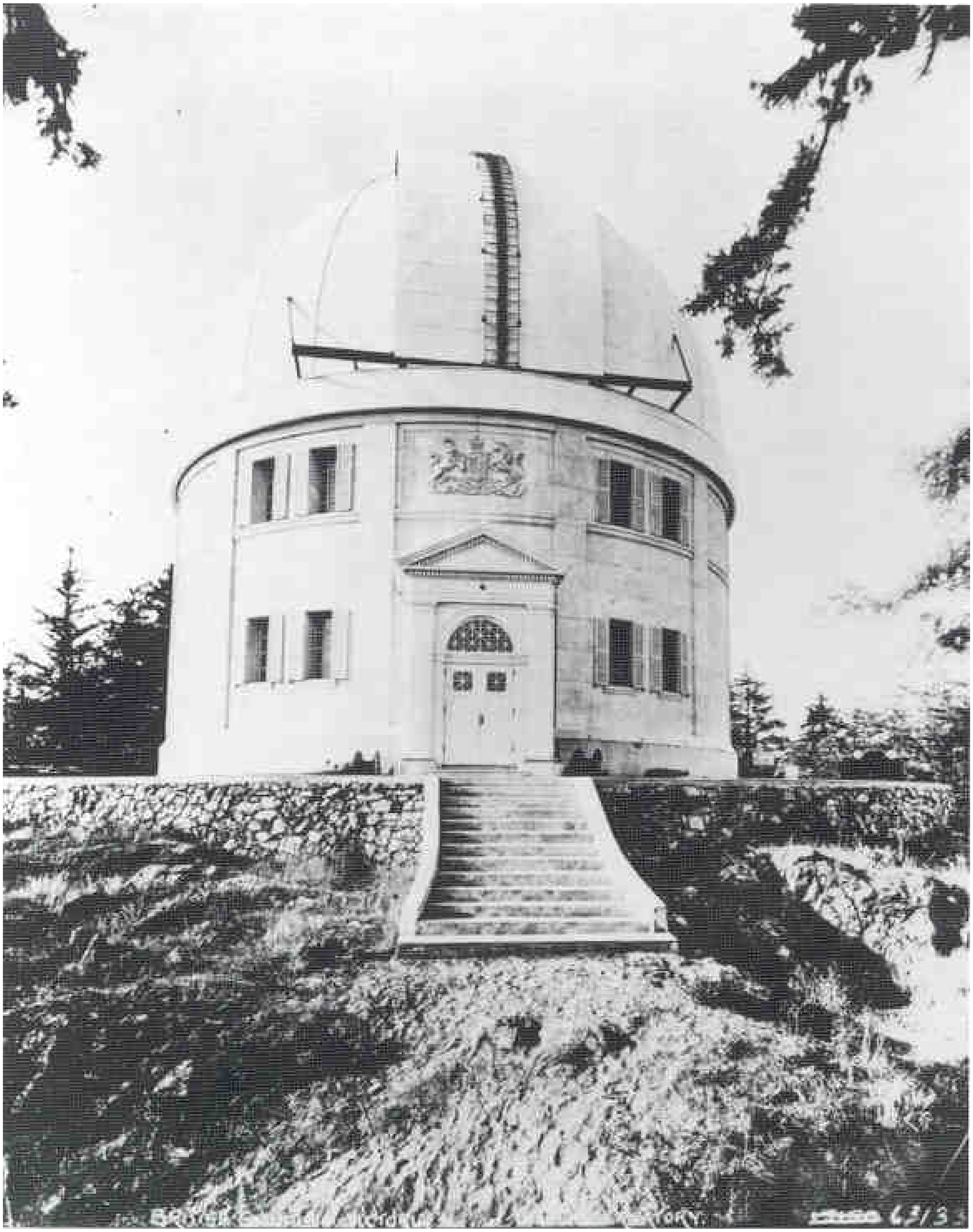

Figure 34. Dominion Astrophysical Observatory on Little Saanich Mountain. Seismographs were moved to the Observatory grounds in 1939. (Photo courtesy of B.C. Archives and Records Service. No. HP63133).

