was written especially for the map by the late Dr. François E. Matthes, whose interest and enthusiasm did much to stimulate the project. His death in late June brought a sense of great personal loss to those who had enjoyed the privilege of working with him. A very complete description of the glacier, by Weldon F. Heald, Director of the original survey, follows the foreword. Both texts emphasize the need for glacial observation, as well as the value of glacial surveys and maps for information which will lead to increasingly accurate and earlier forecasts of changes in climate.

Folded copies of the map, inserted in envelopes to fit and suitably backed by cardboard, are obtainable at one dollar a copy, postpaid, from the American Alpine Club Research Fund, 113 East 90th Street, New York 28, N. Y.

9. STATUS REPORT OF GLACIOLOGICAL WORK ON THE SEWARD ICE FIELD, YUKON TERRITORY

ROBERT P. SHARP, *Director*

[Professor Sharp is a member of the Department of Geological Sciences, California Institute of Technology. As a recently elected member of this Club, he joins that distinguished group of scientists—Le Conte, Matthes, Chamberlin, to name a few—whose work in mountain geography has reflected increasing credit on the Club. As our activities focus more significantly upon research and on our enhanced understanding of the scientific aspects of our sport, it will be through the leadership of men like Bob Sharp that we shall succeed in guiding our work to the profit of mankind, without diminishing the personal gratification which our sport provides us.—
WALTER A. WOOD]

Thanks to generous support from the American Alpine Club Research Fund, the Office of Naval Research, the Arctic Institute of North America, and the California Institute of Technology, our group was able to capitalize upon the excellent opportunity for glaciological research offered by Walter Wood's "Project Snow Cornice." The glaciological party, consisting of Maynard M. Miller, George P. Rigsby, Bernard O. Steenson, F. Beach Leighton and R. P. Sharp, ventured forth with high hopes, ambitious plans, and much equipment. The fact that some of the high hopes and ambitious plans failed to materialize during the summer on the Seward Ice Field was disappointing but not surprising. It must be recognized that the summer's work was well worth while if for nothing more than the information it provided as to what can and should be done in the way of future glacier studies in this area.

Some aspects of American glaciological research have kept apace of foreign advances through the efforts of Max Demorest and François Matthes, now both deceased, and a small group of zealous workers. However, we have never had on this continent a program comparable to that of Ahlmann and his associates in the North Atlantic or to that of the British Jungfraujoch Research Group and the Swiss investigators in the Alps. It will not be possible to catch up with foreign glaciological programs in one, two, or perhaps even ten field seasons, but it is our hope that "Project Snow Cornice" will give birth to a generation of vigorous glaciologists with the training, drive and enthusiasm to give North American glaciers the treatment they deserve and to bring our work up to the same level as that carried on in Europe. This should be recorded as one of the objectives of the present project, and the American Alpine Club is playing an important role in furthering American glaciological research through the activities of its members and by its financial support.

A large part of the 1948 program was designed to obtain as much information as possible on the physical properties of ice and firn in the Seward Ice Field. We were interested in determining the temperature regimen of the firn, not only for comparison with other areas, but because it is an expression of the environment and geophysical condition of this ice field. In order to record temperatures at various depths, a number of holes were "bored" into the firn by means of an electrically heated hotpoint activated by a gas-engine generator. A maximum depth of 204 feet was attained by these thermal borings, and a greater depth could easily have been reached if additional drill pipe and cable had been available. Temperatures were measured by means of thermohms (resistance coils) and a specially calibrated Wheatstone bridge kindly loaned by the National Bureau of Standards and previously used by F. Alton Wade in Antarctica and Greenland. Twelve thermohms were set in the firn at depths ranging from 3 feet 5 inches to 204 feet. All temperatures recorded were essentially at zero degrees Centigrade. In other words, by mid-July the firn mass was isothermal—that is, essentially at the pressure melting temperature—to at least a depth of 204 feet. This was somewhat disappointing, as we had hoped to catch a remnant of the winter's cold wave in the firn and to trace its dissipation as the season progressed. However, the fact that the firn of the Seward Ice Field was isothermal by mid-July is a worthy discovery in its own right. This is a surprisingly early date for such a condition to be attained and is an expression of the unexpectedly temperate summer environment of the area—if the conditions of 1948 are at all representative.

