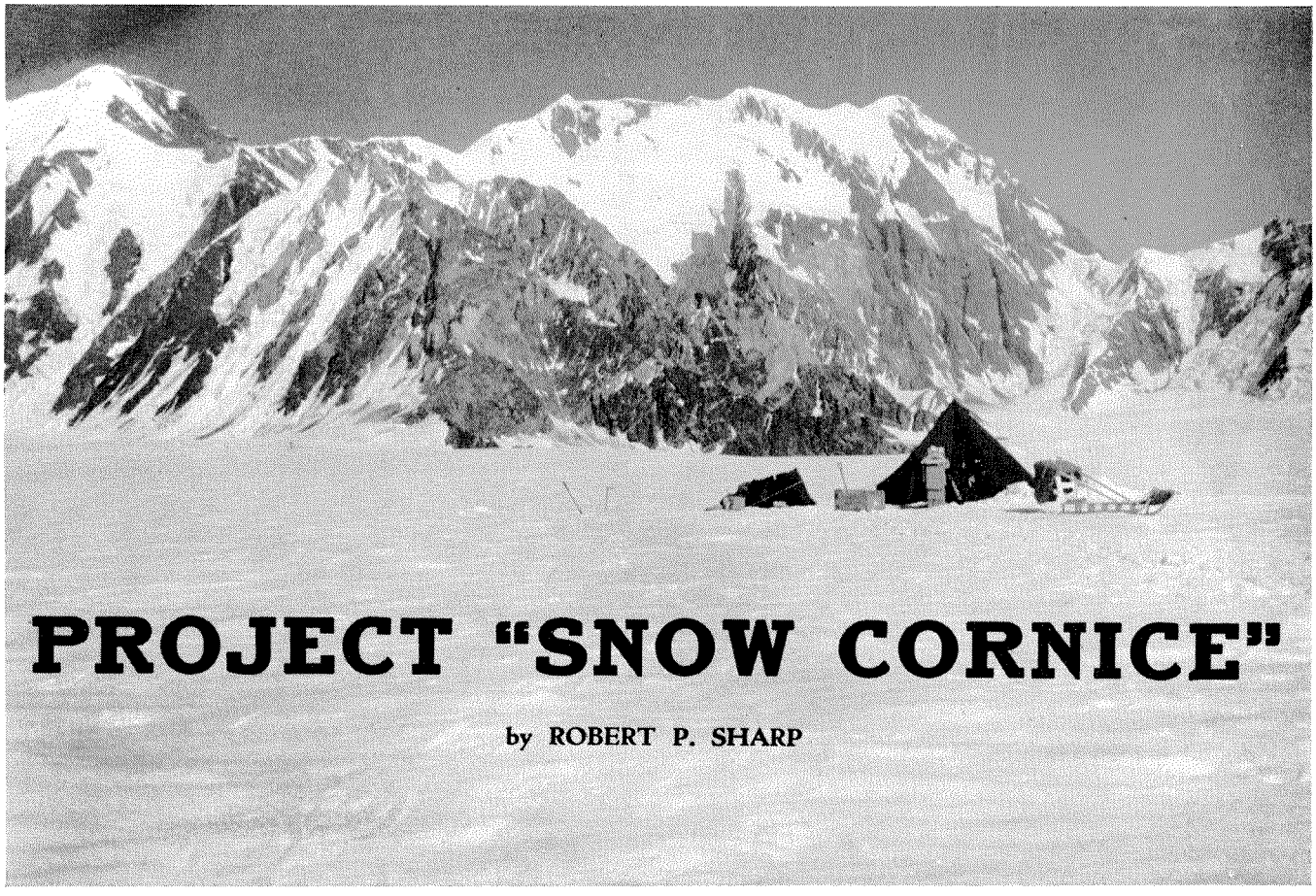
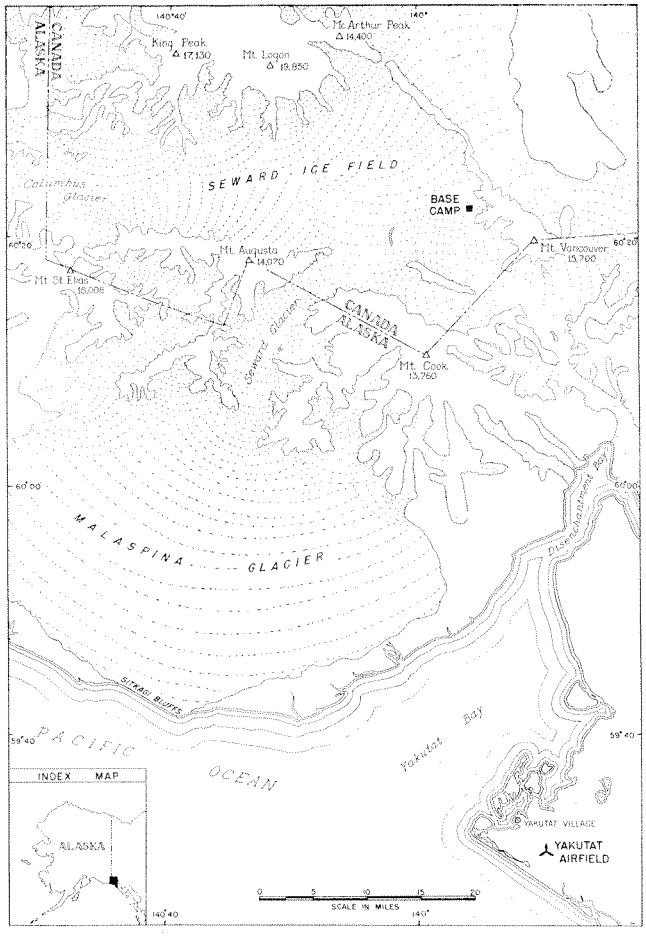


