Annals of Glaciology 8 1986

MAPPING CANADA'S GLACIERS SINCE 1965

by

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ABSTRACT

The extent and nature of Canadian glacier mapping since 1965 is traced, from snout surveys to high-order, large-scale maps, Swiss-style publications and stereo-orthophoto maps. Many maps were produced during the IHD for specific tasks, such as the determination of mass balance, plotting of isolines, etc; most were multi-coloured, with scales ranging from 1:5000 to 1:25 000. Subsequent developments have been with cartographic techniques (e.g. orthophoto maps) and in support of individual projects.

INTRODUCTION

The first Symposium on Glacier Mapping, held in Ottawa in 1965 at the instigation of the Photogrammetric Research Section of the National Research Council of Canada (PRC-NRCC) and organized by the NRCC Subcommittee on Glaciers under the chairmanship of G. Hattersley-Smith, demonstrated the remarkable progress made in Canadian glacier mapping during the previous ten years. Papers by Blachut and Müller, Konecny, Arnold, and Paterson in 1966, highlighted these developments. The most influential agency was the PRC-NRCC, whose first contributions were maps of the Salmon Glacier (1:25 000, with contour interval of 20 m) and its snout (1:12 500/20 m), in British Columbia (Haumann 1960). In the High Arctic, collaborating with the Jacobsen-McGill University Arctic Research Expedition to Axel Heiberg Island, N.W.T., they had produced maps of the Thompson Glacier Region (1:25 000/25 m), White Glacier (1:10 000/10 m), and the snouts of Crusoe, Baby, Thompson, and White glaciers (1:5000/5 m). Copies of these maps were included with the report by Müller (1963). The Department of Surveying Engineering at the University of New Brunswick was another major contributor, assisting in the work of the Water Survey of Canada in the Rockies (Konecny 1966) and the Defence Research Board, on Ellesmere Island (Faig 1966).

This paper discusses some of the mapping activity which has taken place in Canada following that first Symposium.

INTERNATIONAL HYDROLOGICAL DECADE MAPS

The International Hydrological Decade (IHD) was the major stimulus for glacier mapping in Canada during the 1960's. This activity included both small- and large-scale maps.

1:1 000 000 Glacier Maps of Canada:

Canada had already initiated a programme of small-scale glacier mapping prior to the 1965 Symposium. The decision to map glaciers at 1:1 000 000 arose from the Geographical Branch's need for small-scale maps, accurately depicting the distribution of glaciers and suitable for planning glaciological research. Glaciers were delineated with heavy, ink lines on the best-available maps in 1965 and reduced to the common scale (Falconer and others 1966, Henoch and Stanley 1969). The three maps of the Cordillera show glaciers in purple on a white background, whereas, on the four Arctic maps, glaciers are white on a brown background. They have been used for plotting glaciation levels, equilibrium lines, ice-cored moraines, transient snow-lines, glacier mass balance, etc. (Østrem 1966, 1973; Østrem and Arnold 1970; Miller and others 1975), as base maps for the 4th National Atlas of Canada (in particular the map of Lakes, Rivers, and Glaciers (Fremlin and Mindak 1968), and in schools.

Glacier Atlas of Canada, 1:500 000

Detailed information on all Canadian glaciers is being compiled through a glacier inventory. The region, basin, and individual glacier codes are provided to users through a Glacier Atlas of Canada. Modified 1:250 000 National Topographic Series (NTS) maps form the basis for the four-colour plates. Glaciers appear in a blue vignette within their hydrological basins and the maps are bordered in brown (Ommanney 1980). The series was used in compiling the base map (1:2 000 000) for the new 5th edition of the National Atlas of Canada (now being published in individual sheets at 1:7 500 000 or smaller), on which glaciers are shown with a light, purple vignette. The glacier numbers are used by glaciologists, geologists, and mountaineers, etc., for referencing unnamed glaciers and have been incorporated into the national, toponymic data base.

Large-scale IHD Glacier Maps:

Canadian participation in the IHD included mass-balance investigations on several glaciers in Western Canada and the North, for which metric maps at a scale of 1:10 000, with 10 m contours, were required for plotting the data. Those of the Berendon, Place, and Sentinel glaciers were printed in four colours; the maps of Ram River and Wolsey glaciers were embellished with shaded relief. The Peyto Glacier map is discussed below. Two maps were made of Per Ardua Glacier, Ellesmere Island, by Konecny (1966): the whole glacier (1:2 000/10 m) and its tongue (1:5000/5 m). Maps of the Barnes Ice Cap were prepared by the Surveys and Mapping Branch, either as Arctic Provisional Maps (1:50 000/25 ft), or as standard NTS maps (1:50 000/50 ft).