A total of 193 density determinations were made in the firn, mostly in a shaft 50 feet deep excavated at the so-called airstrip station about three miles west of the base of Mount Vancouver. Densities ranged from 0.50 at the surface to 0.85 at a depth of 50 feet, with blue ice bands within the firn having densities close to 0.90. The minimum density of 0.46 was measured at a depth of 4.5 feet in a firn layer just below an ice band. Low density layers below ice bands were characteristic to a depth of about 11 feet, and this relation supports the concept that refreezing of descending melt-water has much to do with increasing the density of firn and converting it to glacier ice. The undulating upper surface of ice bands in the firn and their horizontal structure, which was clearly co-extensive with layering in the firn, also suggest that the ice bands grew principally by refreezing of descending melt-waters. The existence of densities as high as 0.50 at the surface shows that the winter's snow can be converted to firn, density 0.45 or greater, within a period of only a few months in this environment.

In addition to the many blue ice bands, we were impressed with the numerous roughly cylindrical, vertical, pipe-like masses of coarsely crystalline blue ice in the firn, which we christened "firn pipes" as a field designation. A typical firn pipe extends downward for several feet, has a diameter of 5 to 10 inches, and usually ends abruptly at an ice band. Some firn pipes extend downward from ice bands or serve to connect two ice layers, and a few extend without interruption through ice bands. Firn pipes appear on the surface of the ice field as small rounded knobs a few inches high. It seems that the pipes must mark the channels of melt-water circulation through the firn, but why they are so regular and pipe-like is still not clear. It is also possible that exudation of water vapor from the firn may have something to do with their development and growth, but this thesis is not too highly regarded.

The amount and mode of melt-water circulation in the firn has been recognized as highly significant in many glacier areas, but it appears to be especially important here because of the abundance of melt-water. The studies of melt-water behavior in 1948 suffered from the fact that our melt-water pans were poorly adapted to the conditions existing on the Seward Ice Field. Our efforts might be described as a "dry run" if one can use such terminology in connection with studies of melt-water. The results obtained, although of only relative value, are intriguing. Specific layers in the firn made water at rates up to 300 cc. per hour for a pan of 1439 cm^2. Layers between 4 and 10 feet beneath the surface carried the most water, and only small amounts were collected at depths greater than 10 feet. Most puzzling was the frequent shift in major water flow from one layer to another without apparent rhyme or reason. When we know the reason for this, we shall know a lot more about the internal constitution of firn fields and the changes produced in them by circulating melt-waters.

Another significant matter in connection with melt-water was the discovery of standing water in crevasses at depths between 60 and 70 feet. This, plus the behavior of the thermal boring apparatus at and below 65 feet, suggests that the entire Seward Ice Field may be saturated with water at a depth of 60 to 70 feet, or in other words has a ground water table at about that level. This is probably too deep to be affected by the winter's freeze, so the Seward Ice Field may harbor a great year-round reservoir of water available to anyone who cares to use it.

Pits dug in the firn near the airstrip station showed two faint dirty bands thought to represent the summer layers for 1946 and 1947. If this interpretation is correct, the excess of accumulation over ablation at this locality was 17.5 to 18 inches of water in 1946-1947. Preliminary data indicate the excess of accumulation for 1947-1948 to be about 23.5 inches.

Ablation, primarily by melting, at this same locality totaled 27 inches in 39 days between mid-July and late August. Elsewhere on the ice field, melting of 16 to 17 inches of firn per month during July and August was recorded. Daily ablation ranged between the extremes of zero and 1.5 inches in areas away from the complicating influence of bedrock exposures. No ablation occurred between 22 and 29 August, so the ablation period may have come to an end by that time. Water equivalents for the above figures may be obtained by halving them, as the average density of the melted firn was close to 0.50.

