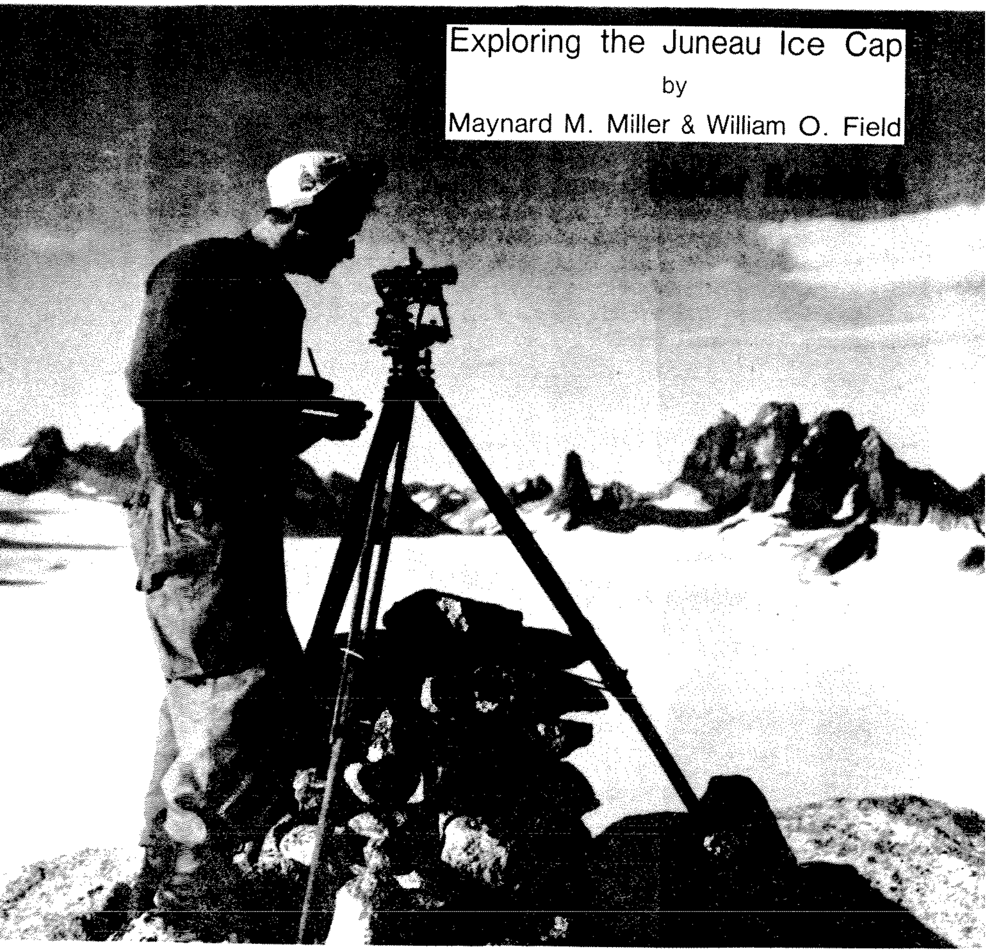
OFFICE OF NAVAL RESEARCH • APRIL 1951

RESEARCH REVIEWS



NAVEXOS P-510

DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

FOR OFFICIAL USE ONLY

COVER PHOTO: This scientist is carrying out mapping operations from a so-called "triangulation station", one mile up in the Juneau Ice Field. Ten miles away, on the eastern edge of the Ice Field, Devil's Paw, an elevation of 8,584 feet, is visible. This photograph, taken by Zach Stewart, illustrates only one phase of the extensive work being carried out on the glaciers of this region by ONR investigators. The article on pp. 7 to 15 of this month's issue tells more about their work.

Reprinted from

RESEARCH REVIEWS

APRIL 1951

Exploring the Juneau Ice Cap

by

Maynard M. Miller, Columbia University
and
William O. Field, American Geographical Society

OFFICE OF NAVAL RESEARCH

DEPARTMENT OF THE NAVY WASHINGTON, D. C.

