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100 YEARS OF GLACIER OBSERVATIONS IN CANADA (1890-1990)

ABSTRACT: OMMANNEY C.S.L., *100 years of glacier observations in Canada (1890-1990).* (IT ISSN 0391-9838).

This paper describes glacier investigations in Canada from 1880 to 1990. It discusses the initial influence of the Canadian Pacific Railway and Alpine Club of Canada, then reviews those developments, before, during and subsequent to the major international initiatives of the IGY, IHD and IHP, that laid the groundwork for current programs.

KEY WORDS: History of Glaciology, Snow and Ice Research, Canada.

RIASSUNTO: OMMANNEY C.S.L., *100 anni di ricerche glaciologiche in Canada (1890-1990).* (IT ISSN 0391-9838, 1995).

Questo articolo descrive gli studi glaciologici in Canada dal 1880 al 1990. Viene dapprima discussa l'influenza iniziale della Canadian Pacific Railway e dell'Alpine Club of Canada, poi vengono riassunti quegli sviluppi prima, durante e dopo, le principali iniziative internazionali del IGY, IHD e IHP che hanno posto le basi per gli attuali programmi di studio.

TERMINI CHIAVE: Storia della Glaciologia, Ricerca nivologica e glaciologica, Canada.

INTRODUCTION

The nature of glacier observations in Canada has been somewhat different from that in the European Alps. The glacierized mountain regions are largely unpopulated and few of the limited highways and railways that pass through them come close to glaciers. There has been no sedentary population, sensitive to changes that were taking place, able to observe the ice cover over decades, centuries and millennia, and pass on a record to their descendants. Furthermore, the pragmatic needs of hydro-power companies and water providers have played a fairly minor role in the development of glaciological studies in Canada. Scientific curiosity, apparent concerns over sovereignty, and a desire to participate in major bilateral and international initiatives, have been much more influential.

Although Indian legends do refer to glaciers, the earliest recorded description seems to be that by James HECTOR in 1861, who visited the Southeast Lyell Glacier (51°54'N, 117°2'W) in the Rockies in 1858. In 1871, the Government promised British Columbia a transcontinental railway if it joined the Confederation. This was completed in November 1885 and the first passenger train left Montréal in June 1886. At last it was possible to pass through the mountains, and the string of hotels constructed by the Canadian Pacific Railway meant those with money, time and the inclination, could explore what became known as the Canadian Alps and make the first observations of glaciers. Facilities such as Château Lake Louise and Glacier House were built, providing bases from which the early amateur and professional scientists worked. Imported Swiss guides were made available to those wishing to climb or do glacier research.

HISTORIC (PRE-1945)

Passengers crossing Rogers Pass, in the Columbia Mountains, the central of three major north/south mountain chains in British Columbia, had to leave the train for refreshments at Glacier House because the grade was too steep to accommodate a restaurant car. This stop was within sight of the Illecillewaet or Great Glacier (51°14'N, 117°26'W) which, together with the neighbouring Asulkan Glacier, became the object of the first glaciological investigations. The Vaux family of Philadelphia, who spent their summer vacations here from the late 1890s onwards, carried out systematic studies of these two glaciers, as well as of Yoho Glacier (51°36'N, 116°32'W) on the British Columbia side of the Rockies (CAVELL, 1983; VAUX & VAUX, 1899, 1908; VAUX, 1913; and VAUX, 1909) for about 15 years.

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Victoria Glacier (51°23'N, 116°17'W) in the Rockies, visible and easily accessible from Château Lake Louise, was another object of early attention. Studies here, and on the neighbouring Wenkchemna (51°19'N, 116°14'W) and Yoho glaciers, were conducted by the Smithsonian Institution (SHERZER, 1907; GARDNER, 1978), with scientific curiosity as the principal motivation.

In many European countries, mountaineering clubs have been at the forefront of glacier observations. Recalling this tradition, when the Alpine Club of Canada (ACC) was founded in Banff in 1906, it included in its constitution a commitment to the scientific observation of glaciers. Studies on Yoho Glacier were extended by A.O. WHEELER and fellow members of the ACC, which held a number of field camps in that valley (WHEELER, 1911, 1934). Club members also contributed incidental information on several other glaciers in the region. Activities ceased during the First World War and were quite sparse in the interwar years (MCCOUBREY, 1938; MUNDAY, 1931; PALMER, 1924; THORINGTON, 1938).