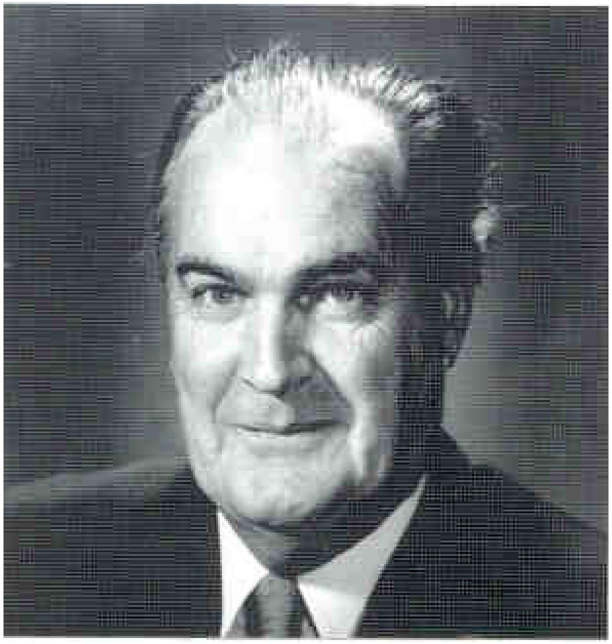

Figure 35. William G. Milne was transferred from Ottawa in 1951 to start a research program on west coast earthquakes. He was named Chief Scientist when the Pacific Geoscience Centre was established in 1976.

Figure 36. The Pacific Geoscience Centre moved to new facilities at Patricia Bay Institute of Ocean Sciences complex near Sidney, B.C. in 1978. The first seismograph commenced operation on March 18 with the complete move of all instruments made by September 1.

Canada. W.G. Milne was named the Chief Scientist. On February 14, 1978 the Pacific Geoscience Centre moved to its new facilities at the Institute of Ocean Sciences near Sidney, British Columbia (Figure 36).

During the 1980s a telemetered seismic network was developed to monitor the subduction zone region of southwest British Columbia. This revealed clearly the subducting Juan de Fuca Plate as an easterly dipping zone of earthquakes extending to a depth of 80 kilometres. It also revealed that no thrust earthquakes associated with the subduction process were detected, one of the key pieces of information leading to the suggestion that the subduction zone is locked and may represent a very significant earthquake hazard (Rogers, 1988). Crustal deformation monitoring was also expanded to address the subduction zone problem and revealed both horizontal and vertical motion consistent with a locked subduction zone.

A local seismograph network was also set up on the Queen Charlotte Islands during the 1980s to provide information on the region of Canada's largest historical earthquake (M=8.1). A new, more refined set of seismic hazard maps was developed and incorporated into the National Building Code in 1985.

The first seismic data transmitted via satellite was received in August 1990 and by the mid-1990s high quality digital data should be arriving at the Pacific Geoscience Centre from about 100 stations across the country.Crustal deformation studies are also increasingly utilizing satellite technology. The majority of the horizontal deformation measurements are now being made by use of the Global Positioning Satellite (GPS) system. This technology allows more measurements to be made with the same manpower and same budget and for measurements to be made in just about any location.

In less than a century, earthquake studies in British Columbia have progressed from Indian legend to satellite technology.

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THE SEARCH FOR THE OLDEST FOSSILS IN THE CORDILLERA

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ABSTRACT

In the late 19th century, discoveries of Cambrian fossils in the Cordillera were coincidental consequences of the activities of the Geological Survey of Canada in the service of the Canadian Pacific Railway. These activities centred on exploration of possible routes through the mountain barriers and on the search for coal. One serendipitous result was George Dawson's discovery of the Lower Cambrian trilobite Olenellus gilberti along the Canadian Pacific Railway main line at Kicking Horse Pass.

Cornelius Van Horne, the General Manager of the Canadian Pacific Railway, attempted to reduce the company's massive debt by exploiting the budding Victorian interest in mountain scenery. This initiation of tourism in the Canadian west also had important implications for Cambrian paleontology. In 1886, workmen building the CPR tourist hotel at Field discovered abundant trilobites in shales on Mount Stephen.A collection from the trilobite beds was sent to Carl Rominger at University of Michigan who published a quickie paper on these fossils. This paper, inept as it was, piqued the interest of Charles Walcott, the Cambrian paleontologist at the United States Geological Survey, who recognized that these fossils were of Middle Cambrian age. But Walcott had to wait twenty years before his curiosity about these fossils and their stratigraphic setting could be satisfied. He left the federal service in 1907 to become Secretary of the Smithsonian Institution, and in July of that year we find him on Mount Stephen collecting fossils from the trilobite beds. Until his death in 1927, most of Walcott's research was devoted to Lower Paleozoic stratigraphy and paleontology of the Canadian Cordillera, including description of the Burgess shale fossils which he discovered in 1909.