Exploring the Juneau Ice Cap

by

Maynard M. Miller, Columbia University
and
William O. Field, American Geographical Society

For the past few decades glaciological research in the Alps and Scandinavia has consisted of intensive studies on certain glaciers where comprehensive observations could be carried out systematically over a period of years. Because of the complexities involved the trend has been to study one or two glaciers exhaustively rather than to conduct cursory examinations of many. Closely related with the shift to greater concentration has been a realization that, in order to achieve useful results, studies of snow and ice and related glaciation require close cooperation between a number of different scientific disciplines. Professor Hans W:son Ahlmann, the eminent Swedish glacier expert, has stated: "To serve its aims, glaciology must in future be founded in the first place on physics, mechanics, crystallography and meteorology, and must belong to the complex of sciences that in certain countries goes by the name of geophysics".

It is natural that such investigations should have originated among the glaciers of the Alps and the Scandinavian Mountains which are relatively close to centers of population and therefore exert a considerable influence on the economic life of these areas. On the other hand, in North America glaciers have usually been considered as rather remote phenomena, and the motivation to study them as a feature of our immediate environment has been largely absent. As a result, most of our studies have been spasmodic and have been carried out either by individuals on a summer vacation basis, by occasional small parties from scientific institutions, or by Geological Survey parties as a minor adjunct to other investigations and mapping activities.

Despite this handicap, a considerable amount of data has been accumulated in the past three-quarters of a century. It is largely confined, however, to descriptive observations of the lower portions of the glaciers, to short-term variations of glacier termini, and to the geomorphological aspects of glacial erosion and deposition. Prior to 1948, few if any, worthwhile observations in North America had been made of regimen (that is, the relationship between water accumulation and dissipation) or of the conditions prevailing in the areas of accumulation in upper parts of any glaciers. This is not for lack of direction or the

---

Maynard M. Miller, now a candidate for a doctorate at Columbia University, has been the leader of a number of expeditions into the mountainous and glacial sections of Alaska. He received degrees in the geological sciences from Harvard and Columbia and has published several papers on his research.

William O. Field is Head of the Field Research Section of the American Geographical Society and Chairman of the Committee on Glaciers of the American Geophysical Union. For many years he has made detailed observations on glacier fluctuations in Alaska and other parts of the world.

realization of need, but rather it has been due to the difficult operational problems posed by such undertakings--the relative inaccessibility of study areas, increased expense, the need for mountain-trained personnel, and the involved logistics.

Yet in recent years several factors have made possible the extension of detailed glaciologic studies in the Western Hemisphere. These are: (1) the stimulation offered by the leadership and experience of British, Swiss, and Scandinavian scientists; (2) the development of, and recent improvements in, aerial photography and techniques of aerial supply; (3) increased interest in the scientific exploration and study of alpine and arctic areas in the Western Hemisphere; and (4) newly available financial support, equipment, and logistic assistance from interested Government agencies.

It is not a coincidence, therefore, that two independent but closely cooperative projects for high-level observations were initiated in Alaska and the Yukon in 1948. The Arctic Institute of North America's project, "Snow Cornice", chose for its area of operation the Seward-Malaspina Glacier System on both sides of the international boundary in the St. Elias Mountains. The American Geographical Society selected the smaller but more accessible glacier system, some 250 miles to the southeast, composed approximately of 700 square miles of central névé and outward-flowing glaciers in the highlands of the Coast Range north and east of the city of Juneau. The area is shown in the map, Figure 1. Most of these outward-flowing glaciers are named, and the big central névé from which each takes its rise has long been known locally, but unofficially, as the Juneau Ice Field or Ice Cap. Thus the name of the Juneau Ice Field Research Project was chosen to describe the program