Thus, until the middle of this century, observations in Canada were largely limited to a few glaciers close to the railway line, principally the Illecillewaet, Asulkan and Yoho, and were not continuous. A hint of what the future held in store could be seen in the 1931 aerial survey of glaciers in Labrador, completed under the auspices of the American Geographical Society (AGS) by FORBES (1938), which included some ground observations of Bryant's Glacier (59°19'N, 63°56'W; ODELL, 1933).

1945 TO MID-1950s

A different perspective came in the immediate postwar period with a recognition by the Dominion Water and Power Bureau (DWPB) that the melting of glaciers might be an important factor in the assessment of western Canadian water resources. The Bureau decided to initiate an annual survey of glaciers. In 1945, seven glaciers in Alberta (Angel [52°41N, 118°04W], Athabasca [52°12N, 117°15W], Freshfield [51°46N, 116°54W], Peyto [51°41N, 116°33W], Saskatchewan [52°12N, 117°08W], Southeast Lyell, and Victoria) were selected for observation by the DWPB's Calgary office and eight in British Columbia (Bugaboo [50°44N, 116°46W], Franklin [51°14N, 125°28W], Helm [49°58N, 123°W], Illecillewaet, Kokanee [49°45N, 117°08W], Nadahini [59°44N, 136°41W], Sentinel [49°54N, 122°59W] and Sphinx [49°55N, 122°58W]) were chosen by their Vancouver office. The position of the snout and changes in its areal extent were measured and plaques placed on the ice surface to measure velocity. Although some annual surveys were abandoned after a few years, many continued until 1950 when they became biennial. By the mid-1960s, observation was by terrestrial photogrammetry. Although the detailed reports were prepared by the DWPB as internal documents, some results were published (COLLIER, 1958; LANG, 1943; MCFARLANE, 1946; MEEK, 1948). Summaries of the reports for Peyto Glacier and the Victoria Glacier were published later (e.g. OMMANNEY, 1972).

In 1948, the AGS established the Juneau Icefield Research Project. Although this concentrated on glaciers in Alaska, it laid the groundwork for the Summer Institute of Glaciological and Arctic Sciences that, from its subsidiary base in Atlin, B.C., has contributed to knowledge of some Canadian glaciers in the area, particularly the Cathedral (59°20N, 134°06W; FIELD & MILLER, 1950; MARCUS, 1964; MILLER & ANDERSON, 1974). Another AGS expedition visited several glaciers in the Rockies in 1953, mapping them and determining variations for the Robson (53°08N, 119°06W), Columbia (52°10N, 117°23W), Southeast Lyell, Peyto, Freshfield, Athabasca and Saskatchewan glaciers using photographic and botanical techniques (FIELD & HEUSSER, 1954; HEUSSER, 1960).

Advances in transportation technology, first seen in Labrador, made a significant impact on post-war field research in Canada. Previously inaccessible areas were opened up to scientists. Pat Baird, through the Arctic Institute of North America (AINA), mounted a major expedition to Baffin Island in 1950 to study the Barnes Ice Cap (70°10N, 73°30W; BAIRD, 1952a) and to the Penny Ice Cap (67°10N, 66°13W; BAIRD & *alii*, 1953) in 1953. These expeditions provided the first substantial information on glaciers in this region (BAIRD, 1952b; ORVIG, 1953, 1954; WARD, 1954). Other scientists also found it easier to work independently in such areas, e.g. MERCER's (1956) study on Grinnell Glacier (62°32N, 66°51W).

Meanwhile, in the High Arctic, a group sponsored by US military agencies, starting in 1953, was attempting to understand the nature and origin of ice islands, such as Fletcher's Ice Island or T-3, by working on them and by studying the Ward Hunt Ice Shelf (83°7N, 73°30W) (CRARY, 1956).