INTRODUCTION

In the two decades following British Columbia's entry into Confederation, most geological exploration in the Rocky Mountains was carried out as part of a loose collaboration between the Canadian Pacific Railway (CPR) and the Geological Survey of Canada. Two objectives were emphasized: exploration of possible routes for the transcontinental railroad through the mountain barriers and documentation of the distribution of critical deposits of coal (Zaslow, 1975, p. 108). The initial focus was on a northern route.Alfred Selwyn, the second Director of the Survey, ascended the Thompson River as far as the Yellowhead Pass and later explored a possible route along the Peace River. George M. Dawson, who later succeeded Selwyn as Director, travelled through Pine Pass and also explored the upper Columbia River. In the early 1880s, when the CPR decided to build the railroad along a southern route, Dawson and George McConnell were sent by Selwyn to explore geologically the country along the Bow River and into the passes to the west (Dawson, 1886).

No Cambrian fossils were collected during these geological reconnaissances even though extensive fossiliferous strata of this age occur in the areas explored. But in 1885 Dawson discovered the trilobite *Olenellus gilberti Meek* in limestones exposed near the Kicking Horse Pass, immediately east of Field, British Columbia. This trilobite documented, for the first time, the presence of the Lower Cambrian *Olenellus* Zone in the Canadian Cordillera.

Later discoveries of Cambrian fossils from the area around Field were closely linked to the CPR's attempts to establish a lucrative tourist industry in the Canadian Rocky Mountains.

THE CANADIAN PACIFIC RAILWAY, TOURISM AND CARPENTERS

Tourism and vacations are fairly recent social phenomena which date from the late 19th century when the middle and upper classes began to seek out seaside and mountain resorts to escape the heat and pollution of the industrialized cities. Travel for pleasure had become a new and original vacation option for affluent and adventurous tourists in the 1870s.Jules Verne's book *Around the World in 80 Days* had just been published, Thomas Cook began to offer round-the-world excursions, and Yellowstone National Park had recently been established. The late Victorian era was also the time of beginning awareness of the significance of wilderness through the writings of John Ruskin in Britain and Henry David Thoreau and John Muir in America. Mountains assumed almost mystical significance in their writings – *mountains are the beginning and the end of natural landscape* according to Ruskin (Hart, 1983).

Cornelius Van Horne, the astute General Manager of the CPR, identified a way to reduce the massive debt load of the company. He decided to exploit the public's fascination with wilderness experiences and mountain scenery. *If we can't export the scenery, we'll import the tourists.* To service this anticipated rush of tourists, Van Horne ordered the construction of a series of hotel dining stations along the main line through the mountains: Fraser Canyon House at North Bend, Glacier House at Rogers Pass and Mount Stephen House in Field. These were not to be hotels, like those in Banff and Lake Louise; rather they were to be restaurants which eliminated the need for the locomotives to pull heavy dining cars up the steep grades.

Mount Stephen House was finished in 1886 at a cost of $20 000. Its interior was executed in high Victorian style with gas lights, heavy brocades, pump organ and caged canaries. The food was less distinguished. Van Horne, who investigated every minutae of his railroad, noted,*The hotel at Field, in addition to being excessively expensive, is very badly managed. I have never yet seen a decent meal in the house, and complaints are numerous* (Hart, 1983).

Some of the workmen who were building Mount Stephen House during the summer of 1886 spent their Sundays scrambling across the steep slopes of the surrounding mountains.One day, a group of now-forgotten carpenters discovered abundant and well preserved *stone bugs* high on Mount Stephen above Field (Figure 37) in what was later to be known simply as the Trilobite Beds (Collins, 1986). This discovery was to have profound implications for Canadian Cambrian paleontology.

Figure 37. Mount Stephen House at Field, British Columbia as photographed by Otto Klotz in 1886.Workmen discovered "stone bugs" in what was later to be known as the Trilobite Beds on the flank of Mount Stephen (shown by white arrow).

