

## SYMPOSIUM ON GLACIER MAPPING OTTAWA, CANADA, 20-22 SEPTEMBER 1965

THE Symposium on Glacier Mapping, which was held in Ottawa, Canada, on 20-22 September 1965, was sponsored jointly by the Sub-Committee on Glaciers of the National Research Council and the Commission of Snow and Ice of the International Association of Scientific Hydrology. Dr. G. Hattersley-Smith and his Canadian colleagues were responsible for the local organization and they are to be congratulated on their fruitful efforts. The proceedings of the Symposium, including the discussion, which was recorded, are to be published as a special issue of the *Canadian Journal of Earth Sciences*.

Some 90 people attended; half were from Canada, a fair proportion from the United States, and the rest from England, Germany, France, Peru, Switzerland and the U.S.S.R. Many disciplines such as cartography, photogrammetry, geology, geography, glaciology, geophysics, hydrology and remote sensing were represented and they led to useful and instructive discussions.

The participants were welcomed by Dr. Howlett, Director of the Division of Applied Physics of the National Research Council. Dr. Mark Meier, as one of the Vice-Presidents of the Commission of Snow and Ice, gave the opening address, illustrated the problems of glacier mapping by his own experiences and drew special attention to modern remote sensing techniques. This address, the following paper by Dr. Valter Schytt on the purpose of glacier mapping and the next critical yet constructive paper by Dr. T. J. Blachut and Dr. Fritz Müller established the general patterns of thought for the rest of the Symposium. Discussions following these three presentations made it clear that there were three *lignes de force*—a group pressing for inventory type of mapping in relation to the programme of the International Hydrological Decade, another interested mainly in the detailed technical problems of mapping, and another concerned with presenting every kind of glaciological data in the greatest detail on maps. All groups agreed, however, that the cartographer and the glaciologist needed to co-operate much more closely in the future in order to appreciate each other's problems in producing satisfactory maps.

Over 20 papers were presented in three days and there was adequate time for discussion after each presentation.

Continuing with the first day's proceedings, Dr. M. G. Marcus and Miss Karen Ewing (University of Michigan) drew particular attention to the problems of symbolization on glacier maps, problems that were encountered by Fritz Müller and Peter Kasser in their outstanding maps of the Axel Heiberg and Aletsch glaciers and which arise whenever maps are used for storing and displaying research data at regular intervals of time in all field sciences. They reminded us, as Colonel Helk did later, that the principal purpose of a map was to re-create selectively the landscape, or to give a picture of the surface. They also drew attention to the growing use of computer-controlled plotting machines and the likelihood that much of the growing volume of quantitative information would never leave the machines as maps but remain stored as coded symbols on tapes.

Colonel Helk of Dansk Geodætisk Institut spoke of the formidable task his small country faced in compiling an accurate map of Greenland and its ice cap to serve as a basis for glaciological measurements. The northern third of the island was still imprecisely mapped. The mere 25 lines which expeditions had drawn across the ice with tremendous efforts were only very thin threads in a vast desert, from which he would hate to make a map, and moreover he warned us against drawing conclusions about the ice on such weak foundations. He was clearly sympathetic to glaciological interests, but awaited the day, not too distant, when modern automated techniques were sufficiently developed to ease his task.

Professor R. Chevallier presented a factual paper prepared by the French Institut Géographique National on the series of three aerial photographic maps of the Mont Blanc massif, made to a scale of 1:10,000 in 1939, 1952 and 1958. Observations on snout positions of several glaciers, on changes in surface elevation and on the velocities of the Mer de Glace deduced from ogive movement were given.

Ing. W. Kick (West Germany), following in the footsteps of the Finsterwalders, gave us a beautifully illustrated talk of his practical experiences in mapping the long-term variations of glaciers in the Himalaya and in Norway by terrestrial photogrammetry. We were pleased to see the successive maps printed of the Chogo Lungma Glacier and of Tunsbergdalsbre.

No less than five old students were present of the Finsterwalder school, which had pioneered terrestrial photogrammetry of glaciers, two of them, Dörrer and Reinwarth, being on their way to

Antarctica with the U.S. expedition. At the close of the meeting it was agreed that if possible the Proceedings should be dedicated to the memory of the late Richard Finsterwalder.

Another of R. Finsterwalder's old students, Dr. G. Konecny (New Brunswick University) presented his experiences with photogrammetric and electronic surveys of the Athabaska, Saskatchewan, Per Ardua and Otto-Fjord (Ellesmere Island) Glaciers, of the Ward Hunt Ice Shelf, of parts of several Alaskan glaciers and of Mount Kennedy. He clearly had a large fund of recent experiences with terrestrial and aerial photogrammetry and of the use of electronic surveying instruments under a variety of conditions. He drew special attention to the high and variable cost of existing glacier maps and of the need to use the most economical methods in order to complete the great task that lies ahead.