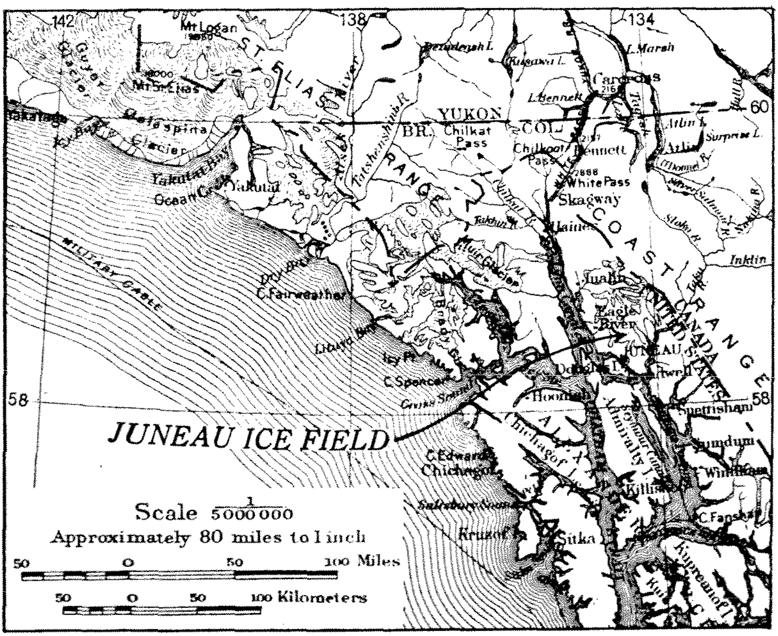


Figure 1. The Juneau Ice Field (scale 1:5,000,000)

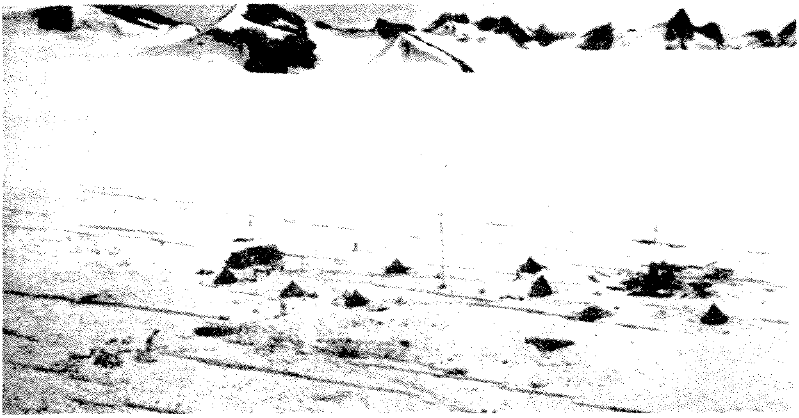


Figure 2. Aerial view of the main ice study camp on Taku Glacier (1950). View west toward a portion of the upper névé.

of study in the névé area and on the individual glaciers radiating from it. To date, the high-level work has been conducted primarily on the Taku and Twin Glaciers, the former being the largest of the outward-flowing ice streams. Studies have also been carried on in and near the terminal areas of many other glaciers in the vicinity.

In 1948 six men conducted a four-week reconnaissance to work out routes of approach, establish camps, determine supply needs, and initiate a few long-term scientific observations. The following year, a full season was spent studying the glaciers at both high and low levels, during which a total of 24 persons took part in the program. A small research station was built at a 400-foot elevation on a rock island 16 miles above the terminus of Taku Glacier, and a network of a dozen camps was established over an area of some 400 square miles. The program of observations begun the year before was continued and greatly expanded. It was further extended in the summer of 1950 by another full field season in which a total of 19 operating personnel and scientific advisors, as well as 12 visitors, took part in the ground program. Figures 2, 3 and 4 show the installations which had been established by this time.

In 1948 substantial airlift was provided by the U.S. Navy Medium Patrol Squadron Four, then engaged in a photographic aerial survey of Southeastern Alaska. The following year, the project was carried out under a Task Order of the Office of Naval Research. Through the Research and Development Board further valuable assistance was provided by other branches of the National Military Establishment. In 1949 and 1950 the U.S. Navy and the Air Force 10th Rescue Squadron provided air support, while supplies and equipment were made available by the Quartermaster Corps, Signal Corps, Corps of Engineers, and Air Materiel Command. Personnel were assigned to the meteorological program by the Arctic Weather Central of the Air Weather Service. Civilian agencies, both government and private, also furnished support and facilities, among them the U.S. Forest Service, the Arctic Institute of North America, the Geological Society of America, the Weather Bureau, the Blue Hill and Mount Washington Observatories, the University of

Minnesota, and the U.S. Geological Survey. Stanford Research Institute, the E.J. Longyear Company, and the Eastman Oil Well Survey Co. aided respectively in seismic investigations, in core drilling for ice samples at depth, and in instrumental determination of englacial rates of ice flow.