The workmen told McConnell of the Geological Survey of Canada of their discovery. He had been sent out to investigate the stratigraphy and structure along the CPR main line. In September, he made a larger collection from the Trilobite Beds and he was able to place these fossiliferous shales some 600 metres upsection from the *Olenellus*-bearing limestones that G.M. Dawson had discovered the previous year.

Otto Klotz, a Dominion surveyor who was in Field to determine the latitude and longitude of points along the CPR, was also told of the discovery. Like McConnell, he made a fossil collection from Mount Stephen which he sent to Carl Rominger, professor of geology at the University of Michigan in Ann Arbor. Even though he had no prior experience with fossils of this age, Rominger (1887) published a hastily assembled paper in which he described mostly new species of trilobites. This was clearly a paper written by a non-specialist. Rominger did not refer to a single published paper on trilobites. Correlations to other successions in North America were not attempted and he used the even-then antiquated term *Primordial* to indicate the age of these beds.

PIQUING WALCOTT'S INTEREST

Rominger's paper is important, not for its scientific content, but because it alerted Charles Walcott of the United States Geological Survey to the quality of Cambrian fossils preserved in long stratigraphic sections in the Canadian Cordillera, particularly in the area around Field. During the 1880s and 1890s Walcott had achieved unchallenged mastery of the fields of Cambrian and Precambrian paleontology and stratigraphy. In response to Rominger's paper, Walcott (1888) published a note in the American Journal of Science, but this was much more than a simple critique. In order to properly identify these trilobites (Figure 38), he borrowed both Klotz' and McConnell's collections from the Trilobite Beds. As one very familiar with Cambrian fossils of western North America, he was able to show that the Mount Stephen fossils are of late Middle Cambrian age.

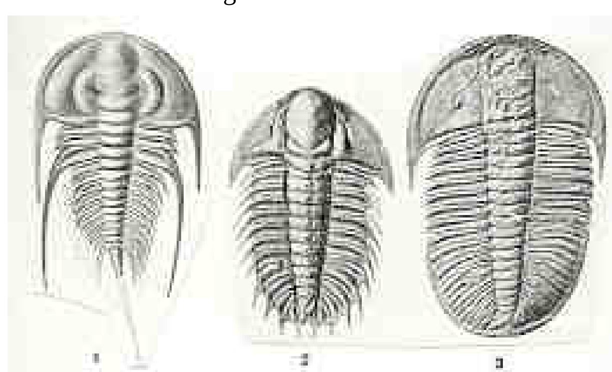

Figure 38. Cambrian fossils from the Field area. 1. *Olenellus gilberti Meek* - the Lower Cambrian trilobite collected by George M. Dawson at Kicking Horse Pass in 1885. 2 and 3. The most common fossils in the Middle Cambrian Trilobite Beds on Mount Stephen - *Olenoides serratus* (Rominger) and *Ogygopsis klotzi* (Rominger). (from Walcott, 1908).

The pace of Walcott's research was hardly interrupted when he succeeded John Wesley Powell as Director of the United States Geological Survey in 1894.

Walcott was the first paleontologist in North America to systematically study the limited biota of the Late Precambrian, mainly stromatolites and possibly a few metazoans (Walcott, 1899; Yochelson, 1979) and particularly the fossils of the Belt Series. *Beltina danai* Walcott, reputed to be a merostome crustacean more advanced than a trilobite, was considered a very important discovery because it was tangible evidence of the gradual diversification of the arthropods which must have started well below the Cambrian according to Walcott's evolutionary thinking. These fossils came from Belt strata a few thousand metres below Cambrian rocks in Montana and British Columbia. Despite intense collection efforts, no other arthropod or other metazoan fossil was discovered in the Belt, and Walcott was becoming increasingly troubled by the morphologic discrepancy between the extreme simplicity of the organic structures such as stromatolites in the Belt and the great complexity of the diverse shelly fossils in the Lower Cambrian. To explain why these unmetamorphosed sequences of strata did not contain the fossils which document this slow development, Walcott was forced to reinterpret most of the Belt strata as nonmarine in origin and, therefore, well removed from the locus of metazoan diversification which took place in late Precambrian marine settings. This late Precambrian period of marine sedimentation and early metazoan diversification was assigned to the Lipalian Era. According to Walcott (1910), the fossil record documenting this gradual diversification had been lost because the marine rocks were eroded prior to the Early Cambrian transgression.

