

Fig. 1. Cavern at icefall in glacier to the southwest of Base Camp. Ice flows from right to left.

Photo: W. R. B. Battle

BAFFIN ISLAND EXPEDITION, 1953: A PRELIMINARY FIELD REPORT

P. D. Baird* and other members of the expedition

THE Arctic Institute's second Baffin Island expedition, organized from the Montreal office, was in the field in the Cumberland Peninsula area from May until September of 1953. The expedition was on similar lines, but a smaller scale than that of 1950 to the Clyde district (*Arctic*, Vol. 3, pp. 113-49). The major financial support came from the Institute itself through the Banting Fund, the United States government, and the McGill University-Arctic Institute Carnegie program which assisted three expedition members. As before the Swiss Foundation for Alpine Research gave generous help and selected a strong team of four Swiss scientist-mountaineers. Other welcome contributions came from the Canadian Geographical Society and several private subscribers in Montreal.

The party was composed as follows:

P. D. Baird	Leader and Glaciologist	Arctic Institute
W. R. B. Battle	Geomorphologist	McGill University
B. H. Bonnlander	General Assistant	McGill University
D. J. Kidd	Geologist	Toronto
J. Marmet	Physiologist and Surveyor	Switzerland
S. Orvig	Meteorologist	Arctic Institute
H. Röthlisberger	Geophysicist	Switzerland
F. H. Schwarzenbach	Botanist	Switzerland
H. R. Thompson	Geomorphologist	McGill University
J. A. Thomson	Photographer	McGill University
W. H. Ward	Glaciologist	England
A. Watson	Zoologist	McGill University
J. R. Weber	Geophysicist and Photographer	Switzerland

Cumberland Peninsula was first visited by John Davis in 1585 and some of the names he gave to features still appear on the map. Nearly three hundred years elapsed before any white explorer penetrated its interior though the coasts became known to whalers, especially to Captain Penny who "rediscovered" Hogarth Sound (Cumberland Sound). Boas, the German anthropologist, spent the year 1883-4 in the area. He crossed Kingnait Pass, made a remarkably accurate map mainly from native report, and named the ice-covered mountain region to the west of Pangnirtung Pass the Penny Highland.

After the Hudson's Bay Company and R.C.M.P. posts were established at Pangnirtung in the early 1920's, winter patrols went through Pangnirtung Pass gaining a healthy respect for its difficulties as a sledge route. So did J. Dewey Soper in 1924 who gave the first detailed description of the route. Parties of

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the Geological Survey of Canada, under Weeks 1926-7 and Riley 1951, examined the Cumberland Sound coast but the interior was largely a scientific blank.

Our expedition had the 1948 and 1949 air photographs available for study, but our knowledge of the altitude was based on the estimate of 8,000-8,500 feet for the Penny Icecap and several 7,000-foot spot heights for mountains, together with Soper's report of a 1,200-foot altitude for the summit of the pass.

In 1950 many of the most valuable results of the Institute's expedition were those in the field of glaciology, and as this subject had been given an important place in the general research aims of the Institute it seemed a logical step to explore the other large ice area of Baffin Island which was known to be higher and believed to lie in an area of greater precipitation than that of the Barnes Icecap near Clyde Inlet.

We planned to determine whether a firn area existed on the summit of the Penny Icecap and to examine the glacial regime there and at various points on a representative outflowing glacier. For logistic reasons Highway Glacier leading to the centre of Pangnirtung Pass was selected. Studies of the thickness and movement-rate of the ice were planned for this glacier. A geomorphological investigation of the whole pass area, where results of existing as well as past glacial processes could be seen together, was to be undertaken, as were studies on bergschrunds. The geology, botany, and zoology of the district were to be investigated according to the special interests of the scientists concerned.

Thirteen tons of expedition stores had been sent to Pangnirtung settlement by sea in 1952. Owing to the tragic loss of the Institute's Norseman aircraft in 1951, it was not possible to have the luxury of an aircraft available throughout the season but a Norseman, chartered from Arctic Wings of Churchill, was used to establish the expedition in the field after the party and 4,000 lbs. of equipment had been kindly flown to Frobisher Bay by the Royal Canadian Air Force on May 12. The latter also assisted the expedition towards the end of the season when a Canso of 408 Photo Survey Sqn. engaged in local Shoran operations, picked up the party of four men who had evacuated our ice-cap station by a 28-mile sledge trip to tidewater, transferred them to the Base Camp, and then took much heavy equipment from there out to the settlement at Pangnirtung.

The Norseman aircraft flew about 65 hours for the expedition; 30 of which were on the flight to and from its base at Churchill, 15 ferrying the party in 4 loads from Frobisher to Pangnirtung, and 20 establishing the field camps and moving personnel out of Pangnirtung. Its local operations were all over on May 26, and it was away from Churchill only three weeks.

Main expedition camps were the Base Camp at Summit Lake in the centre of the Pangnirtung Pass at 1,300 feet, A1 on the ice cap at 6,725 feet, and A2 at the head of Highway Glacier at 6,300 feet; the latter was later moved to A3 at 3,400 feet and subsequently all the way down the glacier to the Base Camp. The Biological Camp in Owl valley (600 feet) was established in June from a lakeside cache 1,800 feet above it, the nearest point where our



Fig. 2. Base Camp at the end of May.

Photo: W. R. B. Battle

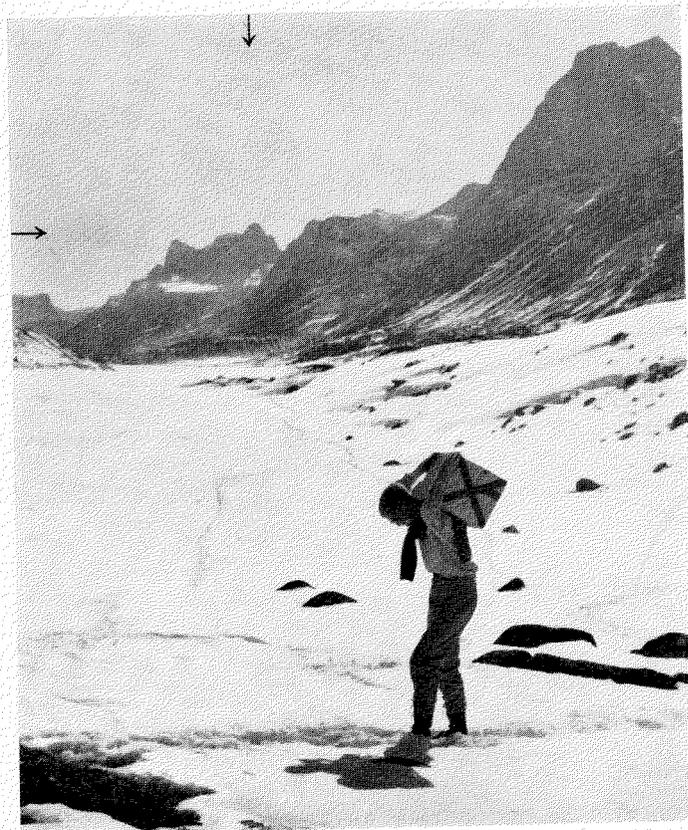


Fig. 3. Bonnlander carrying ration box (14-man-day) from aircraft landing place to Base Camp, about 1,000 yards. Arrows indicate mountain called "The Queen".