The basic glaciological aims of the program have been to study external and internal characteristics of this glacier system, the meteorological conditions which influence it, and the variations in length and volume of the outflowing glaciers. A meteorological record was maintained at two stations during the 1949 and 1950 field seasons, as well as for

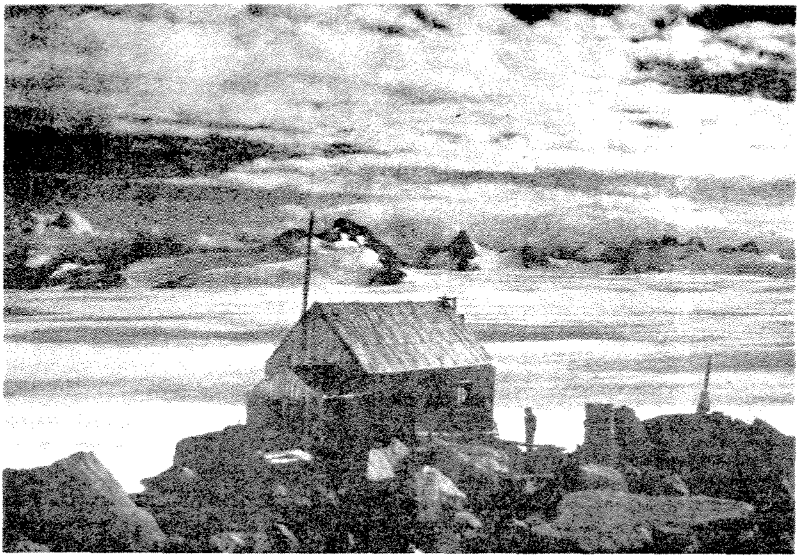


Figure 3. Research station at 4,000-foot elevation on a rock island above the névé of Taku Glacier, 16 miles above its terminus (1950). The lower Taku Glacier is shown at left and the head of the Norris Glacier is visible at right center.

shorter periods at four outlying camps. Glacio-meteorological data was also obtained on the surface of the upper Taku and Twin Glaciers, including observations and instrumental records of solar radiation.

These accumulated data are being analyzed and correlated with the records from the nearby lower-altitude weather stations at such points as Juneau and Annex Creek, immediately adjacent to the ice field on the west and south, and with those obtained in past years at four other nearby stations to the north and east. Closely connected with these meteorological data are periodic observations of short-term changes near the surface of the glacier at selected localities; and determination of surface accumulation and ablation and the position of the late summer névé or firn line during the three years of operation. Instrumental measurements have been made of glacier surface movement at different places both above and below the névé line. Several of these lines of measurement are along profiles where the thickness of the glacier has been determined by geophysical means. Efforts are being made to obtain a vertical velocity profile as well as to provide an answer to the fundamental question of whether ice in such a glacier as the Taku moves faster at depth than at the surface and if so why. This has been a significant unknown in the effort to calculate the volume of ice being transferred from the upper glacier to the area of wastage nearer sea level. Eventually it should be possible to determine the approximate net accumulation and net wastage from which one could then theoretically calculate the volume transfer of ice along any specific line where the depth of ice is known. This, it is hoped, will permit a more accurate interpretation and comparison of the average rates of flow of such glaciers as a whole with their measured rates at the surface.