MID-1950s TO MID-1960s

Internationalism in this period exerted a strong influence on Canadian glaciological investigations. Although the International Geophysical Year (IGY) (1957-1959) did not have a specific emphasis on such studies, it prompted some organizations to undertake new programs or to extend existing ones. Canadian participation in the IGY led to a University of Toronto Expedition to study the Salmon Glacier (56°08N, 130°04W; DOELL, 1963; HAUMANN, 1960; RUSSELL & *alii*, 1960). On Ellesmere Island, the Defense Research Board (DRB) started a program on the Gilman Glacier (82°6N, 70°37W) and took over the observations on the Ward Hunt Ice Shelf (HATTERSLEY-SMITH, 1954, 1959; LISTER, 1962; LYONS & *alii*, 1972; RAGLE & *alii*, 1964; WEBER & *alii*, 1961).

In the period immediately following the IGY, concern in Canadian government circles about security and sovereignty in the Arctic, and a lack of knowledge about that region, translated into funding for several major projects. The Geological Survey of Canada mounted Operation Franklin to map the geology of the Queen Elizabeth Islands. A consortium of McGill University professors, in conjunction with George Jacobsen, obtained a major expedition grant from the National Research Council to launch

the Jacobsen-McGill Arctic Research Expedition to Axel Heiberg Island under the direction of Fritz MÜLLER. The Department of Mines and Technical Surveys (DMTS) established the Polar Continental Shelf Project (PCSP) to organize Arctic logistics and a multi-disciplinary investigation of the continental shelf, appointing Fred Roots as its first Coordinator. The AINA received support for an expedition to Devon Island, and the DRB continued and expanded its studies on Ellesmere Island. The latter expedition, led by Geoffrey HATTERSLEY-SMITH, named Operation Hazen after the lake on which its base camp was located, later became Operation Tanquary when the camp was moved to the head of that fiord. All these activities combined to raise glaciological research in Canada to a new level and helped establish a reputation in the international scientific community that continued long after the expeditions finished.

The McGill expedition started with a small reconnaissance party in 1959, followed in 1960 and 1961 by large multi-disciplinary parties, working on glaciers in the Expedition Area (Crusoe, Baby, White [79°27N, 90°40W] and Thompson) and on Müller Ice Cap (79°54N, 90°59W; ADAMS, 1966; ANDREWS, 1964; HAVENS, 1964; HAVENS & *alii*, 1965; MÜLLER, 1961; MÜLLER 1962; MÜLLER & *alii*, 1963; REDPATH, 1965). A comprehensive list of publications arising out of this early work was included in the glacier inventory of Axel Heiberg Island (OMMANNEY, 1969).

Although principally a logistics body, provision was made within the mandate of the PCSP for the hiring of staff scientists to cover disciplines not present within the participating government departments. Stan PATERSON joined the PCSP and started working on the Meighen Ice Cap (79°57N, 99°8W). By the mid-1960s, his program on that ice cap had been expanded to include the Melville Island ice caps (75°38N, 114°) and the Devon Ice Cap (75°20N, 82°30W), taking over in the latter case from the AINA program that was winding down. The AINA program involved mass-balance and meteorological studies on the Devon Ice Cap as well as on the Sverdrup Glacier (75°41N, 83°16W; APOLLONIO, 1962; HOLMGREN, 1971; HYNDMAN, 1965; KEELER, 1964; KOERNER, 1966).

Operation Hazen on Ellesmere Island was a large multi-disciplinary investigation, similar to the McGill one on neighbouring Axel Heiberg Island. The glaciological part was concentrated on Gilman Glacier, the Ward Hunt Ice Shelf and Ward Hunt Ice Rise. It resulted in reports on glacier surveying (DORRER, 1971; FAIG, 1966), mass balance (HATTERSLEY-SMITH, 1960a, 1961; HATTERSLEY-SMITH & SERSON, 1970; SAGAR, 1964), temperatures (HATTERSLEY-SMITH, 1960b; LYONS & RAGLE, 1962), radio-echo sounding (HATTERSLEY-SMITH, 1969b) and a popular account of the work done (HATTERSLEY-SMITH, 1974). A comprehensive bibliography covering this and other work on Ellesmere Island has been published (OMMANNEY, 1982).