Photo: W. R. B. Battle

aircraft could land. A mountain cache was also put down (Camp M on the map) at 4,500 feet. These last two were established on our last flying day, in difficult cloud and snow surface conditions.

From then on the party was on its own; foot, ski, and manhauled sleds were the means of transportation between camps. The main routes travelled were the full length of Pangnirtung Pass, Highway Glacier from the pass to the ice cap, and June River to Padle Fiord. An initial dog-team trip in the Padloping area gave Watson and Kidd a chance to examine the birds and rocks of that region, the latter returning there by Kingnait Pass to make a closer examination of the geology in August.

The camps were evacuated in August; the ice cap on August 10 and the Base Camp on the 27th. The personnel sailed from Pangnirtung aboard the C.G.S. *C. D. Howe* on September 7, arriving Montreal September 13.

One member of the party did not return. Ben Battle, Senior Fellow in the McGill University-Arctic Institute Carnegie program, was accidentally drowned on July 13 near the Base Camp. He was buried on the moraine overlooking the finest part of the pass in the area in which he had last worked with such enthusiasm.

The map (Fig. 4) shows the main camps and the routes travelled by the expedition. The following sections describe the various scientific investigations.

Glacier physics. By W. H. Ward

The Penny Icecap extends northwestwards from Pangnirtung Pass for some 90 miles, and is about 20 miles wide. It is bounded on the northeast and southwest sides by two remarkable straight valleys partly filled with tributary glaciers coming from the ice cap and partly with ice-dammed lakes. It is comparable in area with the Barnes Icecap, which was visited in 1950, but in other respects is quite different. The ice generally appears to be a few hundred feet thick and its surface takes the form of domes fused together by broad valleys which spill relatively thick ice into more than a dozen major valley glaciers. The outer domes frequently terminate in ice cliffs only 100 to 200 feet high above 3,000-foot-high rock walls that form the valley glacier troughs. On the north and east sides three glaciers reach sea level in the heads of fiords. One of them, Coronation Glacier, is 2 miles wide and over 20 miles long.

The highest ice-cap dome at 6,725 feet, where Svenn Orvig and the writer established Camp A1 on May 16, lies near the southeast end of the ice cap and from here the general level of the ice decreases towards the northwest to an elevation of about 2,000 feet. Southwards from the southeast end of the ice cap lies the 10-mile-long Highway Glacier, one of three glaciers that flow into the head of Pangnirtung Pass. This glacier was used as a ski route between the Base Camp and Camp A1. Studies in glacier physics were concentrated at Camp A1 and at numerous sites between there and the Base Camp along this route.

Some of the observations made at these sites between elevations of 6,725 and 1,430 feet are listed briefly below, together with the results.

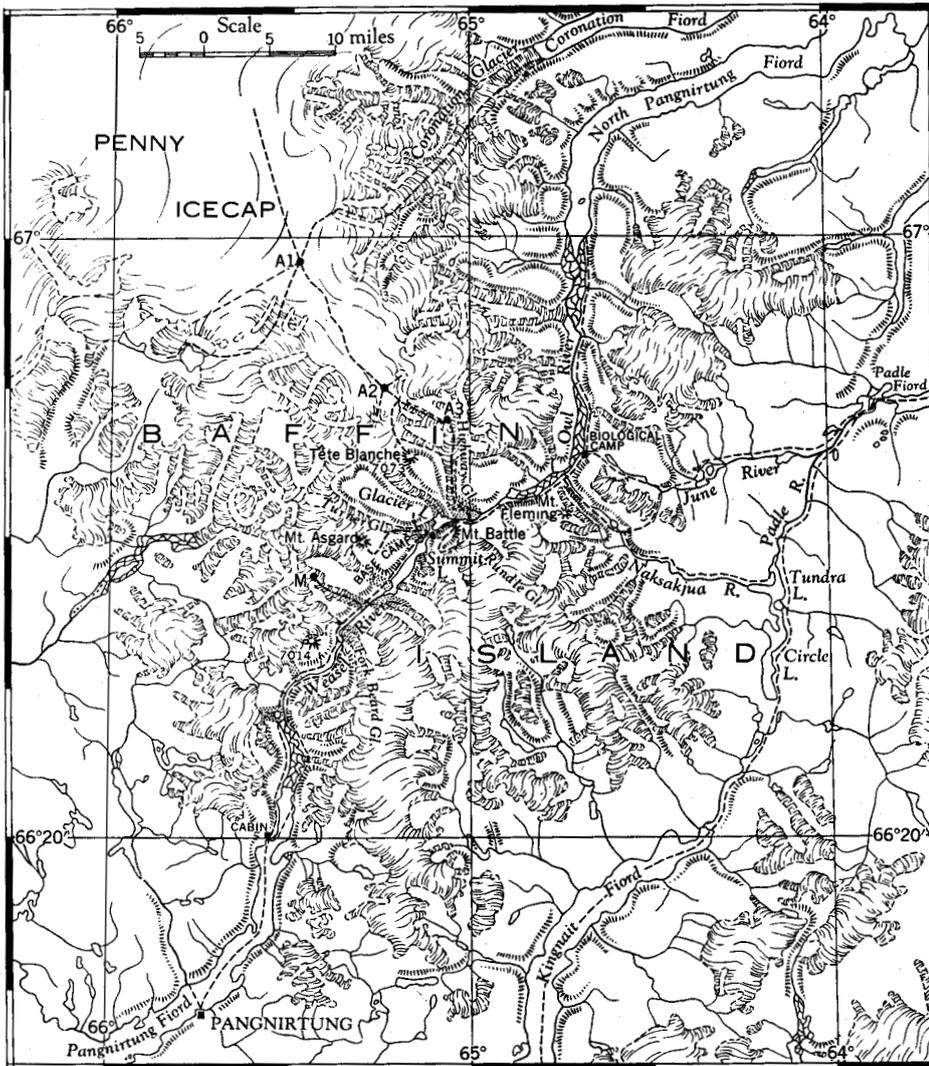


Fig. 4.