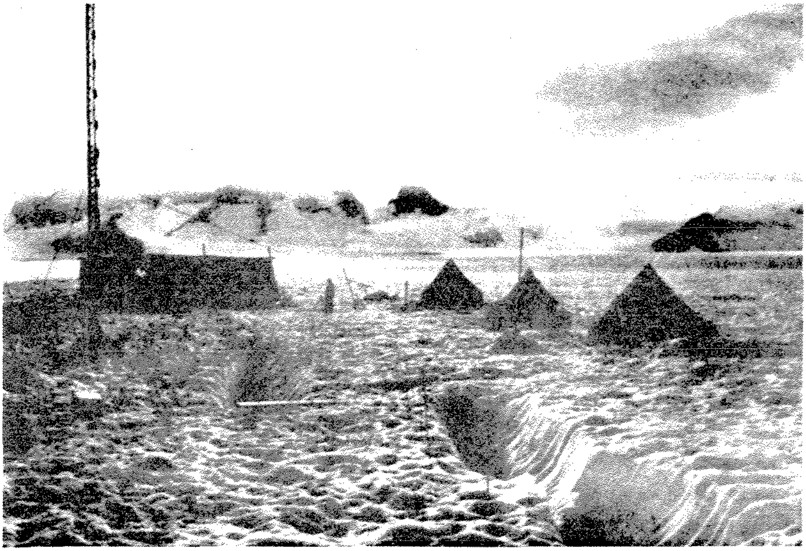


Figure 4. Main camp on upper Taku Glacier (1950). The 40-foot mast at left has metal-sheathed thermistors (radiation reflectors) to record in 1/100 °C the micro-meteorological temperature profile immediately above the surface of the névé.

Studies within the Taku glacier were carried out during 1949 and 1950 and are still underway, to determine the structure and physical properties of winter snowfall, of summer névé, and of the underlying crystalline ice at different seasons of the year. Crevasses have been used to penetrate surface layers of névé for detailed observations of ice banding, snow density, melt-water circulation, and crystal structure, at depths down to 60 feet (Figure 5). In 1949 a team from Stanford Research Institute, under the leadership of Dr. Thomas C. Poulter, using a Unitized Portable Seismograph (Figure 6), determined the thickness of Taku glacier along four related profiles, 2, 11, 13, and 16 miles above the terminus. At these, the maximum thicknesses of ice recorded were respectively 1378, 1033, 1534, and 1144 feet.

In 1950 the E. J. Longyear Company provided a rotary Pioneer Straitline Core Drill, shown in Figure 7, to bore holes for the purpose of obtaining ice cores for crystallographic and petrofabric study. In addition, a string of electric thermocouples and several hundred feet of 2″ I.D. aluminum pipe were to be inserted in different drill holes in the glacier for later determinations of temperature at depth and the vertical velocity profile of ice flow. It appears, however, that the depth attained (about 292 feet) is not sufficient to provide more than a partial answer to the problem of subsurface ice motion. Further experimentation with either a modified rotary drill or an electrical "hot point" drilling equipment yet to be devised, will be needed to reach a greater depth and to obtain all of the information desired.

As an adjunct to these studies, control points for detailed mapping have been established in various parts of the study area. This will greatly aid in determining the main topographical features and drainage patterns, and in the pursuit of further scientific work and the testing of equipment and field techniques in this region.

Systematic studies of the variations in length and volume of these glaciers have also been made. At the termini, the work of earlier observers was continued and more exact measurements of the age of moraines were accomplished by means of age counts on trees and on other forms of vegetation. Dr. Donald B. Lawrence of the Department of Botany, University of Minnesota, carried out this work in 1949 - 1950. He has attempted to relate the glacier oscillations to known variations in solar radiation during the past 600 years. His findings indicate that in the middle of the eighteenth century all these glaciers were more advanced than during a number of previous centuries and that considerable net recession has since occurred. Although the general over-all pattern in Alaska is ice shrinkage, two of the glaciers from the Juneau Ice Field have had re-advances which have been observed. The Norris exhibited a minor advance for about a decade which culminated about 1915, and the Taku, since about 1900, has advanced some 3-1/2 miles. It may be that regimen studies can disclose the basic causes for this most interesting and paradoxical phenomenon and thus shed light on other related problems facing glaciologists. At higher elevations botanists have been studying plant life on the nunataks and ridges to help in determining details of the lowering which has recently occurred in the surface level of the ice field. The geologists also have made observations on the manner of rock weathering on recently deglaciated terrain and on geologic factors pointing to the existence of isolated expanses of bedrock during the most recently expanded major stage of Pleistocene glaciation. At the termini, further

Figure 5. This photograph, made last August, shows scientists taking samples of névé in a pit dug at one of the glacier camps. Determinations will be made of density, liquid water content and other properties of samples. Tubes and funnels protruding from wall recesses in the pit represent melt-water collection pans used to determine rates of water percolation downward.