Walcott's interpretations of *Beltina* and Lipalian did not survive long into the 20th century. Although clearly organic, *Beltina* is not a metazoan; the specimens probably comprise broken sheets of algae (Yochelson, 1979). Walcott's concept of the Lipalian foundered with the realization that most of the Belt strata were marine after all, and that they lacked shelly fossils for the simple reason that metazoans had not yet developed. Shelled metazoans did not appear until much later, close to the base of the Cambrian.

WALCOTT'S CANADIAN PHASE

In 1907 Walcott left the United States Geological Survey to become Secretary of the Smithsonian Institution and now, no longer a federal employee, he was free to do fieldwork and to pursue research interests beyond the borders of the United States. Remembering the collections of Klotz and McConnell that were described by Rominger 20 years before, he headed straight for Field, British Columbia, and in July of that year he was on Mount Stephen collecting fossils at the Trilobite Beds. Walcott treated these fossils and their stratigraphic setting in the first volume of the Canadian Alpine Journal in 1908. This was the first of many papers based on Walcott's extensive fieldwork in the southern Canadian Rocky Mountains. Walcott's final contributions were two posthumous publications (1927, 1928) which dealt with Cambrian, Ozarkian, Ordovician and Silurian sedimentation and stratigraphy of the southern Canadian Rocky Mountains. In all, over 200 pages of text amply illustrated by metre-long fold out panoramic photographs of mountain scenery showing formational boundaries.

Returning to Field across Burgess Pass in August, 1909 Walcott discovered the celebrated Burgess shale fauna (Gould, 1989), the description of which occupied most of his research time until his death in 1927.

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THE HISTORY OF MARINE GEOLOGY IN BRITISH COLUMBIA: FROM INFANCY TO TODAY

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ABSTRACT

The history of marine geological explorations on the west coast of Canada has been characterized by sporadic advances in knowledge and activity followed by long periods of quiescence.The earliest people to make measurements in the general field of marine geology were marine explorers from Spain and Britain.These were followed, in turn, by a number of hydrographic studies by the British Admiralty. The Geological Survey of Canada became involved in marine geological studies in the region with the work of W.A. Johnston in the early 20th century.

The next group that became active in this area were the faculty and graduate students from the University of British Columbia who first enjoyed the support and cooperation of the Earth Physics Branch and subsequently the Geological Survey of Canada.Government activities accelerated rapidly in 1970 with the construction of the Pacific Geoscience Centre at Patricia Bay on Vancouver Island, and recruitment of a core of researchers conducting integrated marine geological and geophysical studies.

New initiatives at the University of British Columbia and the University of Victoria may provide important new stimulation to marine geological and geophysical research in this region in the future.

INTRODUCTION

The west coast of Canada is most fortunate to have been blessed with visits from some of the greatest names in maritime exploration. Our shores were visited by such famous people as Juan Perez in 1774, Juan Francisco de la Bodega y Quadra in 1775, James Cook in 1778, La Perouse in 1786, Alejandro Malaspina in 1791 and 1792, and finally Captain George Vancouver in 1792 and 1793 (Kendrick and Inglis, 1991). These early explorers not only charted the coastline (e.g. Cook, 1784; Vancouver, 1798) and searched for the mythical Straits of Anian (the fabled Northwest Passage), but also made crude hydrographic charts, undertook bathymetric surveys, sampled the sea bottom and conducted both gravity and magnetic measurements.

The next group to become active in marine geological research were the hydrographers. The British Admiralty published hydrographic surveys for part of this region from the years 1827 to 1860. These charts made an enormous contribution to our understanding of marine geology and hydrographic surveys continue to provide fundamental knowledge of our coast today.

It was not until the mid 1950s that the University of British Columbia's Department of Geology faculty and graduate students became active in marine geological research. Their work reached a climax in the 1970s, but decreased in intensity with the opening of the Pacific Geoscience Centre in 1978. Recently it shows signs of reviving with some new players entering the scene.

Government activities accelerated quickly in the mid 1970s with the construction of the Pacific Geoscience Centre at Patricia Bay on Vancouver Island and this institution continues to play an important coordinating role in marine geological activities for the region. Growth and new progress, however, are now limited due to curtailed operating budgets and lack of commercial exploration in the offshore.