Further south, the Geographical Branch, another division of the Department of Mines and Technical Surveys, was continuing the work begun by the Baird expedition on the Barnes Ice Cap. Geomorphologists were intrigued by this remnant of the last Ice Age and started a major investigation to map and study evidence of Wisconsinan glaciation in the area. Included were studies of the Barnes Ice Cap itself and the small Lewis Glacier (70°26N, 74°46W) at its northern margin (ANONYMOUS, 1967; IVES, 1967, LØKEN & ANDREWS, 1966; SAGAR, 1966). Some additional observations were also made on the Penny Ice Cap (WEBER & ANDRIEUX, 1970).

Most of the expeditions described above owed much to the transportation revolution mentioned previously. In the mid-1940s, early 1950s and early 1960s, long-range aircraft acquired the trimetrogon and vertical aerial photographs that provided the first basis for really understanding the nature of vast areas of Canada. Military air-photo interpreters, returning to school as mature students after the war, and others, used their knowledge to analyze these photographs, providing the necessary preliminary information for planning major expeditions. Finally, the use of small fixed-wing aircraft equipped with low-pressure balloon tires, able to land on unprepared ground, and pilots who were willing to accede to scientists' often unreasonable requests, ensured the successful deployment of innumerable field camps in these desolate areas.

During this time of major activity in the Arctic regions of Canada, there were also significant developments on the mainland.

In 1961, the AGS and AINA jointly established the Icefield Ranges Research Project (WOOD, 1963), similar in scope and intent to the McGill and DRB expeditions. It was centred on what is now Kluane National Park and included detailed glaciological and climatological studies, particularly of Kaskawulsh Glacier (60°45N, 139°06W) and around Mount Logan. It was partly an outgrowth of the earlier U.S. Operation Snow Cornice. The results of the scientific investigations were published in four volumes by the AGS (BUSHNELL & MARCUS, *1974;* BUSHNELL & RAGLE, 1969, 1970, 1972).

Further south, in the Coast Mountains, a study in connection with a mining development was initiated on the Leduc, Frank Mackie, Berendon (56°15N, 130°05W) and Salmon glaciers by Bill MATHEWS (1964b) of the University of British Columbia. Of particular concern was the activity of the Berendon Glacier (FISHER & JONES, 1971; UNTERSTEINER & NYE, 1968). Later work here focused on the provenance of material within and on the glacier (EYLES & ROGERSON, 1977, 1978; ROGERSON & EYLES, 1979).

The number of active glaciologists around the world who had some affiliation with these early Canadian programs is very impressive.

MID-1960s TO 1990

The most important stimulus, in what might be termed the modern period, was provided by the International Hydrological Decade (IHD) (1965-1974), which led to a further expansion of glaciological studies in Canada (LØKEN, 1971; OMMANNEY, 1975). In the Cordillera, five glaciers (Place [50°25N, 122°36W], Sentinel, Woolsey [51°08, 118°], Peyto and Ram River [51°51N, 116°12W])

were selected for an east/west transect of the Cordillera, and Berendon Glacier was added to provide a link in a north-south chain. The program was run by the Glacier Section of the Geographical Branch, DMTS, the forerunner of the Snow and Ice Division of Environment Canada and now part of the National Hydrology Research Institute (NHRI) (FOGARASI & MOKIEVSKY-ZUBOK, 1978; MOKIEVSKY-ZUBOK & STANLEY, 1976a, 1976b; ØSTREM, 1966, 1973; YOUNG, 1981; YOUNG & STANLEY, 1976). Standardized mass-balance measurements followed procedures initially outlined by ØSTREM & STANLEY (1966) and subsequently refined (ØSTREM & BRUGMAN, 1991).

Decade Glacier (69°38N, 69°50W) on Baffin Island was selected as a contribution to the north-south chain in the eastern Arctic (LØKEN, 1972; ØSTREM & *alii*, 1967), which included the DRB studies on Per Ardua Glacier (81°31N, 76°27W) and the McGill studies on White and Baby glaciers (YOUNG, 1972). The effective network was much larger than the official «representative glacier basins» as existing research investigations continued or were expanded to include a larger hydrological component. Thus, in the Arctic, data continued to be collected from the Ward Hunt Ice Shelf and Ice Rise (Hattersley-Smith and Serson, 1970), Gilman Glacier, Meighen Ice Cap (ALT, 1979; ARNOLD, 1965; PATERSON, 1969), the Melville Island ice caps (PATERSON & KOERNER, 1974; SPECTOR, 1966), the Devon Ice Cap (ALT, 1978; KOERNER, 1970, 1979; KOERNER & RUSSELL, 1979), and the Barnes Ice Cap (LØKEN & SAGAR, 1968). New studies included those on an unnamed ice cap near St. Patrick Bay, Ellesmere Island (81°57N, 64°12W; BRADLEY & ENGLAND, 1977) and on Boas and Akudnirmuit glaciers, Baffin Island (67°35N, 65°14W) by the University of Colorado (WEAVER, 1975).