Unfortunately, on account of the Allelein glacier incident in Switzerland which Professor R. Haefeli described to us, Peter Kasser could not be present to open the meeting on the second day. His paper with Hans Röthlisberger on their problems in preparing the recent map of the Aletschgletscher was presented by Fritz Müller, who had been closely associated with the field work. He stressed the great difficulties and expense they encountered in establishing and maintaining on foot the artificial glacier markers for the aerial survey. Dr. Østrem later told us how he had overcome this problem during the mapping of Jostedalsbre by dropping hundreds of paper packets of powdered ochre from small low-flying aircraft immediately ahead of the photographic plane. His success seemed to be the result of careful planning and a share of good luck with the weather.

The Aletsch mapping again brought out the difficulties of defining precisely a glacier boundary when it is confused with dead ice, moraine or fresh snow. This problem needs an arbitrary decision with international agreement.

Mark Meier (U.S. Geological Survey) related some of the interpretations that could be made from his re-mapping of the South Cascade, Nisqually and Klawatti Glaciers. Readers will already know some of this important work from publications in the *Journal*. He drew attention to the problems of attaining sufficient accuracy in elevations from vertical aerial photographs of steep glaciers and to the orthophoto map. The latter is an interesting development in photogrammetric technique which he thought was of considerable value in glacier mapping. The map is virtually a large photograph, accurately rectified, and produced by a machine that automatically eliminates the effects of relief and camera tilt.

William O. Field (American Geographical Society) gave an illustrated summary of his extensive series of records of the variations of glacier termini in southern Alaska, which have been carried out at frequent intervals by simple and inexpensive ground surveys and photographs since 1931. He emphasized the need to co-ordinate this type of work and to document the records for future use.

G. Petrie and R. J. Price (Glasgow University) were interested in the use of photogrammetry for both glaciological and geomorphological purposes and presented their experiences in using topographical plotting equipment of second-order accuracy in mapping the changes in the Casement Glacier and its surroundings in Alaska from photographs taken in 1948 and 1962 with very little ground control. A fortuitous pattern of sea inlets provided level control. In their view, periodic surveys of a large number of glaciers can only be accomplished in a reasonable time and economically by using the topographical plotting machines which are much more widely available than the high precision machines that some photogrammetrists consider necessary for glacier mapping.

Mr. Doudin from the Soviet Embassy presented the paper by his Russian colleagues, Professor Avsyuk, Dr. Vinogradov and Miss Kravtsova, which gave a survey of the extent of the glacier mapping programme in their country. Three types of maps are being pursued. On the general topographical maps at scales ranging from 1:25,000 to 1:100,000 conventional glacier symbols are steadily being introduced and it has been necessary to get co-operation with glaciologists to obtain correct interpretation of the field data. The most recent maps of this type cover the T'ien-shan, the polar Urals, El'brus and the coastal belt of East Antarctica. Special glaciological maps are being produced in association with field research and will cover Zemlya Frantsa-Iosifa and El'brus. These maps apparently include all kinds of glaciological data and from their description seem to be more comprehensive than those produced so far in other countries. In the case of El'brus and the Antarctic special atlases are being compiled.

It was a great pity that no Soviet maps were included in the display of glaciological maps arranged at the Symposium, but we certainly look forward to seeing them as soon as they become available.

Professor A. J. Brandenburger gave a brief account of the extensive programme of glacier surveying carried out by Ohio State University. It included maps of many Alaskan glaciers, several in the western

United States and the Ice Field Ranges, Yukon Territory. Aerial photogrammetric measurements of ice motion on Byrd Glacier and on a line between "Byrd" station and the Whitmore Mountains in Antarctica were also reported. Both of the latter projects involve aerial triangulation and standard errors of  $\pm 3$  m. and  $\pm 5$  m. respectively were claimed. The maximum speed of Byrd Glacier proved to be 2.3 m. per day. The second measurement from "Byrd" station is to be made this season.

Professor R. Haefeli (Switzerland) opened the third day's meeting by recalling the various maps that had been prepared of the Unteraargletscher since 1842 and interpreting several features of its behaviour. He also had some interesting deductions about the ogives and the ice motion of the Aletschgletscher following its recent detailed mapping.