PROJECT "SNOW CORNICE"

by ROBERT P. SHARP



Caltech's four-man glaciological team cut a pretty wide swath.

Why study glaciers? Here's the answer

THE NEWS COMING IN through our small S P F radio transceiver as we cooked supper in a tent on the vast Seward Ice Field was not good. Definitely not good. It was the 15th of August. On the 27th, we had planned to fly 70 miles south to Yakutat, on the coast of Alaska, and thence 30 miles west to a beach near Sitkagi Bluffs, for further work on the Malaspina Glacier. But now the voice coming through the earphones reported in a jocular, almost light-hearted fashion, that the expedition plane, a red Noordyn Norseman, lay on its back in the middle of the Seward Ice Field—with its ski-wheels extended to the sky, its propeller bent, wing struts broken, and rudder crumpled.

Fortunately, only minor injury, in the form of small cuts and bruises and a cracked rib, was suffered by personnel in the plane as it flipped over during a routine landing on soft snow. However, not only were possibilities of work on the Malaspina Glacier dimmed to the point of extinction; there was the immediate prospect of having to evacuate 15 men from the heart of the St. Elias Range by a tortuous, unexplored route over ice fields, snow-clad mountain ridges, and badly crevassed glaciers. As far as we knew, not another plane in all Alaska was equipped to take off from a regular airfield runway and land on a snowfield. At this particular moment we felt with firm conviction that this was a problem in logistics to which aircraft manufacturers and the armed forces should have devoted more time and effort.

Thus, the prospects were far from happy. But we underestimated the ingenuity and know-how of our pilot, Maury King, an experienced Alaskan bush flyer. With considerable help from eager expedition personnel, and by means of miscellaneous bits of equipment designed for other purposes, he righted the plane, straightened the prop, unfolded the rudder, substituted 4 x 4-inch timbers from our glaciological shaft for the broken struts, and flew the plane out to the airfield at Yakutat. Suitable repairs were made in about a week, and the entire expedition personnel was safely evacuated from the Seward Ice Field by the end of August.