Elsewhere on the mainland, related studies began on Rusty or Fox (61°12N, 140°18W; CLARKE & CLASSEN, 1970; COLLINS, 1972; CROSSLEY & CLARKE, 1970), Cathedral (CIALEK, 1977; GUIGNE, 1975; MILLER, 1975) and Drummond (51°36N, 116°02W; BRUNGER & *alii*, 1967) glaciers. Many of these did not continue throughout the Decade and of the representative studies, those on Woolsey, Ram River, Berendon, Decade and Per Ardua were terminated during or at the end of the Decade. The others continued to the 1990s as part of the International Hydrological Programme (HAEBERLI & HOELZLE, 1993).

The availability of semi-permanent facilities at most of these glaciers, and core staff to maintain a measurement program throughout the summer melt season, led to the development of many other complementary glaciological investigations. The case of Peyto Glacier exemplifies this. Studies here, during and since the IHD, have included the following: cartography (SEDGWICK & HENOCH, 1975; YOUNG & ARNOLD, 1977), dendrochronology (PARKER & HENOCH, 1971), depth sounding (GOODMAN & TERROUX, 1973; HOBSON & JOBIN, 1975), instrumentation (YOUNG, 1976), hydrochemistry (COLLINS & YOUNG, 1979), hydrological modelling (DERIKX, 1973, 1975; YOUNG, 1982), mass balance and techniques (YOUNG, 1975, 1981) and meteorology (FÖHN, 1973, GOODISON, 1972a, 1972b; MUNRO, 1976; MUNRO & DAVIES, 1978; MUNRO & YOUNG, 1982; NAKAWO & YOUNG, 1982; STENNING & *alii*, 1981). The need to place these single-site observations within the larger regional context was recognized. So the studies were extended to include Yoho Glacier on the other side of the Continental Divide, and the intervening Waputik Icefield, from which both glaciers flow. By the 1990s, it had reverted to annual surveys of winter and summer balance on Peyto Glacier, complemented by occasional university collaborations (HAEBERLI & HOELZLE, 1993).

In the Coast Mountains, continuous records were maintained on Sentinel and Place glaciers, which became benchmarks for comparison with shorter-term mass-balance investigations in other parts of the range. In a move towards more applied science, most of these were closely related to the operational needs of various water-management agencies: the Bridge River glaciers for the Downton Reservoir (50°49N, 123°33W; MOKIEVSKY-ZUBOK, 1980); the Andrei, Alexander, Forrest Kerr, Natavas, and Yuri glaciers for a hydroelectric development in the Stikine and Iskut river basins (56°55N, 130°55W; FOGARASI, 1981; MOKIEVSKY-ZUBOK, 1983b); and Bench and Tiedemann glaciers for a similar study in the Homathko basin (51°20N, 125°W; MOKIEVSKY-ZUBOK, 1983a). However, the success of energy-conservation programs, an environmental ethic opposed to new dam construction, and an economic downturn caused hydro companies to reassess their options and led to the withdrawal of private-sector support for glacier-monitoring and the return to a minimum level (SCHMOK, 1990).

On the Barnes Ice Cap, the mass-balance program soon changed to one emphasizing glacier physics (CLASSEN, 1977; HOLDSWORTH, 1975; HOOKE, 1973, 1976, 1981; HOOKE & CLAUSEN, 1982; HOOKE & HUDLESTON, 1981; HOOKE & *alii*, 1979; HUDLESTON, 1980; JONES, 1972). Following cancellation of the NHRI program here, continuity was maintained for a few years by University of Minnesota studies that have now finished.