Accumulation and ablation

The accumulation and ablation of snow and ice were observed relative to a dozen bamboo stakes drilled into position. In the vicinity of these stakes 38 pits were excavated at frequent time intervals to measure the density, temperature, and structure of the deposition and to follow the progress of accumulation and ablation in quantity. The current annual snow attained a maximum thickness of between about 32 and 42 inches (10 to 15 inches of water). There was no significant increase with altitude and a few values greater than that quoted above could be attributed to local drifting. Much of the snow that fell during May, June, and July at 6,725 feet was blown

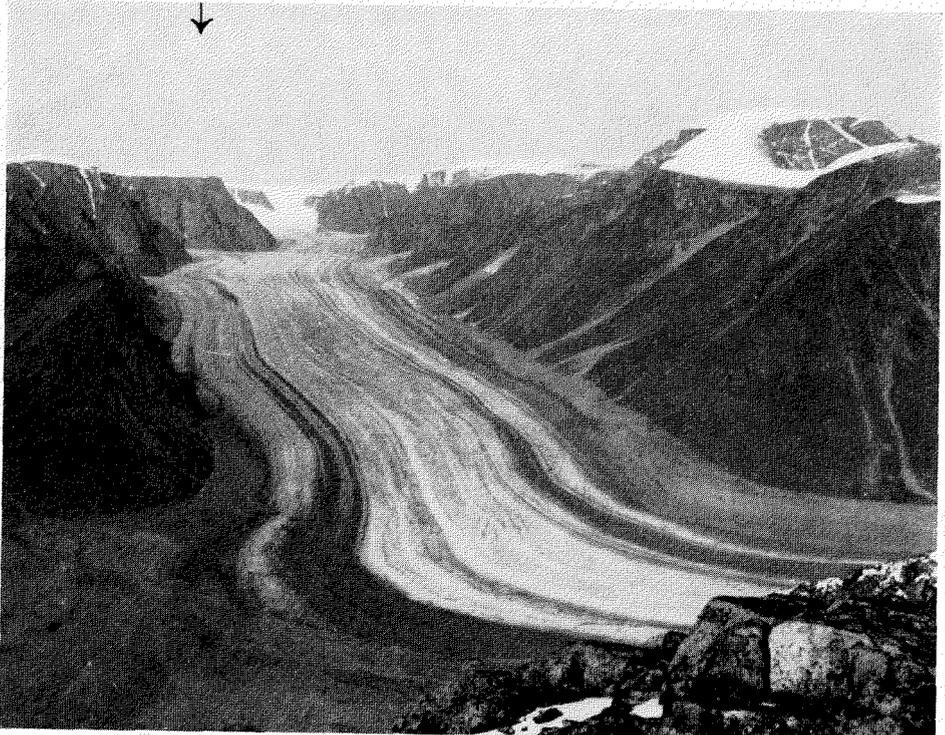


Fig. 5. Highway Glacier from summit of Mt. Battle. Arrows indicate position of Camp A3.

Photo: W. H. Ward

away the day after it fell. Rime and hoar frost deposits on all upstanding objects were considerable and very frequent at this altitude, but the amount that formed on the snow surface was relatively small. The firn melted away up to an elevation of about 5,000 feet, that is approximately at the level of the head of most of the outflowing glaciers. Superimposed ice formed directly from meltwater reached a maximum thickness of about 3 inches over the old ice surface of the glaciers, but the total area of superimposed ice remaining in August was quite small on account of the steepness of the glacier surface just below the firn.

Melting of the snow started in mid-May at 1,430 feet and all the snow and over 7 feet of original ice was lost from lower Highway Glacier by the end of August.

At 3,340 feet, only 27 inches of original ice was lost, together with the current snow. Melting started here on June 23 and lasting snow returned about August 16.

At 6,725 feet, on the summit of the ice cap, surface melting was not continuous for more than about 60 hours. A melt of that duration commenced on July 13, another of 30 hours started on July 19 and one of 60 hours began on July 23. Thereafter, until August 10, when this camp was evacuated, another 40 hours of surface melting occurred in short periods lasting a few hours. The firn did not melt to a depth greater than about 5 feet, and was

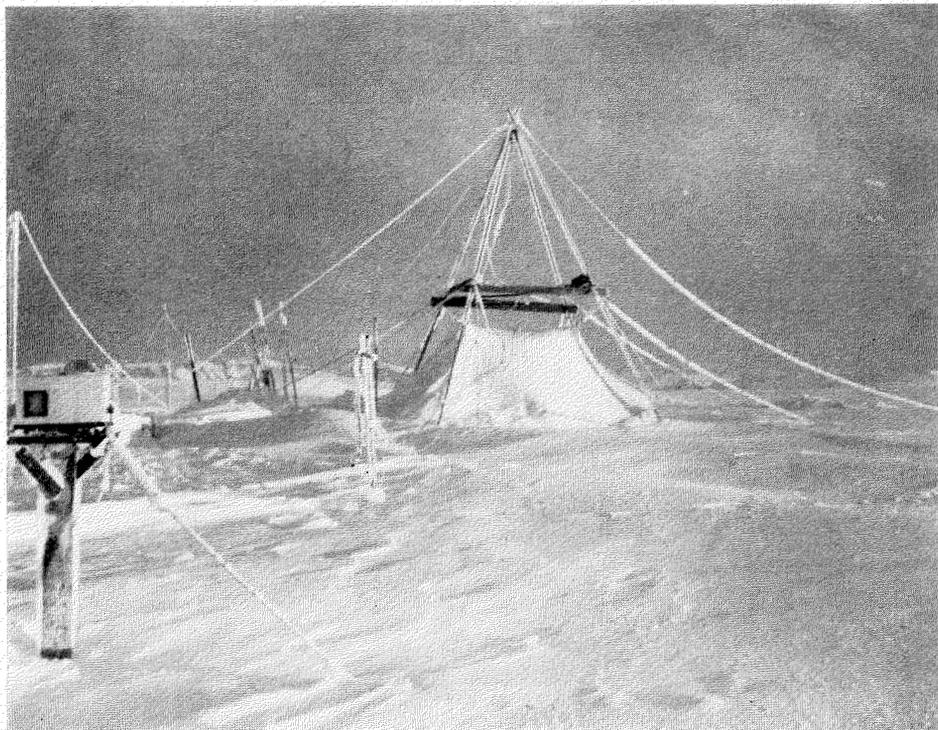


Photo: W. H. Ward

Fig. 6. Main tent at Camp A1 with hoar frost on guy-ropes. Kew Robitzsch actinograph in foreground.

refreezing downwards from the surface and upwards from below for several days before we left. The total amount of melting is provisionally estimated to be about 4 inches of water.

Thermal measurements

Ice temperatures were observed to a depth of 32 feet at elevations of 3,340 and 1,430 feet and to a depth of 70 feet in the dense firn at 6,725 feet. The steady temperatures below the zone of seasonal change are about -13.3 , -5.8 , and -5.5°C at altitudes of 6,725, 3,340, and 1,430 feet respectively.

A heat-meter plate pushed into the snow from the side of a shallow pit was used to measure the heat flow through the snow during the period before melting commenced at 6,725 feet.

Radiation measurements

Continuous recordings were made of the incoming short-wave radiation on the new Kew type Robitzsch instrument at 6,725 feet. The maximum intensity amounted to about $1 \text{ cal./cm.}^2/\text{min.}$ on a clear day, and at midsummer the total daily radiation was about 780 cal./cm.^2 (Latitude $66^{\circ}58\frac{1}{2}\text{N.}$).