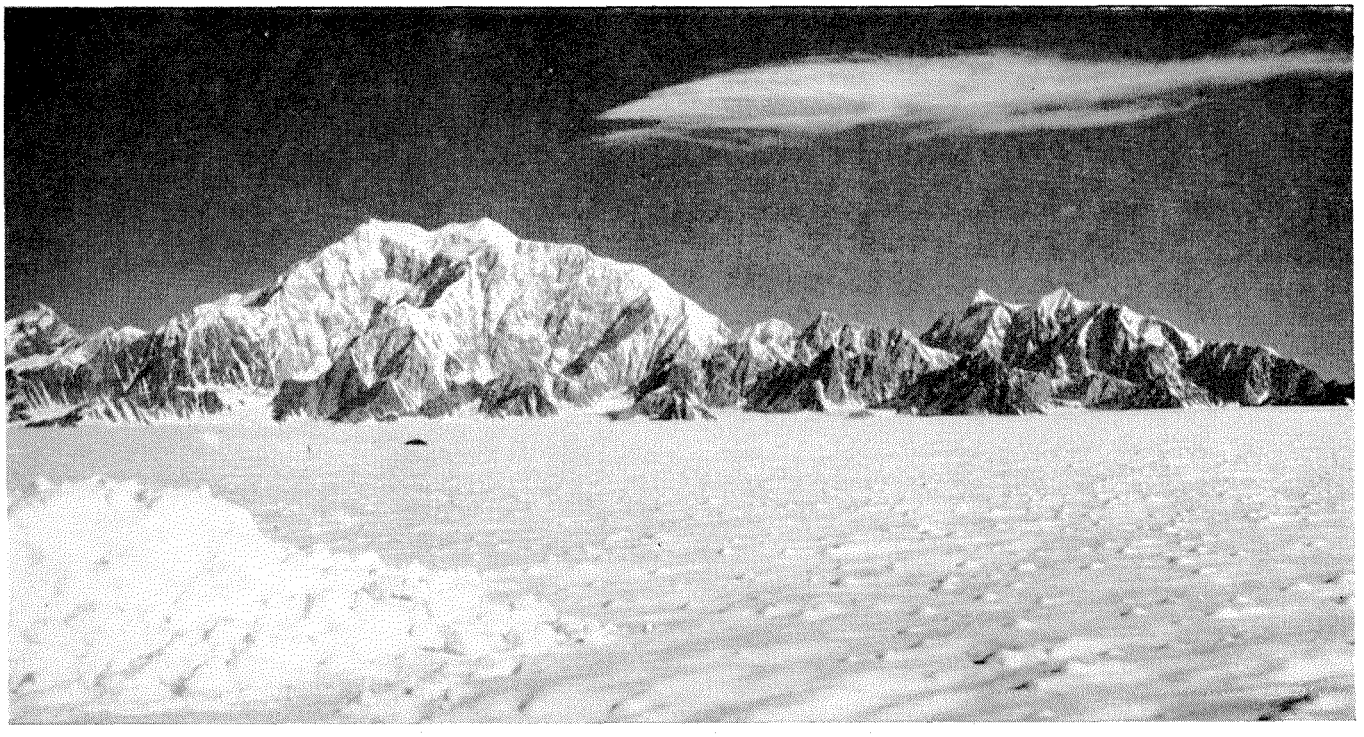
The incident merely emphasizes a principle well known to anyone who has undertaken scientific work in remote regions. To be specific, about 60 to 70 per cent of one's time and energy goes into the day-to-day task of simply keeping body and soul together, and in moving supplies, equipment, and personnel from one place to another. Project "Snow Cornice" was no exception, but we feel that the 30 to 40 per cent of one's time devoted to scientific work in areas such as the Seward Ice Field pays off at a relatively high rate of interest.

In this instance the "we" refers to three Caltech men, besides myself: Bernard O. Steenson, M.S. '48, graduate student in Electrical Engineering; and George P. Rigsby, '48, and F. Beach Leighton, graduate students in Geology. This group comprised the glaciological research team of a project set up and sponsored by the Arctic Institute of North America and led by Walter A. Wood, noted mountain explorer, photogrammetrist, and director of the New York office of the Arctic Institute.

On July 10th our Caltech contingent took off from the airfield at Yakutat, Alaska. Slightly over an hour later we landed on the Seward Ice Field, in the midst of some of the wildest, most rugged mountain country on this continent. The scenery was superb, for this great ice field—some 38 miles long by 15 miles wide—is completely encircled by towering snow- and ice-clad mountains, except for one small gap to the south through which the Seward Glacier drains, and a second low saddle or col leading westward to the Columbus Glacier. To the east lay Mt. Vancouver (15,700), the highest unclimbed peak in North America; to the south rose Mt. Cook (13,760); to the southwest Mt. Augusta (14,070) and Mt. Elias (18,808), imposing markers of the Canadian-Alaskan-border; to the north-

A problem in logistics—the expedition plane turned turtle.