Interest in reconstructing past climates in the High Arctic led to deep ice coring on the Meighen Ice Cap, the Devon Ice Cap and the Agassiz Ice Cap (80°25N, 75°W) by the PCSP. Mass-balance investigations had been an integral part of the observations, but the focus now is really on the interpretation of the ice cores (DOAKE & *alii*, 1976; FISHER, 1979; FISHER & KOERNER, 1981; KOERNER, 1977a, 1977b, 1992; KOERNER & FISHER, 1979; KOERNER & PATERSON, 1974; KOERNER & TANAGUCHI, 1976; LICHTI-FEDEROVICH, 1975; OSWALD, 1975; PATERSON, 1968, 1976, 1977; PATERSON & CLARKE, 1978; PATERSON & *alii*, 1977; WALFORD & *alii*, 1977). In the late 1980s, the group was incorporated into the Terrain Sciences Division of the Geological Survey of Canada. It responded to budget cuts by seeking external funding to support its field work. The latest initiative in 1995 was a deep drilling on Penny Ice Cap, in collaboration with the Japanese.

McGill University continued the Axel Heiberg investigations after the 1959-1962 Jacobsen-McGill phase. When Fritz MÜLLER moved to the Geographisches Institut in Zürich, the work was largely directed from Switzerland. Many excellent research reports and papers have been written by expedition members (ALEAN & MÜLLER, 1977; ARNOLD, 1981; BRAITHWAITE, 1981; HAMBREY & MÜLLER,

1978; IKEN, 1974; MAAG, 1969; MÜLLER, 1976). Regular mass-balance observations survived into the 1990s, thanks to Trent University, making the records from White Glacier amongst the longest anywhere in the world (COGLEY & *alii*, 1995).

Changing priorities and reduced resources led to the abandonment of the Arctic glacier program of NHRI. Per Ardua Glacier, which had been handed over to this group on the termination of the DRB Operation Tanquary, was given up, as was a new project on Leffert Glacier (78°41N, 75°1W) and a shorter-term study of d'Iberville Glacier (80°26N,77°33W; HOLDSWORTH, 1977b). Some work has continued on the Ward Hunt Ice Shelf (JEFFRIES & *alii*, 1990).

In the mid-1960s, following the Glacier Mapping Symposium held in Ottawa and recommendations from the National Research Council's Subcommittee on Glaciers, the Water Survey of Canada (WSC) had switched to a program of terrestrial photogrammetry that involved mapping only the ablation areas of their glaciers every two years (REID & CHARBONNEAU, 1979a, 1979b). Snout and plaque surveys of the Athabasca and Saskatchewan glaciers were carried out in the intermediate years by the Calgary office of the WSC (CANADA, 1976). But by the 1980s, all these studies had been abandoned.

The accessibility of the Columbia Icefield (52°10N, 117°20W) and the availability of a fairly good historical sequence of observations, favoured its selection as the site for a whole variety of glaciological studies. These have included glacier chemistry (EPSTEIN & SHARP, 1959; MAYEWSKI & *alii*, 1979), glacier flow (MEIER, 1960; PATERSON, 1964, 1970; PATERSON & SAVAGE, 1963; RAYMOND, 1971; RIGSBY, 1960; SAVAGE & PATERSON, 1963), depth measurement (GOODMAN, 1975; KANASEWICH, 1963; ROSSITER & *alii*, 1973), photogrammetry (KONECNY, 1966; PATERSON, 1966; REID, 1961), resistivity (KELLER & FRISCHKNECHT, 1960), sediment transport (MATHEWS, 1964a) and temperature (PATERSON, 1971). With some encouragement from the Canadian Parks Service, this area continues to attract researchers from a variety of universities (LUCKMAN & COLENUTT. 1992).