EARLY HISTORY OF EXPLORATION

The most celebrated navigator of his time, Captain James Cook, undertook a third voyage to the Pacific which brought him to the northwest coast of America in 1778. He stayed for one month at Nootka Sound on Vancouver Island in the spring of 1778 where he undertook some bottom soundings in the local area before hurrying north to Alaska. In Alaska he surveyed what is now known as Cook Inlet, a modern, fore-arc, petroleum-producing basin.

Spain's response to the voyage of Captain Cook into what they considered as their rightful area of the Pacific was to organize a major expedition under Alejandro Malaspina in 1791 and 1792 (Kendrick and Inglis, 1991). Apart from their mapping, and all the astronomical work that went into it, the physical sciences also received a fair share of attention. For example, gravity measurements were made along the shore using a Licot pendulum swinging, while another officer timed it on the chronometer. By taking such measurements at various latitudes, the ellipticity of the earth could be calculated. Further, if the latitude was known, the magnetic variation could be calculated by observing the magnetic bearing of the sun at sunrise and sunset. To measure the vertical direction of the earth's magnetic field, a *dipping needle* was used.

The next player on the scene of the Pacific Northwest was Captain George Vancouver. In 1792, west of Point Grey he met Senores Don Dionisio

Galiano and Cayentano Valdes of Spain. They knew the water was fresh and a large river entered the sea close by, but Captain Vancouver's chart shows a solid shoreline at this point, even though his Second Lieutenant, Peter Puget, thought there were *two large rivers*. It wasn't until 1807, that Simon Fraser established that the Fraser River was the source of this fresh water. The two groups explored the coastline to the north together and then separately circumnavigated Vancouver Island (Kendrick and Inglis, 1991).

SPECIAL STUDIES

Following the early expeditions to the Pacific Northwest coast, the next group to make very significant contributions to the marine geology of the region were the hydrographers. The Spaniards started this work; in particular, they hydrographically surveyed Friendly Cove in Nootka Sound a number of times in the late 1700s. Then Emilius Simpson provided the first detailed chart of the Fraser River delta in 1827 from the Hudson's Bay Company schooner Cadboro. This chart, later published by the British Admiralty, laid the hydrographic foundation for much subsequent research. Further hydrographic studies were organized during this period by the British Admiralty in the Strait of Juan de Fuca, Nootka Sound and Friendly Cove. The excellent work of Captain George Richards, who in 1859 surveyed in detail the Fraser delta and Burrard Inlet in detail, was published as Admiralty Chart Number 1922 (Richards, 1860).

As a result of this early work of the Admiralty and the subsequent continuing outstanding work of the Canadian Hydrographic Survey (C.H.S.), we have been most fortunate to have accurate base maps for all subsequent marine geological research. Without the excellent work of the C.H.S., marine geological studies on the west coast would be much less successful.

In the 1920s studies on the marine geology of the Pacific Northwest by the Geological Survey of Canada began with the outstanding pioneer work of W.A. Johnston in which he accurately calculated the growth and described the sediments of the Fraser delta complex (Johnston, 1921a, b, c).

Other special studies of the marine geology and geophysics of the Pacific Northwest contributing to our knowledge of the sea floor include: the work of Terzaghi (1956) on the land-slip at Woodfibre in Howe Sound, studies of submarine slope failures and loss of the loading dock at Texada Iron mines in the late 1960s, together with other slope-failure studies and engineering investigations such as those at Kitimat and Ripple Rock. Further, during this same period, W.G. Milne (personal communication, 1992) and his colleagues recorded seismic crustal data for the Strait of Georgia from underwater explosive sources including those from Ripple Rock.

