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REVIEW

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THE first international Symposium on Glacier Mapping was held in Ottawa from 20 to 22 September 1965. This special issue of the *Canadian Journal of Earth Sciences* contains 19 papers, of which 18 were presented at the symposium.

It was not by chance that Canada issued the invitation to this symposium: the centre of glacier mapping has shifted during the last 20 years—at least quantitatively—to the New World; and a new centre of glacier research was developed at the National Research Council in Ottawa under T. J. Blachut. The roots can easily be traced back to Europe. They proceed from Germany and from Switzerland. This fact is well known in North America, and due honour was rendered during the symposium, and again in this publication in the introductory paper by G. Hattersley-Smith which is dedicated mainly to the pioneer work of Sebastian and Richard Finsterwalder.

Geodetic glaciology was one of the first fields where photogrammetric methods were tried with success. Glacier mapping today means photogrammetric mapping. With photogrammetry glacier survey progressed from terrestrial to aerial photogrammetry. At the glacier, the two methods are in competition, and the problem of their relative rationale and suitability is one of the present major issues in geodetic glacier research.

The Ottawa papers can be loosely classified in four groups, the titles of which could run as follows:

(1) Purpose and value of glacier maps;
(2) Terrestrial photogrammetry in glaciology;
(3) Glacier mapping with aerial photogrammetry;
(4) Special methods in glacier survey.

To the first group belongs the opening paper by V. Schytt (Sweden), "The purpose of glacier mapping". The topographic map has special significance in glaciology in that glaciers undergo constant changes, caused by climatic variations. There is no better way of measuring glacier variations, as changes in length, area, altitude and volume, than by repeated mapping of the glacier on an appropriate scale. But as a single glacier only has limited significance in a major climatic region, standardized mapping of typical glaciers, systematically distributed over the whole earth, becomes an essential.

The extent to which the U.S.S.R., as one of the leading nations in glaciology, participates in this task is shown in the report of G. A. Avsyuk, O. N. Vinogradov and V. I. Kravtsova on "Experience in glaciological mapping of ice sheets and mountain glaciers". The centralized production of these maps guarantees their consistency in scale and content. It leads to such excellent results as the newly published *Atlas Antarktiki* [*Atlas of the Antarctic*] (Moscow, Glavnoye Upravleniye Geodezii i Kartografii, 1966).

In their paper "Cartographic representation and symbolization in glacier mapping" K. J. Ewing and M. G. Marcus (U.S.A.) try, somewhat unconvincingly, to determine the degree of standardization already obtained in glacier mapping by statistical evaluation of over 200 maps.

M. F. Meier (U.S.A.) rightly points out in his paper on "Some glaciological interpretations of remapping programs on South Cascade, Nisqually, and Klawatti Glaciers, Washington" that repeated glacier mapping indicates changes in volume and altitude but provides no data on the mass balance (ablation, accumulation)—a fact which is still often overlooked by one-sided geodesists. Therefore topographic survey should always be combined with physical studies.

On the other hand, R. Haefeli (Switzerland) shows in his paper "Some notes on glacier mapping and ice movement" with examples from the Unteraar and Aletsch glaciers that careful plotting of all phenomena at the glacier surface can give qualitative and quantitative information on the movement of a glacier.

To the second group belongs the report by W. O. Field (U.S.A.) on "Mapping glacier termini in southern Alaska, 1931–1964". Though the annual position of the ice margins is determined partly by photography, the determination of the state of a glacier by marginal variations dates from the early stages of glaciology. Nevertheless, corresponding series of observations are carried out even to this day in Switzerland and Austria. In a region as inaccessible as southern Alaska the method still provides initial criteria.

The practice of terrestrial-photogrammetric glacier survey is described in the contributions of W. Kick (Germany) and G. Konecny (now Canada, formerly Germany), both pupils of Finsterwalder's school. In his paper "Measuring and mapping of glacier variations" Kick describes the whole scope of terrestrial photogrammetry including photogrammetric speed measurements with examples from the Himalaya and Norway. Konecny goes still further with his "Applications of photogrammetry to surveys of glaciers in Canada and Alaska". He shows how the establishing of ground control can be accelerated and rationalized by the use of electronic distance measuring instruments. Also, he compares terrestrial and aerial surveys; in his view, the latter have no decisive advantages on account of their high cost. However, here (as in the other contributions) the essential difference between the two methods in surveying techniques is not mentioned: namely, that the accuracy of the plotting of terrestrial-photogrammetric surveys decreases with the square of the distance from the survey station, whereas aerial survey yields a practically homogeneous plotting accuracy.