Intersecting crevasses at outlet from Seward Ice Field where Seward Glacier flows south to feed the great Malaspina ice sheet.



Mount Logan (19,850 feet), second highest peak in North America, dwarfs double-peaked Mount McArthur (14,400 feet).

west lay Mt. King (17,130), and grandest of all, Mt. Logan (19,850)—second in height only to Mt. McKinley on this continent.

Gradually, as we became satiated with the stark beauty and tremendous scale of this scene—and especially after our means of departure from the region became a matter of doubt—we began to wonder what type of insanity it was that had brought us to this never-never land in the first place.

The reader is probably asking the same question at this point.

There is an answer. An answer that, to us at least, is satisfactory. We were here to study glaciers, and in what better place can these great streams of ice be studied than where they roll off the production line? Glaciers have been extensively studied in the Alps, in areas bordering the North Atlantic—such as Norway, Iceland, Spitsbergen, and Greenland— and in many other regions of the world. Indeed, most of the fundamental contributions to glaciology, the study of existing glaciers, have come from those areas. But we are slowly coming to the realization that the nourishment and wastage, the constitution and structure, and even the mechanics of a glacier in the Alps may be considerably different from those of a glacier in Alaska. Hence our desire to study Alaskan glaciers. Furthermore, the finest display of mountain glaciers anywhere in the world is in the mountains of Alaska and Canada, bordering the Gulf of Alaska. Great moisture-laden storms sweeping inland from the Pacific leave a heavy blanket of snow on these lofty ranges, and this, of course, is the major cause of the extraordinary glacier development.

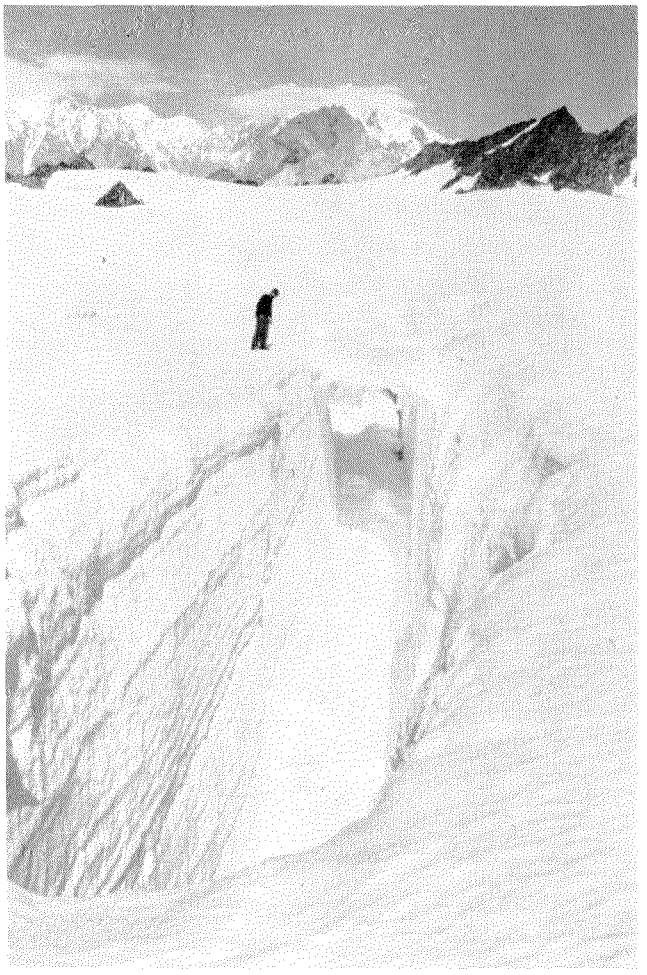
Alaskan glaciers have by no means been ignored during past decades. Excellent studies of their lower ends, where they approach or even reach the sea, are available. And they have been beautifully photographed from the air, chiefly by Bradford Washburn, Director of the Boston Museum of Science. However, the need for work on the upper reaches of these glaciers has become gradually more obvious—especially in the light of productive studies on glacier genesis, morphology, and behavior in the upper reaches of glaciers in other parts of the world, by British, Swedish, Norwegian, Danish, German, Dutch, French, Swiss, and a whole community of foreign scientists. It seems high time to us that a similar program should be launched in our own backyard, and we hope eventually to bring the California Institute to a prominent position in such endeavors. With the financial aid of the Office of Naval Research, the American Alpine Club, the Arctic Institute of North America, and the Division of Geological Sciences at Caltech, a start has been made.