PIONEER UNIVERSITY STUDIES

University study of marine geology on the West Coast was started by Professor Bill Mathews, who was appointed by Henry Gunning in 1951 with the understanding that he was to work with the oceanographers who had founded the Institute of Oceanography in 1949. Bill's initial work in the early to mid-1950s included seafloor studies of Howe Sound. Then in the mid-1950s, Dr. W.A. Clemens of the University of British Columbia and Dr. J.P. Tully, of the Pacific Oceanographic Group, generated a project proposal for Bill to work on in Hecate Strait with support from both the Pacific Naval Laboratory and the Federal Department of Fisheries. This project got as far as the meeting of the Federal Interdisciplinary Committee on Oceanography in the winter of 1955. George Hanson, then Director of the Geological Survey of Canada, was invited to participate because this was to be a major oceanographic study with significant marine geological content. It is reported that George Hanson's sole remark was the *Geological Survey is not interested in this type of research*. Consequently, the project was cut back to a study of the bottom sediments of Dixon Entrance where underwater gravel deposits of this region were mapped in considerable detail (Mathews, 1958). This pioneering study may well have some major international repercussions dealing with the boundary disputes between Alaska and British Columbia in Dixon Entrance, as the full width of the strait was surveyed and mapped under the jurisdiction of a Canadian agency.

In the spring of 1956, the Pacific Naval Laboratory expressed interest in acquiring a geologist to help with the study of bottom sediments and their seismic behaviour, as part of anti-submarine activities. A promising student, H.J. Greenwood, was recommended for the position but before it was filled, the terms of reference were changed in favour of a geophysicist and Greenwood went on to a rewarding career in metamorphic geology. The time seemed not yet ripe for marine geology; but the atmosphere changed very quickly in 1956. George Hanson retired that year and his position was filled by Dr. Jim Harrison, a very enterprising individual.

Also in 1956 another influential scientist, Dr. William W. Van Steinburgh with the Department of Energy, Mines and Resources in Ottawa, became interested in developing marine geology and geophysics. In both his position with the Department of Energy, Mines and Resources and as Chairman of the Canadian Committee on Oceanography, he and Dr. Harrison fostered oceanographic work by supporting university research investigations in the field and providing a supply of scientific personnel. Their combined efforts had much to do with the formation in 1972 of the Atlantic Geoscience Centre at Bedford, Nova Scotia, which was followed in turn by the Pacific Geoscience Centre in Sidney, British Columbia in 1978.

Bill Mathews' subsequent marine geological works extended into the Powell River region in 1961 where he, Pete Williams and George Pickard reported on fossil marine water at the bottom of Powell Lake (Williams *et al*., 1961). This was an old fjord isolated from the adjacent marine water of the Strait of Georgia by the delayed isostatic rise of the land, after removal of its load of glacial ice.

In 1962 Bill Mathews and Francis Shepard published their benchmark paper on the Fraser River delta in which they determined among other things, the advance of the Fraser delta and the annual sediment budget at its mouth (Mathews and Shepard, 1962).

In 1964 Jim Murray was invited to come to the University of British Columbia by Bill Mathews and George Pickard and started work on Boundary Bay, Howe Sound, the Strait of Georgia and Queen Charlotte Sound (Kellerhals and Murray, 1969). This research program was given a significant boost in 1966 by Dr. John Wheeler of the Geological Survey of Canada, who provided contract funding for offshore research for three years, including the research of graduate students John Luternauer, Lionel Carter and Bob Macdonald (*e.g*. Luternauer and Murray, 1973). Meanwhile Don Tiffin did his graduate research on the sub-bottom structure of the southern Strait of Georgia and contributed to continuous seismic profiling studies on the continental shelf off Vancouver Island (Tiffin *et al*., 1971, 1972).

In 1967, Bob Macdonald and Jim Murray discovered underwater manganese nodules on a submarine sill near the head of Jervis Inlet, British Columbia (MacDonald and Murray, 1973). This scientific discovery and the resulting publicity tended to focus attention on the need to continue and expand marine geological research on the west coast of Canada.

In 1968 Dick Chase came to the University of British Columbia from Woods Hole Oceanographic Institute and conducted research on the offshore regions west of Vancouver Island and the Queen Charlotte Islands with his graduate students including Sandra Barr, Wayne Bertrand, Arnie Thomlinson and Wolfgang Weise, to name but a few. Their research involved early fundamental studies of seafloor spreading, transform faults and associated volcanism, and hydrothermal mineral deposits around undersea vents (Murray *et al*., 1975).