Observations of the net radiative flux into or out from the snow surface were made with a Gier and Dunkle type blown-plate radiometer constructed by the writer, which uses thermistors for the sensitive elements. Measurements of both incoming and outgoing short-wave radiation were made with

two other specially constructed radiometers employing thermistor elements. The observations enable the long- and short-wave components of the incoming and outgoing radiation to be evaluated, and will be used in a study of the heat exchange at the snow surface.

Glacier movements

Measurements were made by theodolite triangulation of the absolute movement of 8 points on the surface of the mile-wide Highway Glacier at an elevation of about 2,500 feet, where the surface slope is about 3 degrees. The points formed two transverse lines over $\frac{1}{2}$ mile apart down the glacier. There were 4 points on each transverse line; they were observed on July 7 and 38 days later. The horizontal movement of the points parallel to the general longitudinal axis of the glacier varied irregularly from 10 to 52 feet. The largest movement occurred near one rocky boundary in the most crevassed zone and where there was also a considerable transverse movement towards the boundary. On the other side of the glacier the longitudinal (and horizontal) movements were more uniform and averaged about 20 feet. Here it was found, by comparison with an air photograph taken in 1948, that a lateral moraine of limited length and travelling at the same speed as the ice had moved about 1,000 feet in 5 years. This rate of strain compares well with the short-term measurement. The rate at which crevasses adjacent to the steep rock walls visibly opened and closed around one of our tents on the glacier confirms the rather high rates of strain in the glacier. These observations are to be used in conjunction with the seismic depth soundings carried out by Röthlisberger to analyse the mechanics of the glacier flow.

The writer was ably assisted in maintaining continuity in the observations at the various sites by Baird, Orvig, and Bonnlander. All the figures quoted in this report are preliminary only and may be subject to correction later.

Seismic sounding. By H. Röthlisberger

The seismic work was carried out in two different locations, first in the flat firm area around Camp A2, on the southeastern edge of the ice cap, and secondly on Highway Glacier between Camp A3 and the tongue of this typical valley glacier. A2 was chosen as it was a good landing place for the Norseman aircraft, and we could reach Highway Glacier without being troubled by crevasses or very steep hillsides.

The equipment, donated by the Magnolia Petroleum Company, consisted of 6 geophones (plus 4 spares), 6 amplifiers with high level and low level output, a 16-channel recording camera (12 of the galvanometers connected to the amplifier outputs, one recording the time break, leaving 3 in reserve), and the blasting equipment with telephones. To cut down weight we used four motorcycle batteries, charged by a very light 400-watt generator (DKW type GG 400), for power supply instead of a car battery. Since most of the equipment had been used before on trucks for oilfield work, the whole equipment was rather heavy, the packed total being 700 lbs. The surveying was done with a theodolite T 0 lent by Wild of Heerbrugg.



Fig. 7. Weber with the geophones.

Photo: J. A. Thomson

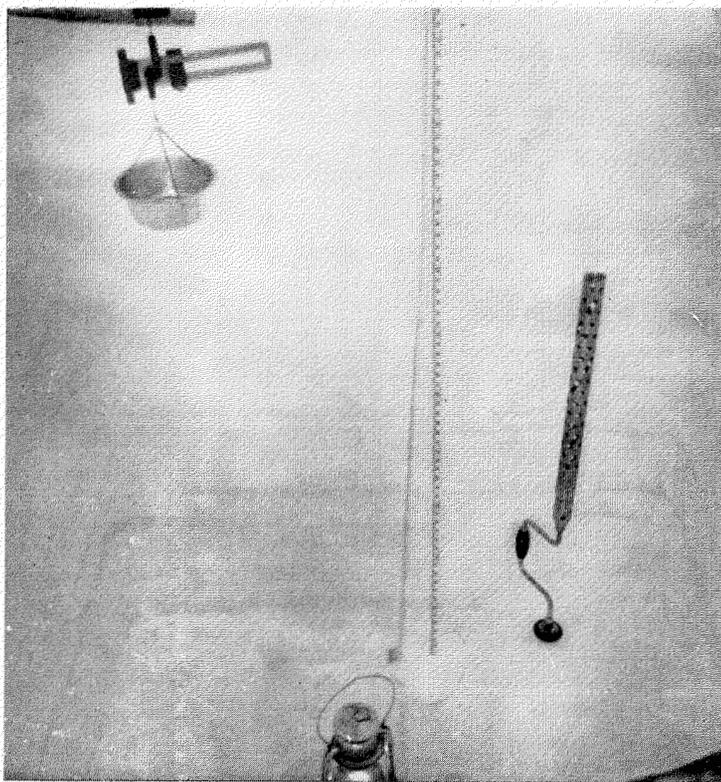


Fig. 8. The pit at Camp A1 after 10 feet of digging was continued to 70 feet with device connected to brace.

Photo: W. H. Ward

On May 20 Weber and the writer set up camp at A2. We started the seismic work on May 27 after the other two members of our Swiss team had arrived, and carried on, mainly in bad weather with temperatures around 5°F, but not too strong winds, until June 5. During the next five days the four of us moved some 2,500 lbs. of food, camping material, and seismic equipment down to A3. One hundred and seventy pounds were carried as backpacks, 1,500 lbs. in 5 trips on a Gaillard-Dufor ski-improvized sled, 500 lbs. in one trip on a magnesium sled similar to a small Nansen sled in design, and 300 lbs. on one of the Canadian Army "pulkas", also in one trip. In the deep fresh snow on the plateau none of the three sleds ran well, but farther down we were lucky to have suitable conditions for each sled: the ski-improvized sled ran best in light snow below freezing; the magnesium sled better above freezing or on a solid crust, and the pulka well on a smooth ice crust only. Later in the season the magnesium sled worked extremely well on bare ice and proved remarkably strong.

From June 11 to July 6 we stayed at A3 and worked from three different centres on Highway Glacier, the total length of shooting profiles being 8 to 9 miles. Towards the end of this period we were working in the full-melting season, the conditions for walking and transportation became atrocious, and we lost some 1,000 feet of telephone cable by the sudden outbreak of a meltstream. On July 7 we moved the seismic equipment to a safe place on a medial moraine about 2 miles farther down the glacier, and left for mountaineering. The seismic work was taken up again from July 29 to August 9 on the lower parts of Highway Glacier. The more precious parts of the equipment were then brought over to the Base Camp to be flown out by the R.C.A.F. Canso. Altogether the seismic work took some 140 man-days, working mostly in groups of two to four men. The greater part of the work was done by the Swiss, though we were helped considerably by J. A. Thomson and occasionally by others.