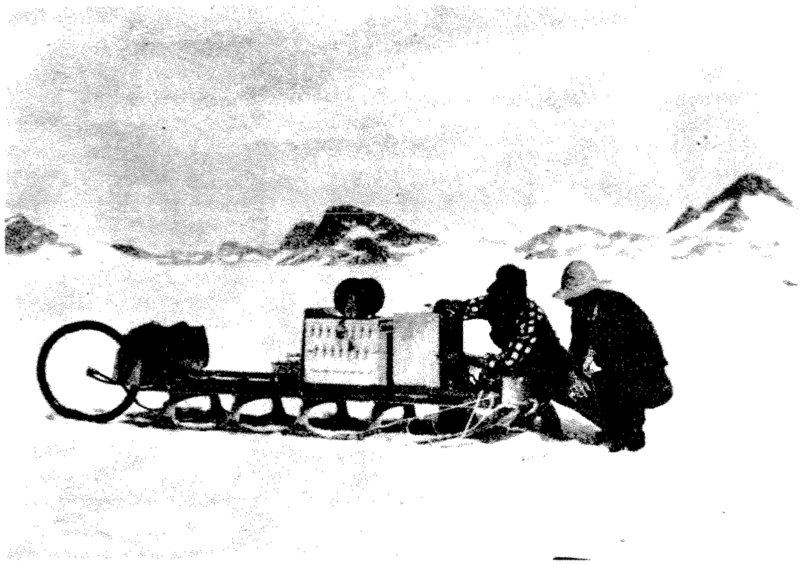


Figure 6. Stanford scientists making depth soundings in upper Taku Glacier. Maximum thickness of 1534 feet was recorded.

mapping and photography have been undertaken to determine changes in their position and the resulting modifications in landform. Such observations have long been made, and established photographic and survey stations exist which have been occupied periodically for comparative data over a number of decades.

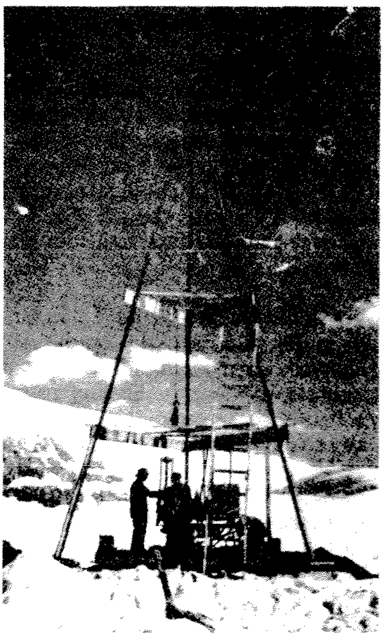


Figure 7. Drill Rig set up at the main camp on upper Taku Glacier, 1950. Cores were obtained to a depth of nearly 300 feet.

In addition to purely glaciological investigations, studies have also been carried out on bedrock geology to determine the origin and nature of the rocks of the area and their relation to the geologic structure of this portion of the Coast Range. The project has also provided an opportunity for studying logistics, testing equipment, and working out field procedures for an operation of this kind. Training personnel to live and work effectively in such an environment has also been accomplished. In three field seasons, 36 different individuals have spent considerable time encamped on the glacier or on the rocks immediately

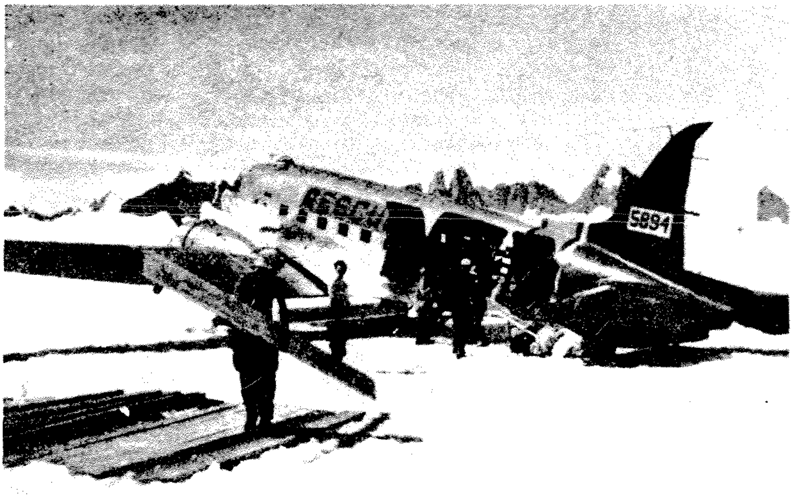


Figure 8. Supplies being unloaded from the Air Force 10th Rescue Squadron ski-wheel C-47 aircraft at the airstrip camp on the upper Taku Glacier, July 1950.