Professor R. P. Goldthwait (Ohio State University) then gave an account of a re-survey of the ice cliff in Nunatarssuaq (North Greenland) and a reinterpretation of its behaviour.

Dr. A. O. Poulin (U.S. Cold Regions Research and Engineering Laboratory) and Mr. T. A. Harwood (Defence Research Board, Ottawa) showed us some fascinating comparisons between conventional aerial photographs and infrared thermal imagery of Arctic ice features such as frozen lakes and the Ward Hunt Ice Shelf. The potential value was clearly demonstrated of thermal views taken in the dark for estimating surface temperatures of ice and snow masses, thickness of ice over water and possibly hidden crevasses.

Mr. A. H. Waite (U.S. Army Electronics Laboratory) described the recent developments and astonishing achievements in radio sounding of ice thicknesses. He reported reflections from cold ice as thick as 3,000 metres and seemed confident that the thickest ice in the world could be sounded with little modification. Plans to carry out rapid aerial radar surveys of surface and bottom ice contours in Greenland and later in Antarctica were announced.

An even more enterprising proposal was made by Dr. Gordon Robin (Scott Polar Research Institute). He wanted to put a radio altimeter in a satellite on a polar orbit to obtain an altitude map of the surface and the bottom of the Antarctic ice sheet and claimed that the cost would be a fraction of that of any other survey method. The economics of the alternative projects in the Antarctic need serious and unbiased consideration before either project is mounted.

During the early stages of the Symposium at the suggestion of the meeting, a small *ad hoc* committee was formed to crystallize the needs and implications of the discussions. The committee consisted of Dr. M. F. Meier, Dr. V. Schytt, Dr. F. Müller, Dr. G. Hattersley-Smith and the writer. They drafted a series of resolutions, which, after amendment, were finally adopted at the closing session. These resolutions are given below.

W. H. WARD  
Secretary, Commission of Snow and Ice

Resolutions adopted by the Symposium on Glacier Mapping of the IUGG-IASH Commission on Snow and Ice, 20-22 September 1965.

The Symposium on Glacier Mapping, sponsored by the IUGG-IASH Commission on Snow and Ice, in Ottawa, 20-22 September 1965, adopted the following resolutions, and requests the Commission to take appropriate further action to implement these resolutions.

1. The Symposium recognizes the value of the resolution, adopted by the Council for the IHD, on a World Inventory of Perennial and Annual Snow and Ice Masses. The Symposium recommends that the Commission urge UNESCO to encourage the member states to support glacier mapping activities that are an integral and necessary part of this IHD programme, and recommends that these mapping activities include: (a) small-scale maps, showing the distribution of glaciers, from which total glacier areas can be determined; (b) larger-scale contour maps of as many glaciers as possible in representative areas drawn with sufficient accuracy for valid comparisons of mass changes, at intervals of about ten years. For all maps, the date, means of survey, and accuracy should be specified, and glaciers should be included with (but differentiated from) other masses of snow and ice which persist for more than one year.

2. The Symposium strongly emphasizes the need for detailed, large-scale glaciological maps of representative glaciers, including their complete drainage basins, particularly for the purposes of the study of the glacier-climate relationship as part of the IHD programme, and as a necessary background for many other scientific and technological programmes associated with glaciers. A scale 1:10,000 or larger is desirable.

3. Considering the importance in some areas of glaciers as water resources, as elements of attraction or danger to mankind, and as elements in the natural environment, the Symposium recognizes the great need for proper delineation of glaciers on maps of standard topographical series, and urges government agencies responsible for topographical surveys and international organizations such as UNESCO to pay special attention to the continually changing forms of glaciers and the proper distinction between glaciers and ephemeral or persistent snow masses.

4. The Symposium recommends that the Commission consider the formation of a Committee on Glacier Mapping to have a continuing responsibility to investigate, promote the study of, and report on new techniques for glacier mapping and other ways to record and present spatically distributed glaciological information. This Committee should work in liaison with other groups in similar fields.

5. The Symposium calls to the attention of the Commission the need for (a) a manual on glacier mapping; (b) a standardization of symbols on glacier maps; (c) preparation of recommendations for international exchange of glaciological maps and data, especially those relating to international programmes such as the IHD.

6. The Symposium on Glacier Mapping requests the Subcommittee on Glaciers, National Research Council of Canada, to explore means of giving suitable recognition to Sebastian and Richard Finsterwalder in the Proceedings of the Symposium.

7. The Symposium recognizes the great value of bringing photogrammetrists, cartographers, glaciologists, and other interested persons together for these discussions, and expresses its gratitude to the National Research Council of Canada and to the Organizing Committee.