Here we were then in early July, with a program of investigation and a wholly untouched area in which to exercise it.

This raises another question. "Why study glaciers anyway?"

We feel that the search for fundamental facts and information pertaining to any aspect of our natural environment is sufficient justification in itself for the type of work we were doing. It is not possible to demonstrate in terms of dollars and cents the present or even potential future value of knowing more about glaciers. But countless examples can be cited of advances in sciences which have been made possible by facts gathered solely for their own sake. Understanding and knowledge which lead to real scientific contribution can come only after the pertinent facts have been gathered, scrutinized, and interpreted. Genuine scientific advance seldom comes as a mystical bolt from the blue. In spite of such philosophical generalizations, let's be somewhat more specific with respect to our studies on the Seward Ice Field.

Perhaps some of you will recall being questioned by your elementary geology instructors as to the meaning of the uniformitarian principle. Chances are you booted the matter around for a while and then were much disgusted when the instructor expressed it very simply by saying, "The present is the key to the past."



Crevasses reveal the horizontal banded structure of the firn.

With limitations, one fertile method of deciphering past geologic events is through a study of processes currently active on the earth's crust. Many of the high mountain ranges of the western United States have been extensively glaciated in the not-far-distant past. It is our plan at Caltech to make an extensive study of this western mountain glaciation in years to come. What better way is there to approach an understanding of what has happened in the past in Yosemite, for instance, than to see great valley glaciers in action in Alaska? Thus our Alaskan glaciological studies are designed in part to help unravel the glacial history of the western United States and to train Caltech geologists for such work.

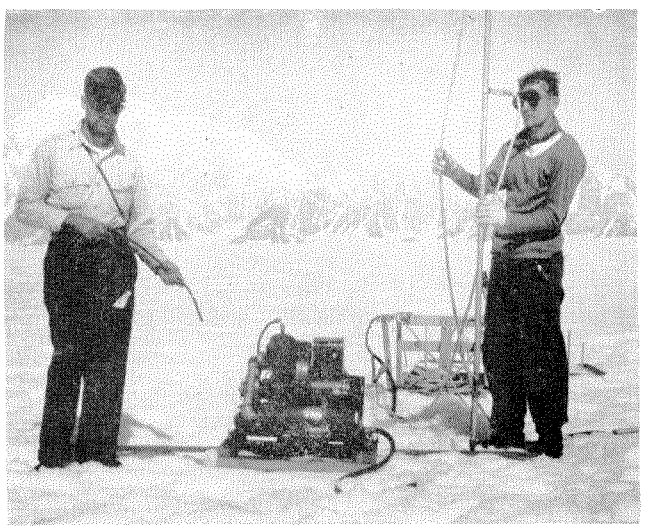
To some degree the uniformitarian principle is double-edged, and might be paraphrased as follows: "What has happened in the past and is happening now may be a key to the future." In other words, through our glaciological studies we hope to look forward as well as backward. Geologists, geographers, climatologists, and others are always searching for climatic indicators. Glaciers, being extremely sensitive to climatic variations, are an excellent climatic indicator. Imagine, if you can, anything more sensitive to temperature changes, in the proper range, than a block of ice. When we know and understand more about glacier nourishment and wastage, we may be in a position to aid meteorologists in long range predictions of climatological cycles. In a sense, glaciers are weather observers stationed in various remote parts of the world where normal weather stations are not, or cannot be, maintained. These glaciers know what has happened in the way of climatological changes if we can just wring the information from them. This is not always hard to do. For instance, a little digging near the center of the Greenland ice cap permits one to determine the relative amounts of precipitation in previous years in that remote area. It is conceivable that data from such remote regions may be essential to long-range climatological forecasts.

The ultimate cause of an ice age is still a matter of speculation, and theories based on earthly or cosmic causes, or some combination of both, are numerous. If we can establish that glaciers all over the world are behaving synchronously—that is, growing or wasting, advancing or retreating all at about the same time and rate—then some of the leading theories of glaciation will have to be abandoned or modified. We shall have made a great step forward in demonstrating that at least one factor in the development of an ice age is extra-terrestrial, be it a variation in the constant of solar radiation or something else.