above it, and have learned the problems of "housekeeping", traveling, and working on such terrain. Experience in carrying out arctic field work has been gained by these men, 20 of whom were at the time graduate or undergraduate students in scientific fields. At the same time the project has afforded an opportunity to both Air Force and Navy air crews to work on air lift and air supply problems of an unusual nature. A ski-wheel C-47 of the Air Force 10th Rescue Squadron (Figure 8) has accomplished 22 landings and jet-assisted take-offs on the upper Taku Glacier.

To date the project has made considerable progress toward the assembly of significant quantitative data for this glacier system, but a great deal still remains to be accomplished. Many years are required to obtain a mean result and to gain a true picture of regimen and prevailing meteorological conditions. During the last two years conditions have varied enormously from an unusually heavy accumulation of snow in the winter of 1948-49 to a subnormal accumulation in 1949-50. The ensuing ablation seasons have probably increased the departure from the normal, so that the 1948-49 accumulation-ablation budget year appears to have been strongly positive and the succeeding one negative. The mean presumably lies somewhere between, but only additional yearly data can disclose its fullest quantitative relationship.

The significance of this project in relation to other glaciological undertakings must be considered. Except for Project "Snow Cornice" it represents the only large-scale systematic study now underway in a névé area in the Western Hemisphere. We must realize that although the general scientific picture will unfold more slowly than we might wish, our main concern must be to amass useful data on a sound and considered basis. Other such projects, we hope, will soon be initiated elsewhere, especially on representative glacier systems in Alaska and British Columbia, and further south in the United States, as well as beyond the equator in the high mountains of South America.

In the meantime, studies of the variations in the terminal portions of the glaciers all along the Western Cordillera, in the interior and coast ranges, from California and Colorado to western and northern Alaska must be evaluated and their relationships established. At this time there is perhaps as much desk work required as there is need for careful and comprehensive field investigations. Particular attention must be paid to systematic classification, collation of all data now existent in published and unpublished reports and photographs, and an analysis and correlation of this data. Nor should we forget that while our immediate concern may be regional, the broader aspects require that the results of studies in one area should be compared with those in other parts of the world. Interchange of information to bridge distance and language barriers is essential if the broader aspects of glaciology, especially those dealing with the relationships of glacier variations to climatic change, are to be adequately understood.

The present glaciological program is thus divided roughly into three parts. First is the concentrated, systematic, and well integrated observations as represented by the Juneau Ice Field Research Project. Second come the still useful though more general and cursory observations of glacier termini on a continental, hemispheric, or even world-wide basis, to determine their over-all characteristics and to record comparative variations and other attendant phenomena. Third is the desk work which must bring together and correlate the results of past and current studies, and provide the means of cooperation and liaison between disciplines and between glaciologists and other scientists whose contributions may also help, not only in our own country but in various other parts of the world. Only by such a well-rounded program can we hope to begin to understand the physical character of glaciers, their meaning, their use to man, and their influence on him, as well as their potential role as registrars of past and future climatic change.

Because we are living at a time when both Antarctica and Greenland are still in an Ice Age and some glaciers in other parts of the world are advancing amid general conditions favoring recession, we have a unique opportunity of studying this interesting and important feature of our planet. The answer to some of the most complex problems of glaciology, such as the mechanics of ice flow and the exact relationship of glacier variation to climatic change may well be found, or at least suggested, in the detailed study of one glacier or a single glacier system and the external factors which influence their regimen. From the glaciological point of view this is the objective of the Juneau Ice Field Research Project. The task cannot be accomplished in one or two seasons but will require a long period of time as well as the continued cooperation of many individuals and organizations. We believe that a significant and useful beginning has been made, however, and that such studies are proving of considerable value in the development of glaciology as well as in the general problem of living and operating in, near, and over areas of perennial snow and ice.

938404 O - 51 - 3