The original intent was to re-map all IHD glaciers after ten years, to compare the accumulated mass balance with photogrammetrically-determined volumetric change. Unfortunately, this has not been done.

WATER SURVEY OF CANADA

From 1945 onwards, the Water Survey of Canada (WSC) had been carrying out surveys of glacier snouts and movement. Konecny (1966) reported on a test of aerial and terrestrial photogrammetric surveys of the Athabasca Glacier, which led to the adoption of terrestrial photogrammetry for future biennial glacier surveys of the Athabasca and Saskatchewan glaciers in Alberta (1963 to 1979) and the Bugaboo, Kokanee. Sentinel, Sphinx and Nadahini glaciers in British Columbia (1964 to 1978). Reid (1972) has discussed the procedures used. Maps were plotted at scales of 1:10 000 to 1:2500, with contours at 5 to 10 m on the ice, depending on glacier size. The biennial volumetric changes were calculated and the maps and results published (Kite and Reid 1977, Reid and Charbonneau 1980, 1981). The map styles vary, but generally solid blue is used for ice and blue stipple for snow, with blue line contours on the glaciers; brown or grey is used off the glacier. Unfortunately, only the exposed ice of the ablation area was mapped. All surveys had been terminated by 1980.

MISCELLANEOUS GLACIER MAPS

Many individual glaciological projects require accurate maps for plotting results and determining changes in the glaciers. A variety of line maps of different glaciers has been produced in support of such projects.

On Axel Heiberg Island, N.W.T., an experiment in the use of terrestrial photogrammetry for the determination of mass balance by Arnold (1981), led to a map of the lowest 2 km of White Glacier (1:2500/5 m). On Ellesmere Island, the snout of d'Iberville Glacier was mapped (1:50 000), to measure displacement values of a tidal glacier (G. Holdsworth unpublished report).

Steele Glacier, which surged during the Yukon Centennial Expedition of 1967, was mapped from 1951 and 1967 aerial photography (1:50 000/25 m; 1:25 000/20 m).

Other surging glaciers in the Yukon and Northern British Columbia have attracted attention. The Army Survey Establishment compiled a map of Rusty Glacier (1:10 000/10 m). In 1983, Nadir Mapping Corporation prepared a map of Trapridge Glacier (1:10 000/10 m) for G.K.C. Clarke. Two maps of Tweedsmuir Glacier (1:50 000/20 m), pre- and post-surge, were made from 1951 aerial and 1974 terrestrial photography, the former being published in three colours. Finally, a three-colour map of Lowell Glacier (1:50 000/20 m) with moraine shading was prepared from the 1974 photography in anticipation of a surge, which took place in the spring of 1983.

The Foundation for Glacier and Environmental Research, in collaboration with the Technical University of Hannover, has included mapping with its other studies of Cathedral Glacier near Atlin (1:5000/5 m). A map of the summit of Mount Logan, with hachured bedrock and relief shading (1:10 000/20 m), was constructed to determine flow fields for a deep drilling by the Glaciology Division.

A joint project between the B.C. Institute of Technology and K. Ricker, resulted in a map of Wedgemount Glacier (1:5000/10 m) to be used for determinations of mass balance and glacier variation.

One of the finest North American examples of the cartographer's art is the commemorative Mount Kennedy map (1:31 680/100 ft) produced by the National Geographic Society, with field surveys by the University of New Brunswick (Washburn 1971). Originally constructed in metric units, it was later reduced into English units! The two-colour map, with hachured bedrock and plastic shading, is a visual delight.

PEYTO GLACIER AND COLUMBIA ICEFIELD

In 1970, a map of Peyto Glacier, Alberta (1:10 000/10 m), was published in nine colours, using the French technique of bedrock portrayal (Sedgwick and Henoch 1970). Subsequently, it was decided to experiment with the enhancement of this map, to create a three-dimensional visual effect using the Swiss technique of hachured bedrock portrayal and shaded relief (Henoch and Croizet 1976). The resulting map, published in 1975 at the same scale as the original edition, was printed in eight colours and accompanied by an explanatory booklet with the ensemble designed to cater to the scientist, teacher, and general public.