Most of the shooting was done by laying the charges on the surface of the ice rather than drilling holes. The charges had to be 5 to 10 times bigger, but the records were as good. We had dynamite to spare, time was more precious. Three hundred pounds of 60 per cent high velocity gelatin (Forcite), which had been stored at Clyde since 1949, were picked up by our Norseman aircraft. For drilled charges we used 40 per cent Forcite in small cartridges of which 50 lbs. were brought with us from Montreal. The dynamite and the blasting caps were donated by Canadian Industries Limited. For an accurate determination of the seismic velocities in firn and ice we had a few special seismocaps, but for most of the work short-period ordinary caps proved sufficient. The surface charges ranged from half a pound to 3 lbs. for distances of $\frac{1}{4}$ to $\frac{3}{4}$ of a mile between blast and geophones. The geophones were laid in two parallel lines of three each, with the same distance of 200 feet between the lines and between each geophone in the line. All the shooting was then done on profiles lining through two or three geophones. This set-up made it possible to obtain the position and slope of the reflecting rock surface fairly accurately by combining groups of three geophones in a triangle for

calculation or geometrical construction. Around 200 records were obtained in the whole period, the greater part showing good reflections. The best records were obtained on Highway Glacier when the ice was covered by one to two feet of snow.

At A2 on the firn plateau no reflections could be recorded; but by the refraction method the total thickness of firn and ice was found to be of the order of 700 feet, the top layer (of looser structure than the main ice body) being some 100 feet thick. The profiles across Highway Glacier showed a rather flat valley bottom with the deepest channel to the west. The thickness of the glacier reached as much as 1,300 feet where the main branches met, and decreased steadily to 450 feet above the steep drop down to the main valley of Pangnirtung Pass. The tongue seemed to be thicker again, but no reflections could be obtained there. A long refraction profile was laid along the tongue which showed the bedrock to be from 500 to 700 feet below the ice surface.

Meteorology. By Svenn Orvig and B. H. Bonnländer

Ice cap station

The ice cap meteorological station was established at Camp A1 on May 16, at $66^{\circ}58\frac{1}{2}'N.$, $65^{\circ}28'W.$, on the highest dome, 6,725 feet above sea level. From May 21 to August 9 the following observations were made every two hours, from 0800 to 2000 daily: pressure (by aneroid and barograph); temperature at 3, 13, and 23 feet above the surface; humidity at 3 feet (by aspirated hygrometer and hygrograph); wind speed and direction at 6 feet; also cloud, fog, visibility, and ceiling. At 0800, 1400, and 2000 hours maximum and minimum temperature and precipitation were measured, and thermograph records were kept for 81 days. Sunshine was recorded by a Campbell-Stokes recorder. Air temperatures at 13 and 23 feet were measured by thermistors, otherwise standard meteorological instruments were used.

Little is known about the climate of the ablation period on Canadian glaciers and ice caps; the problem was studied on the Barnes Icecap in 1950, and it was logical to use identical methods on the Penny Icecap as far as was possible. In systematic investigations of glaciers, glaciological and meteorological studies are complementary, and to evaluate the dependence of ablation on the various meteorological factors a knowledge of the radiation conditions is essential. The expedition was well equipped to undertake radiation measurements, with an M.S.C. Type G Bimetal Actinograph lent by the Meteorological Division, Department of Transport, an actinograph made at Kew Observatory, as well as a net radiation fluxmeter and two radiometers. Both actinographs will be recalibrated before final conclusions can be reached, but from preliminary figures the Canadian instrument gave readings 20 per cent higher than the Kew instrument. The amount of radiation recorded on the M.S.C. actinograph varied within fairly wide limits, averaging from 0.3 to 0.8 cal./cm.²/min.

The total hours of sunshine recorded in June and July were less than that on the Barnes Icecap in 1950 (168 and 143 hours, compared with 207 and 153). Comparison of radiation is difficult because fog on the Penny Icecap was

frequently thick enough to stop the Campbell-Stokes instrument from recording, but not to prevent short wave radiation from reaching the surface. At 6,725 feet, surface and adiabatic cooling of moist, maritime polar air caused fog on 25 days in June, 27 in July, and 8 of the first 9 days in August.

The frequent high relative humidity on the Penny Icecap also affected the moisture gradient above the snow surface, and hence the evaporation. On the Barnes Icecap there was an almost permanent gradient in all but foggy weather, the air at higher levels being warmer and drier than the surface layer. It appears that the total evaporation on the Penny Icecap must have been small.

Ablation, at least in the higher parts of the ice cap, was mainly due to melting caused by radiation, in spite of the low surface temperatures. Convection was not important, since during the whole "summer season" there were only 14 days with maximum temperatures above 32°F. The absolute maximum of 38.5°F was recorded on July 25. Ablation took place in a few interrupted periods, counted in hours, unlike the continuous ablation period of 52 days on the Barnes Icecap.

Accurate measurements of precipitation are always difficult in the Arctic. On the Penny Icecap the problem was further complicated by frequent deposition of hoar frost directly on the surface, which proved to be almost impossible to measure. Drifting snow caused much trouble, as expected. A wind of about 13 m.p.h. would start surface drifting, and as snowfall usually occurred with relatively strong winds, the following figures for snowfall are possibly a little too high. Three inches of snow fell during the last 11 days of May, June had 13 inches, and July had 16 inches of snow and just under 1 inch of rain.

Wind speeds on the ice cap were surprisingly low. The maximum recorded was 36 m.p.h. on May 28 with a mean temperature of -9.4°F. From previous experience we had expected a number of low pressure frontal systems to pass over the area, bringing strong winds. In fact, blizzard conditions occurred on only 9 days out of 85, compared with 18 on the Barnes Icecap in 1950. S.O.

Base Camp station

Continuous weather observations were taken at the Base Camp in Pangnirtung Pass from May 17 to August 27, a total of 103 days. This was possible thanks to the combined efforts of six members of the expedition. The following observations were made daily: pressure by aneroid and barograph trace; temperature, both maximum and minimum, dry and wet bulb, and thermograph trace; precipitation; cloudiness; and wind, both direction and strength, the latter measured by hand-held anemometer. A hygrograph was also kept in operation throughout the summer.

In comparing the data with the records from Pangnirtung the general picture is that of an average season. The weather appears to have been largely controlled by an interplay of two factors: the high and low pressure systems passing over southern Baffin Island, and the local influence of cool, moist,