The surge of Steele Glacier in 1966 (61°15N, 140° 11W) led to studies of its cause (BAYROCK, 1967; CLARKE & JARVIS, 1976; JARVIS & CLARKE, 1974; STANLEY, 1969), spawned an influential symposium (AMBROSE, 1969) and helped generate support for related work. Studies included Trapridge, Backe, Rusty and Donjek glaciers (61°14N, 140°20W; CLARKE, 1976; CLARKE & GOODMAN, 1975; CLASSEN & CLARKE, 1971; COLLINS, 1980; COLLINS & CLARKE, 1977; HOFFMANN & CLARKE, 1973; JARVIS & CLARKE, 1975; JOHNSON, 1972; NAROD & CLARKE, 1980), as well as the Tweedsmuir, Lowell and Walsh glaciers (59°52N, 138°19W; POST & *alii*, 1976), Otto Glacier, Ellesmere Island (81°20N, 84°15W; HATTERSLEY-SMITH, 1969a), Good Friday Bay Glacier on Axel Heiberg Island (MÜLLER, 1969), of the Barnes Ice Cap (HOLDSWORTH, 1977c), and the distribution of such features (POST, 1969). Clarke continues to maintain an active and comprehensive program on Trapridge Glacier in anticipation of its next expected surge (CLARKE & BLAKE, 1991; WADDINGTON & CLARKE, 1995).

Curiosity about the environmental effects of the large polynya known as the North Water, at the head of Baffin Bay between Greenland and Ellesmere Island, prompted F. MÜLLER to launch a major scientific program there. Although the focus was primarily on the energy exchanges, sea ice and atmospheric effects, mass-balance studies were started on Coburg Island, on Wolf Glacier, Laika Glacier and Ice Cap (75°53N, 79°9W; BERGER & MÜLLER, 1977), on Leffert and a neighbouring unnamed glacier (MÜLLER & *alii*, 1980, 1977). A popular account of this work and that on Axel Heiberg Island was also published (MÜLLER, 1981). Unfortunately, the death of the principal investigator led to the premature termination of this project before all the analyses had been completed.

Private photo-mapping and field studies by Karl Ricker have added significantly to our knowledge of recent glacier variations in the Coast Mountains. His studies extend from the St. Elias Range, through the Hazelton Mountains, the Pacific Ranges, the Chilcotin Ranges, the Elaho Range, the Clendenning Range and the Lillooet Ranges to Garibaldi Provincial Park, where he has collaborated with Bill Tupper of the B.C. Institute of Technology (HAEBERLI & MÜLLER, 1988; RICKER & TUPPER, 1992; RICKER & *alii*, 1983).

As small glaciers are expected to respond quite rapidly to changes in climate, a welcome addition to the Canadian program was the study of four glaciers in Labrador (58°57N, 63°47W) sponsored by Memorial University (ROGERSON, 1986). This investigation continued for several years until the provincial agency, that was providing logistic support, moved to a different area.

Two other studies in the Yukon should also be mentioned. Holdsworth has established part of the recent climate history of the southwest Yukon,through analysis of an ice core from the summit of Mount Logan (HOLDSWORTH, 1977a; HOLDSWORTH & *alii*, 1992). The drilling of a second core to verify the results was not supported and the program was terminated in one of the first rounds of budget cuts in the late 1980s. University of Ottawa staff and students have investigated the glacier hydrology of the Grizzly Creek neighbourhood and debris- and moraine-covered ice masses there (JOHNSON, 1976, 1992).

Today, there are few groups or individuals still involved in glacier research in Canada. Within the Federal Government, the National Hydrology Research Institute carries out a very limited program on three glaciers in the Cordillera, and the GSC continues its ice-core/climate program in the High Arctic. Yukon is the primary field area for scientists from the universities of British Columbia and Ottawa, and the University of Victoria has recently begun studies on Vancouver Island. Glaciologists are also on the staff of the Universities of Alberta and Western Ontario, though their primary field sites are in Europe. The coverage is thin, support weak and the continuity of the few long-term observation sites is very much in jeopardy. There is no commitment to any kind of national monitoring program. Recent budget cuts have severely curtailed the Cordilleran studies.

With the gradual elimination of operational budgets for the government groups that do remain, priorities are being dictated by those organizations willing to help fund the field programs; often these are not even Canadian and the national interest or need is not a motive. Regrettably, Canada will becoming increasingly less able to assess the nature and consequences of changes to her frozen water resources, especially in terms of hydro-power development, water supply, hazards and rising sea level. Of particular concern to the community of scientists attempting to address international questions about the effects of climate change, she will not be able to contribute data on her share of the Earth system to the global commons.

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