Following the success of the Peyto Glacier map, it was decided to experiment with a larger glaciological unit and a smaller scale, though continuing to apply the same cartographic techniques. The Columbia Icefield was selected for a joint project with Parks Canada in 1976. In 1981, a ten-colour map with hachured bedrock portrayal, shaded relief, and interpretive information on the reverse, was published (1:50 000/20 m). A part (about ⅛) of this map is enclosed, as a sample, to show the cartographic technique used in the printing of this kind of glacier map.

ORTHOPHOTO MAPS

Blachut and Müller (1966) concluded in 1965 that the orthophoto map would probably find extensive use in glaciological work. Canadian experience has shown a trend towards this, although few of the resultant maps have been published or widely distributed. The focus has been mainly on testing the mapping techniques in glacierized and mountainous areas. Once again PRS-NRCC has been a pioneer (Blachut and van Wijk 1976), producing stereo-orthophoto maps of Axel Heiberg Island glaciers, in collaboration with Environment Canada and the Technical Universities of Vienna and Zürich: White Glacier (1:10 000/20 m), Thompson Glacier and White Glacier Snouts, Crusoe Glacier Snout and Baby Glacier (1:5000/10 m). To the east, a map of Oobloyah Bay (1:25 000/25 m) was prepared as a base map for the 1978 Heidelberg-Ellesmere Island Expedition (Hell 1981).

In Western Canada, the B.C. Institute of Technology compiled a map of Wedgemount Glacier (1:10 000/20 m) and Mount Waddington (1:50 000/50 m). A stereo-orthophoto map of Peyto Glacier (1:10 000) was prepared, as part of a pilot study for the Forest Management Institute. Environment Canada, by Gestalt International Ltd. Contours were not plotted on the map, but elevation data were analyzed from the digital, terrain model which was a by-product of the stereo construction process (Young and Arnold 1977). The Gestalt system was further tested in the construction of three maps of the Columbia Icefield (1:25 000) by the Surveys and Mapping Branch for the Glaciology Division, using 1977 photography (Athabasca Glacier, Saskatchewan Glacier, Athabasca and Saskatchewan Glaciers). A larger-scale map of Athabasca Glacier (1:5000), based on 1980 photography, was produced for the latter agency by Orthoshop of Calgary as part of a study of photogrammetric applications to mass-balance measurements, which was never completed.

SATELLITE MAPPING

While the future technology for glacier mapping in 1965 appeared to be the orthophoto map, derived from aerial photographs, that for the coming decade is now likely to be based on satellite images, as Robin (1966) had foreseen. Significant improvements in resolution, combined with a stereo and all-weather capability, make this technology increasingly viable. The Surveys and Mapping Branch is using LANDSAT images to revise their 1:250 000 NTS maps (Gregory and Moore to be published). Experiments have been carried out on the viability of using existing images to update glaciological information (Howarth and Ommanney 1983) and the full range of applications will be documented in the forthcoming Satellite Image Atlas of Glaciers.

CONCLUSION

One of the most fruitful collaborations has been that between Professor F. Müller of the McGill University Axel Heiberg Island expedition and the PRC-NRCC. This resulted in large-scale, topographic maps and stereo-orthophoto maps of several of the island's glaciers. Another productive relationship has been that of Professor G. Konecny of the University of New Brunswick, with the Defence Research Board, the Water Survey of Canada, and the National Geographic Society. The role of the Glaciology Division in the production of large-scale glacier maps of the five western IHD representative-glacier basins, of specialty maps of Peyto Glacier and the Columbia Icefield, and more recently of orthophoto maps, has also been significant.

Unfortunately, none of the above institutions are still involved in any glacier mapping activity and the Glaciology Division has been disbanded. Glacier mapping activity in Canada is limited to a few small projects, where the product is unlikely to be published or widely distributed and this trend is likely to continue. Students and teachers alike may well regret the loss of this valuable teaching aid. However, financial resources for producing high-quality, multi-coloured, large-scale maps are no longer readily available. The only possible exception may be Parks Canada, with a large tourist clientele from whom costs might be recovered.

With the proliferation of personal computers and growth in their memory capability, the future may see much greater use of digital, terrain models by individual glaciologists. Optical disks will permit the storing, exchange and analysis of photographic and cartographic information, so that the printed thematic map may become a collector's item.

We know that the next generation of satellites will be capable of providing greatly improved and more current information on glaciers. The technology for analysis of this information, using PC's, is also developing rapidly.

Although the heyday of the printed glacier map may be passed in Canada, there are exciting prospects and challenges ahead in computerized mapping, analysis, and remote sensing.

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https://doi.org/10.3189/S0260305500001300 Published online by Cambridge University Press