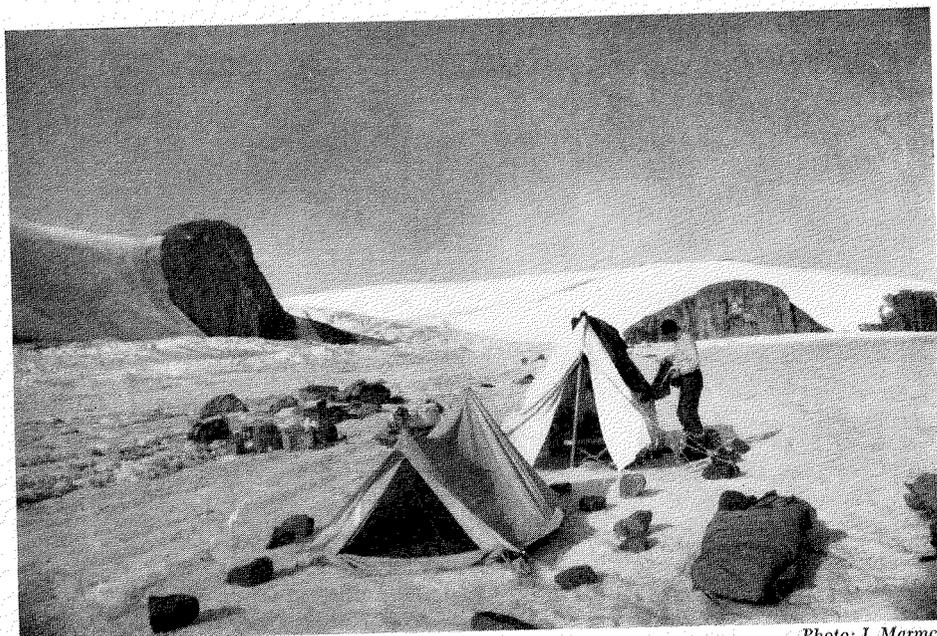


Photo: J. Marmet

Fig. 9. First camp on descent of Coronation Glacier from Camp A1 (on far dome behind tent).

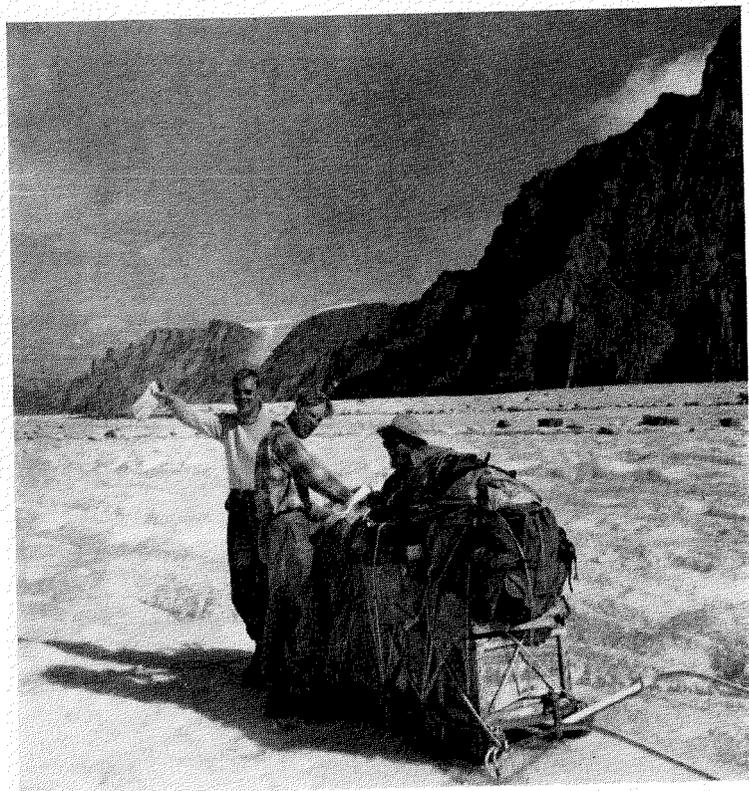


Fig. 10. Orvig, Bonnländer, and Marmet evacuating Camp A1 down Coronation Glacier.

Photo: W. H. Ward

maritime polar air coming up from the fiords at each end of the pass, which produced a particularly unpleasant, misty "base camp weather". Because of the exposed location of the camp at the head of the pass, and the funnelling action of the valley, there was rarely a lull in the steady, but not strong, northeast and southwest winds that came in almost equal frequency. Each month had a period of fine and of bad weather, but otherwise the pattern changed almost daily.

The camp was established during a week of warm and sunny weather accompanied by rapid melting of the snow. During the last four days of May, however, temperatures dropped to the low twenties, with snow and winds that blew steadily between 20 and 30 m.p.h.

The first three weeks of June were cold, moist, and almost without sunshine, with frost every night and a maximum temperature of 40°F reached only on the 16th. The final week at last brought sunny, warm days and mild nights.

Throughout the first half of July the weather was warm and settled and the first heavy rain fell. Cool, moist, and rainy weather persisted for the last ten days, during which time the thick ice on Summit and Glacier lakes finally broke up and disappeared.

August was as mild and rainy as July. The first and heaviest snowfall came on the 16th, and terminated the mosquito season. The final week provided the evacuating party with the best weather of the summer, with daytime temperatures in the upper fifties and cool, almost windless, nights.

B.H.B.

Geology. By D. J. Kidd

Four geological traverses were planned for the summer: (1) by dog team for ten days on the shore ice in the Padloping area at the end of May; (2) overland from Padle Fiord for 25 miles up June River valley to its junction with the remarkable Pangnirtung Pass; (3) across Cumberland Peninsula in June and July along the full 60-mile length of the pass on foot and down Pangnirtung Fiord by schooner; and (4) by R.C.M.P. Peterhead boat along the coast from Pangnirtung to Padloping and return, thereby completing the circuit of the peninsula by the end of August.

The first three traverses were completed as planned. Ice movement at Cape Mercy unfortunately forced the R.C.M.P. vessel to return to Pangnirtung, and Padloping was finally reached by walking over Kingnait Pass, a distance of 40 miles to Padle Fiord, in two days. Nearly two weeks were then spent on foot and by whaleboat in the Padloping area.

The last four weeks were passed on the C.G.S. *C. D. Howe* and C.G.S. *d'Iberville* visiting all the Eastern Arctic ports north of Padloping. On the return trip south on the *d'Iberville*, the coast was examined through binoculars from Cape Searle to Cape Dyer and as far as Exeter Sound. This left a gap of nearly 140 airline miles along the eastern end of Cumberland Peninsula which was not mapped. The writer would like to close this gap in the near future.

Precambrian-type rocks

The majority of rock exposures seen in the Cumberland Peninsula were of Precambrian-type granites, granite gneisses, and quartz-biotite paragneisses with occasional conformable bands of amphibolite and biotite parschists. The granites are ovoidal, myrmeckitic, and "normal". The more basic varieties possibly contain hypersthene or hastingsitic hornblende and thus could be granulites or charnockites. The ovoidal granites are associated with phenomena of granitization, and resemble in texture the Rapakivi granites of Fennoscandia and southern Greenland. The myrmeckitic granites, which occur in areas of minor folds, are devoid of the dark fragments of argillaceous material found in the ovoidal granites. The pegmatites and aplites, both conformal and cross-cutting, are without mineralogical interest. They are absent in large masses of the ovoidal granites but very common in adjoining bands of augen-gneisses, quartz-biotite paragneisses, and amphibolite, and are cut by gabbro or diorite dykes.

Except for rare occurrences of specularite in epidotized granite gneiss, no economic minerals were found in Precambrian rocks. The sole interest of biotite parschists, weathering rusty by oxidation of pyrites, appears to be their use as local horizon markers. Amphibolite bands are also useful for mapping purposes in Pangnirtung and Kingnait passes.