Attempts to make short-period observations of ice movement in valley glaciers came to naught as the glacier observed moved too slowly, about 6 inches a day, to permit the type of analysis desired. This was not entirely fruitless, however, as it demonstrated that surveying instruments have a diurnal period large enough to produce the anomalous effect of making a glacier appear to move up the valley at certain times of the day. Needless to say, such results drive the glaciologists to a point of distraction. A method of reference to fixed points on the far side of the glacier's valley was devised, and in 1949 study of the more rapidly flowing Seward Glacier will be attempted.

Bernard Steenson's work with radar as a means of determining ice thickness gave promising, but as yet unconfirmed, results. A reasonable transverse profile was obtained by radar soundings across a small valley glacier on the west slope of Mount Vancouver. The greatest depth of ice sounded in this profile was 700 feet. Dr. T. D. Northwood, of the Canadian National Research Council, working with acoustical apparatus, confirmed within reasonable limits of error the radar results at one station, but time and other conditions did not permit confirmation of the entire radar profile. A seismic party representing the Canadian National Research Council also operated in the region but experienced difficulty in getting sufficient energy into the ice and was further handicapped by old and unsatisfactory equipment.

Among other matters investigated were free-water contents of various firn layers, the relative movement of crevasse walls, differential ice movement within the Seward Ice Field, size of ice crystals in the Malaspina Glacier, rate of ablation on the Malaspina Glacier, and bedrock geology as exposed on nunataks and rocky ridges around the edges of the Seward Ice Field.

We plan to return to this area in 1949 with a more definitely focused program of investigation. It is hoped that Dr. Henri Bader will join the group to make crystallographic and petrofabric studies

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LEFT: USING A 50-FOOT LADDER
Investigation of englacial conditions in the crevasses at the 5700-foot level of the Seward Glacier

RIGHT: SIX-FOOT "FIRN PIPES"
Excavated from the névé near the Seward Glacier airstrip camp
Photos, M. M. Miller

on the Malaspina Glacier and possibly also on the Seward Ice Field. An extension of the radar studies is planned, and all efforts are being bent toward the procurement of satisfactory seismic equipment with which to confirm the radar results and to carry out a series of profiles across the Seward Ice Field, as well as on the Malaspina Glacier if the logistics of access to the Malaspina can be solved. We shall redesign apparatus and carry out further studies on temperatures, densities, structures, melt-water circulation, and free-water content in the firn. Glacier movement observations will be made in more satisfactory locations. More data on accumulations and ablation will be gathered; and, if proper personnel can be obtained, studies of micrometeorology will be made. We hope to correct some of our mistakes of the past summer and to cash in on preliminary data and information gathered so far.

10. STUDIES OF ICE TEMPERATURES OF SWISS BERGSCHRUNDS, 1948

JOEL E. FISHER, *Director*

In 1939 T. P. Hughes and Gerald Seligman published data on the below-freezing temperature of the ice of the Sphinx Plateau (about 3600 m.) on the Jungfraujoch.[1] Noting that this ice is *above* the bergschrund, and aligning the data with the voluminous observations of temperatures of névé or glacier ice on many glaciers below their bergschrunds—temperatures always found to be exactly the local pressure melting point— I concluded[2] that the bergschrund marks a boundary: below the bergschrund, the temperature of the ice or névé is at the local pressure melting point; above the bergschrund, the temperature of the ice or névé is below the melting point. Since some friends of mine questioned whether the Sphinx Plateau observations alone constituted sufficient basis for such a conclusion, I made observations in September 1948 during a stay at Zermatt:

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[1] "The temperature, melt water movement, and density increase in the *névé* of an Alpine glacier," Monthly Notices of the Royal Astronomical Society, Geophysical Supplement, IV (1939), 631-2 [Publication No. 2 of the Jungfraujoch Research Party, 1938].

[2] "The Pressure Melting Point of Ice and the Excavation of Cirques and Valley Steps by Glaciers," *A.A.J.*, VII (1948), 67-72.

MICHAEL'S SWORD
A meta-volcanic spire on the Juneau Ice Field
Photo, W. R. Latady and M. M. Miller

491

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CONTENTS

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