Marine geophysical studies started at the University of British Columbia with early experiments conducted on the Fraser delta in 1959 and 1960 by Jim Savage, R. Don Russell and Frank Kellar. They did a survey with receiving instruments located offshore and sound sources that were both onshore and offshore. In 1963 Hugh White conducted a study across the southern Strait of Georgia while on leave from the Canada Department of Energy, Mines and Resources. Bob Ellis came to the University of British Columbia in 1964 and was joined by Ron Clowes in 1970. Geophysicists at the University of British Columbia enjoyed a most beneficial scientific collaboration, first with W.G. Milne and his colleagues of the Earth Physics Branch and subsequently with the Pacific Geoscience Centre. Research included seismic experiments on the Explorer Ridge, Queen Charlotte Sound and the northern Strait of Georgia. This excellent co-operation continues up to the present time.

MODERN STUDIES - PACIFIC GEOSCIENCE CENTRE

The Pacific Geoscience Centre opened its doors in January of 1978 and provided the basic infrastructure for bringing together a multidisciplinary team to tackle the problems of understanding crustal structure, tectonics and sediment distribution in an area where an active spreading centre intersects a continental plate.Approximately a dozen earth scientists came from the Geological Survey of Canada in Vancouver and approximately fifteen from the Earth Physics Branch personnel in Saanich. These two groups together with the necessary technical and administrative support staff, comprised a sufficiently large critical mass to allow more integrated, interdisciplinary, group studies to be conducted.

NEW DEVELOPMENTS

In 1989 Dr. Chris Barnes was appointed as the Director of the University of Victoria's new Centre for Earth and Ocean Research. This new centre has already made two good appointments, Dr. Chris Garrett from Dalhousie University and Dr. Michael Witticar from Hanover, West Germany. The University of British Columbia views this development as being very positive for encouraging the growth of earth sciences in the Pacific Northwest. The University of British Columbia is working collaboratively with Dr. Barnes to bring a major new interdisciplinary program involving university, industry and government to this region.

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GEOLOGICAL MAPPING IN THE CORDILLERA - THEN AND NOW

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In 1945, less than a quarter of the Canadian Cordillera had been mapped at 1:250 000 (4 miles to 1 inch) or on larger scales by the Geological Survey of Canada and the British Columbia Mineralogical Branch. After 1945 the Geological Survey of Canada accelerated its mapping to begin the golden age of Cordilleran surveys which ended with the completion of the primary 1:250 000-scale coverage in 1978.

Until the mid-1950s Geological Survey of Canada mapping was done largely by six-man parties using pack horses (Figures 39 and 40), canoes and backpacking (Figures 41 and 42) methods, without radios, serviced in remote areas by fixed-wing aircraft. Topographic maps were inadequate but air photos were gradually becoming available. It took about five years to complete a 1° by 2° quadrangle.

Figure 39. Packing the stove-horse in the Selwyn Mountains, Yukon Territory, 1952.

Figure 40. Packhorse down in beaver slough, 1952, Macmillan River, Yukon Territory.

By the late 1950s piston helicopters were used for geological fieldwork (Figure 43). For efficient operations field parties used radios and were enlarged to include various specialists. The helicopter set out traverse teams, serviced fly camps (Figure 44) and served as a vehicle for geological mapping and revisiting critical localities. The rate of geological surveying increased to two quadrangles per year in Yukon and one every two years in the southern Cordillera. By this time more accurate topographic maps and better snow-free air photos were available.

In the 1970s the advent of faster, larger and costlier helicopters, though they increased the range of operations, required larger parties and a large slice of the Geological Survey of Canada field budget for efficient usage.

By the 1980s the present revision mapping was well under way. This requires selective geological surveys of significant and problem areas at 1:50 000 scale and less detailed coverage elsewhere. The slower pace of the work, in which a 1° by 2° quadrangle is revised in three to four years, coupled with higher helicopter charges and declining field budgets, has led to further logistical changes. Geological Survey of Canada parties, which now include women, have now returned to more old fashioned methods such as fly camping and backpacking, supplemented by judicious use of helicopters.

Figure 41. Geological Survey of Canada field crew backpacking in the Kluane Range, Yukon Territory, in 1954.

Figure 42. Geological Survey of Canada field party fording a glacial stream in the St. Elias Mountains in 1955.

Figure 43. Setting food caches by helicopter for a Geological Survey of Canada camp in the Selkirk Mountains, 1961.

Figure 44. 1961 Geological Survey of Canada field camp at timberline in the Selkirk Mountains.