Tertiary-type rocks

There has been considerable speculation on whether the "belt" of Tertiary volcanic rocks, which extends from Scotland, through Iceland to eastern and western Greenland, can also be found in Baffin Island. McMillan's observations¹ in the region of Durban Harbour suggested that volcanic rocks were to be found in that area.

This past summer erosional remnants of flat-lying Tertiary-type basalt flows were found to occur for 55 miles along the Davis Strait coast from Cape Searle island to Cape Dyer. They seem to extend no more than five miles inland and are separated by fiords and embayments. These flows contain the alternate grey and red members typical of plateau basalts and their lower limits appear from the sea to be uniform in altitude, generally between 1,100 to 1,800 feet above sea level. Some of the basalt tops east of Durban Island may be slightly over 3,000 feet high. The top of the highest basalt flow on Padloping Island is about 2,800 feet.

Near the northeast end of Padloping Island, these basalt flows, which are apparently of subaqueous origin, rest on a series of alternating beds of rusty crossbedded agglomerates, or "submarine breccias" of amygdaloidal basalts, and dense battleship-grey flat-lying beds either of lava or of tuffaceous material. The contact between these rocks is about 1,450 feet above sea level. No ellipsoidal lavas were seen. Cape Searle itself, and the northern neck of Cape Searle island are composed entirely of the crossbedded agglomerates and grey tuffaceous material. Red and grey flat-lying basalt flows were seen only on the top of the highest hill in the centre of Cape Searle island, where about two

¹McMillan, J. G. 1910. "Report" in Bernier, J. E., 'Cruise of the Arctic', pp. 423-4.

hundred feet of basalts rested unconformably on biotite paragneiss and granite gneiss formations. The top of the hill was estimated to be about 1,200 feet high, while the crossbedded agglomerates composing the string of Gothic towers, interconnected by short incredibly-pinnacled ridges of the rocks, are about 800 feet above sea level.

It would appear, then, that the volcanic activity was episodic and that submarine accumulation of agglomeratic beds took place on a shelf area between Cape Searle and Padloping Island. Another possible explanation would be that this shallow channel may have been the site of an ancient river delta consisting of sedimented volcanic ejectamenta. However, the crossbedded agglomerate bands at Cape Searle dip southerly while those in the Padloping massif seem to dip to the north. This suggests that these beds formed the lower slopes of separate volcanic vents. However, the original plateau-like character of the basalt flows would perhaps presuppose that the lavas came not from circular vents but from fissures.

Castellations and pinnacles of dark brown rocks similar to those on the north end of Cape Searle island were seen on a promontory about five miles southeast of Reid Bay. It is possible that they are composed of the same banded agglomerates; no crossbedding could be seen however. The flat dome of the hill behind the promontory seemed definitely to be composed of the red and grey flat-lying basalt flows. Observations at the time were greatly hindered by fog and a choppy sea.

Semi-consolidated beds of sandstone with intercalated shales occur at sea level, in strips a few hundred feet long and 20 to 30 feet or more in width at the foot of the banded-agglomerate massif near the northeast end of Padloping Island and a small strip was seen at the base of the mainland opposite Durban Island. The contacts were obscured at both localities by heavy scree cover. It is possible that the sandstone beds abut against the base of the crossbedded agglomerate at Padloping and are younger than the Tertiary-type basalts.

The sandstones contain several seamlets of soft, occasionally dense, lignitic to sub-bituminous coal up to 10 inches thick and averaging 3 or 4 inches. At the Padloping locality there was also a seam up to 35 inches thick of very crumbly or flaky lignite mixed with considerable sand from the overlying friable sandstone. The sandstones and interlying members at Padloping dip six degrees westerly. Those near Durban Harbour appear to be horizontal. It is possible that some of the lignite has been raised to sub-bituminous rank by local vulcanism; in that case, the sediments would either be intervolcanic or older than the lavas. It is hoped that it may be possible to have carbon-isotope tests made on the woody varieties of the lignite to determine the probable age of the sediments.

Vertical to subvertical dykes of gabbroic material, sometimes with an ophitic (diabasic) texture, finger out upwards from the sea into the agglomeratic and tuffaceous beds, but apparently do not cut the flat-lying basalt flows. These dykes and the dykes cutting the Precambrian-type rocks in the Padle Fiord area may be associated with the source of the vulcanism.

Structure

The Precambrian-type rocks are folded largely northwesterly parallel to the Davis Strait coast, but variations in the regional trend were noted in the Padle Fiord area, June River valley, and the central third of Pangnirtung Pass, where the gneisses and schists strike generally north of east. The structure in Pangnirtung Pass is difficult to determine, because of the predominance of ovoidal and myrmeckitic granites, but the gneisses and schists wherever observed generally vary in strike between northwest-southeast and north-south around North Pangnirtung Fiord and southwest of Summit Lake.

The intensity of folding seemed to increase southwestward from gentle to moderate in the Padloping area to isoclinal at the head of Pangnirtung Fiord, and becomes moderate again south to the Cumberland Sound coast. Minor folds, with axial planes haphazardly oriented, were observed in the June River and central Owl River valleys.

At least three sets of joints may be recognized in the Cumberland Peninsula area. It is the writer's belief that the development of Pangnirtung Pass was bound up with the intensity of jointing of the underlying rocks parallel, transverse, and at acute angles to the axis of the present pass. The numerous glaciers on the peninsula carved out the hanging valleys along structural lines of weakness, and these grooves seem to be controlled primarily by joints rather than faults. In the field no definite signs of large scale faults, or faults with large displacements were seen, but their presence, especially those of the graben type, may perhaps be deduced from a study of the field data and air photographs. Small displacements have been seen, at any rate, especially along Pangnirtung Pass and Highway Glacier, in the form of so-called mylonites. The Precambrian-type granitic rocks appear to fail, when under great stress, in the "dry" state rather than plastically.

Because no recent accumulations of sediments have been found on the basalt flows in the Padloping area, and the agglomerates appear to be of submarine origin, it is assumed that the land mass represented by the original basalt sheets between Cape Searle island and Cape Dyer has risen perhaps 800 to 1,400 feet above the sea since the close of vulcanism, and the erosional debris from that mass has since been sedimented under the waters of Davis Strait.

Geomorphology. By H. R. Thompson

The expedition's two geomorphologists undertook very different types of research. W. R. B. Battle concerned himself almost exclusively with the problem of corrie formation, extending the work which he had previously done in the Alps, in Norway, in east Greenland, and in the laboratory. On June 6 he set up a four-point Taylor thermograph at the mouth of a bergschrund in the corrie glacier immediately south of the Base Camp. Short leads were arranged to measure the temperatures of the open air and of the surface snow. Two long leads were taken 90 feet down into the bergschrund, to record air and ice temperatures in the zone where Johnson's bergschrund hypothesis requires repeated freeze-thaw action. Battle had hoped to insert



Photo: W. R. B. Battle

Fig. 11. Thompson on ice-cored moraine of Turner Glacier.

one lead into bedrock itself, but, as in the other bergschrunds and caverns he visited, the headwall was sheathed with a thick coating of ice. Battle checked the thermograph regularly until July 11, when the last seven-day record sheet was put in. The thermograph pens gave considerable trouble, especially in the early days, but enough traces are available for a valid analysis of thermal conditions in spring and early summer.