The third and largest group of contributions deals with the employment of aerial photogrammetry in glacier mapping. This was initiated by the Swiss school, and reached its first culmination with the survey for the 1 : 10,000 map of the Aletschgletscher in 1957. P. Kasser and H. Röthlisberger report on this in "Some problems of glacier mapping experienced with the 1 : 10,000 map of the Aletsch Glacier". The problem of gaining sufficient contrast in monotonous firn fields was solved by dropping soot bombs. Cartographically, an exemplary presentation of the glacier, its marginal features and the surrounding mountains was attained.

Another example of gaining contrast on the firn areas of Jostedalsbreen is described by G. Østrem (Norway) in his paper "Surface coloring of glaciers for air photography".

One of the collaborators in the Aletsch survey was F. Müller. It is, therefore, not surprising that he strove for glacier maps of the same quality as the basis for his glaciological studies of Axel Heiberg Island (organized from Canada). He succeeded in the survey and in the production of maps in collaboration with the National Research Council of Canada. The principles employed are reported in T. J. Blachut and F. Müller, "Some fundamental considerations on glacier mapping". The questions of scale and accuracy, and above all of the cartographic representation of all features at the glacier surface are considered; the last-named requires close collaboration between cartographer and glaciologist. The result, the 1 : 10,000 map of the White Glacier, contains such a multitude of details that the pattern of contour lines almost disappears in comparison. Blachut goes still further in this direction, with his remarkable proposal to employ orthophotoscopic methods in glacier mapping, thereby preserving the abundance of glaciological information obtained by air photographs.

The remaining contributions on glacier mapping with aerial photogrammetry have the nature of reports on completed or current field work: A. J. Brandenberger and C. Bull (U.S.A.), "Glacier surveying and mapping program of the Ohio State University" (from Alaska down to "Byrd" station in Antarctica); J. V. Helk (Denmark), "Glacier mapping in Greenland" (for which region until recently only small-scale maps have been available); K. C. Arnold (Canada), "The glaciological maps of Meighen Island, N.W.T.", with 3 maps (in the Arctic Archipelago); G. Petrie and R. J. Price (England), "Photogrammetric measure-

ments of the ice wastage and morphological changes near the Casement Glacier, Alaska", with 2 maps; W. S. B. Paterson (Canada), "Test of contour accuracy on a photogrammetric map of Athabasca Glacier" (showing good agreement between the actual error in elevation and the theoretical).

The fourth group of contributions does not deal with glacier mapping in the strict sense but with methods for the determination of glaciologically significant values and factors.

A. O. Poulin (U.S.A.) and T. A. Harwood (Canada) give in their paper on "Infrared mapping of thermal anomalies in glaciers" impressive examples of the locating of subglacial melt water with thermal imagery.

From the report by A. H. Waite, Jr. (U.S.A.), "International experiments in glacier sounding, 1963 and 1964" (northern Greenland) it can be concluded that radio echo sounding has attained the accuracy of seismic methods and will soon supersede the latter because of its greater simplicity.

Finally, G. de Q. Robin (England) presents an interesting and most promising proposal for "Mapping the Antarctic ice sheet by satellite altimetry". A satellite in polar orbit should survey radioaltimetric profiles of the Antarctic continent with a longitudinal interval of $0 \cdot 5°$. Robin estimates the attainable accuracy to be ± 50 m. International collaboration should render possible the realization of this by no means utopian project in the not too distant future.

Apart from their general significance, the 19 papers contain an abundance of detailed information on glaciers in all latitudes and continents which is an inexhaustible treasury for the glaciologist but leads the geodesist almost to despair of the task of surveying and depicting all those phenomena. Nevertheless, the 14 maps in the accompanying folder prove that glacier maps of great cartographic elegance with an astonishing amount of glaciological information can be produced. Their different styles show the need for a classification which was not clearly expressed during the proceedings of the symposium itself, a fact which caused some confusion in the resolutions: the distinction between glacier maps and glaciological working maps. Products of the quality of the Aletschgletscher or White Glacier maps will continue to be exceptional phenomena in the future. But for the purpose of topographic glaciology simple, one- or two-coloured contour maps whose scale should not fall below 1 : 10,000 are completely sufficient.

The Ottawa symposium gave a complete survey of the present state of glacier mapping. This publication makes the survey available to all those who are concerned with this subject but did not have the opportunity to attend at Ottawa.

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