For this reason, it is necessary that glaciers in all parts of the world be studied, and especially along the north-south shore of the Pacific from Alaska to Tierra del Fuego, since this is the world's most continuous line of glacier-bearing mountains, extending through the northern and southern hemispheres. Part of our program on the Seward Ice Field, therefore, was to assess its state of health. This is most easily done by studying the glacier's budget, to see if it is in balance, running a surplus, or developing a deficit. Here it is necessary to find out if the Malaspina Glacier, fed chiefly by ice carried down from the Seward Ice Field by the Seward Glacier, is spending money faster than the Seward Ice Field is taking it in.

So far we have not gathered all the information necessary to strike a balance, but we do know something about the income of this glacier system for the year 1946-1947, and next summer we should be able to confirm preliminary estimates for 1947-1948.

Much information on the physical properties of ice and snow must be gathered before any worth-while interpretations concerning glacial mechanics and behavior are possible. A large part of our summer was devoted to gathering such basic physical data. We needed holes of different depths for determination



Equipment used for boring holes and measuring temperatures.

of temperatures in the ice field. For this purpose we bored ("melted" would be more descriptive) holes into the firn, a cover of granular snow on top of glacier ice, by means of electrically heated hot points designed in the Electrical Shop at Caltech.

This method succeeded beyond our expectations, and we "bored" several hundred feet of hole in all. The greatest depth attained was 204 feet, and we stopped there only for lack of more drill rod and cable. Thermohms, fundamentally resistance coils standardized to a specially calibrated Wheatstone bridge, were used to measure temperatures within these holes. This equipment, loaned by the National Bureau of Standards, had previously been used for similar work in the Antarctic. We found that by mid-July the Seward Ice Field to a depth of 204 feet was at the pressure-melting temperature.

We also dug a number of pits, one 50 feet deep, in the firn, to permit determination of firn and ice densities at various depths, and for study of firn structures. (This pit-digging program brought to mind the remark occasionally heard that some types of geology require a "strong back and a weak mind.") Crevasses also proved useful for penetrating the third dimension of our ice field, and we obtain some information on firn structures in such openings. However, the translucent darkness of a crevasse, particularly when the walls are dripping ice water down your neck, is hardly the most pleasant environment in which to make scientific observations. The amount and mode of circulation of melt-water through the firn layers were determined, and the preliminary data demonstrate that melt-water behavior is a significant aspect of the glacier regimen. In addition to temperature, density, and melt-water measurements, observations of ice flowage were taken at 15-minute intervals on a small valley glacier draining into the Seward Ice Field. The results of these observations were disappointing, as the glacier moved too slowly—about six inches a day—to permit the type of analysis we had hoped to make.

Bernard Steenson, our electrical engineer, made good progress in attempting to adapt radar to the determination of ice thickness in a glacier above its bedrock floor. He obtained a reasonable transverse profile of a valley glacier, and this method appears to have considerable promise. The radar results need to be checked independently by some other means, preferably by seismic reflections, and this is something we intend to do next summer. If the radar method of sounding through ice proves out, it will be valuable because of the lightness of the apparatus, and the ease and speed of operation, compared with other geophysical methods of determining ice thickness.

Toward the end of the summer we found time to make reconnaissance studies of the bedrock geology in so far as it was exposed around the edges of the ice field, and on small rocky peaks and ridges projecting through the ice—as in the picture below. Since this area is absolutely **terra incognita,** information of this type helps fill in great blanks on the geological maps of Canada and Alaska.

From the scientific standpoint our summer was not an unmitigated success. Our strategy mapped out in Pasadena, with the aid and advice of able and experienced men, failed to work on many occasions. Conditions were much different from those anticipated, and much of the equipment designed and fabricated for us with skill and ingenuity by Rudy Von Huene, '34, didn't do the job we hoped, simply because no one had been able to prognosticate correctly the conditions met on the Seward Ice Field.

Next summer we anticipate a higher degree of success, based on the knowledge and experience gained in 1948.

Rock outcrops like that in the foreground, and others projecting through the ice field, yielded information on bedrock geology.