At the Base Camp site Battle used thermistors and a Wheatstone bridge to measure temperatures at numerous points on, in, beneath, and around a snow patch. The readings, taken every two hours for one day, were repeated on several occasions and led to the general conclusion that freeze-thaw action beneath snow banks and in deep bergschrunds must be a rare occurrence.

Ben Battle's researches ended with his tragic death on July 13. His results are now being analyzed by the writer.

I myself made a geomorphological study of Pangiirtung Pass as a whole. Each main type of landform was first examined separately. Then attention was focussed on assemblages of landforms, on the relation between one element of the landscape and another. Later it became possible to divide Pangiirtung Pass into three geomorphological sections and finally to produce a tentative chronology for the evolution of the whole region. Particular stress was laid on accurate description, which is the main function of such a reconnaissance study. Schwarzenbach's ecological-dating studies were of great value to me and usually confirmed the geomorphological evidence.

A five-inch surveying aneroid was used for height determinations at significant points: about 180 such spot heights were recorded, some of them

in the course of systematic traverses. Slope angles of all kinds were measured with an Abney level, which also provided measurements of height for a plane-table survey of the central part of Pagnirtung Pass. This survey showed that considerable glacial retreat and thinning had taken place in the five years since the R.C.A.F. air photographs were taken, as also in the twenty-seven since Soper's journey through the pass.

The geomorphological work was extended southwards in a more general way as far as Pagnirtung itself. In particular it included 48 soundings with a bathythermograph, recording temperatures as well as depths, on five crossings of the sea ice in the upper reaches of Pagnirtung Fiord.

Pagnirtung Pass is a trough sixty miles long, one mile wide, and up to one mile deep, which cuts from north to south across an old erosion surface of low relief. Hanging valleys and larger valleys at lower levels join the pass at frequent intervals, especially in the central and southern sections where the mountains are highest and most heavily glacierized. The great majority of the tributary valleys contain glaciers with fresh moraines: the moraines are believed to have been formed within the last seventy years and the glaciers themselves are now wasting back and rapidly thinning. There was also an earlier advance of the hanging glaciers. Before that time the whole of Pagnirtung Pass and Pagnirtung Fiord was occupied by trunk glaciers which flowed north and south from the summit of the pass, where even today there is a concentration of large glaciers. The apparent absence of raised beaches along the margins of Pagnirtung Fiord suggests that the southern trunk glacier may have been in existence throughout the latest marine transgression.

Evidence based on geological structure, valley gradients, directions and volume of former ice flows, drainage patterns, and other factors supports the view that Pagnirtung Pass *could* have been excavated by local rivers and glaciers: it is not necessary to assume through-flowing glaciers from north or south of Cumberland Peninsula, though these may well have existed.

Zoology. By A. Watson

The zoological work included collecting specimens of the local fauna and biological studies of some species, especially the breeding birds.

The first two weeks of the expedition were spent travelling by sledge from Padloping to the neighbouring outer islands, and included a visit towards the end of May to the fulmar colony on Cape Searle island.¹ It was estimated that not more than 25,000 fulmars were in occupation of the colony at this time, and that open water was only about three miles away. No sign of breeding was noticed and the gonads of several specimens did not appear from external examination to be in full breeding condition. In a sample count of 446, 79 were of the light, white-headed colour phase.

Later, the Biological Camp in the Owl valley was reached after travelling up Padle Fiord and the June River. Permanent camp was set up there in

¹Wynne-Edwards, V. C. 1952. "The fulmars of Cape Searle". *Arctic*, Vol. 5, pp. 105-17.



Photo: J. A. Thomson

Fig. 12. Biological Camp looking up Owl River towards Mt. Battle and Mt. Asgard.

early June and work was concentrated on a 7-mile-long stretch of the main valley for the next two months.

This summer lemmings were abundant in both the Padle and Owl river valleys. Although both genera (*Lemmus* and *Dicrostonyx*) were present, the great majority were *Lemmus*. In the same area, examination of lemming bones from old owl nests showed that in three different previous years *Lemmus* was also dominant.

It was not surprising to find snowy owls, *Nyctea scandiaca*, common. A special study was made of their breeding biology and behaviour, lasting from incubation time until after the young could fly. One bigamous male was found and at least four other males were monogamous. The average clutch size of 6 nests was 8 eggs.¹ At several nests a fairly continuous record was kept of such events as hatching, food, and growth rates of the young. In the owl pellets, the lower jaw bones of the lemmings nearly always remained intact. These were used for quantitative and qualitative estimates of the food eaten by the young. After human invasion of the nesting area or of favourite perching places, the owls showed aggressive and often distraction behaviour. At these times their reactions became confused and a variety of marked "displacement activities", such as displaced coition, hunting, and tearing up of prey, were frequently observed.

From study of the breeding passerine birds, it was clear that the habit of re-using nests built in previous years, discovered in redpolls and wheatears

¹Two with 9 eggs; 2 with 8 eggs, and 2 with 7 eggs.



Photo: J. A. Thomson

Fig. 13. Watson fishing at Biological Camp.



Fig. 14. Snowy owl and young near Biological Camp.

Photo: J. A. Thomson

at Clyde in 1950,¹ also occurred in this area. Pipit, snow bunting, redpoll, and Lapland longspur were found re-using old nests. In these species incubation usually began with the laying of the first egg. This resulted in a spread in hatching and fledging. Territorial behaviour was either lacking or else minute in comparison with temperate regions. There was a marked drop in singing activity in early July; shortly after this time the size of testes from snow bunting and longspur specimens rapidly decreased, and the moult began. Most of the passerine birds left the area about the end of July to early August. There was evidence of a migration route through the pass, used by common and king eider ducks moving north in the latter part of July, and by passerines moving south in August. Common redpolls, *Acanthis flammea*, reared young in several places in the Owl and June river valleys, but only a few hoary redpolls, *A. hornemanni*, were seen.

Arctic fox, weasel, and ptarmigan were all uncommon, and only a few broods of ptarmigan were found in the whole pass. A single caribou was seen by the expedition. Several arctic char were taken in the small stream and lake just south of the Biological Camp, and collections of invertebrate animals were also made, especially insects, spiders, and freshwater fauna. Thirteen mammal and thirty bird specimens were collected.

Botany. By F. H. Schwarzenbach

The main purpose of the botanical work was to compare the plant communities of the Penny Highland with the vegetation of the arctic mountains of east and north Greenland.

During the summer a comprehensive collection was made of the vascular plants in the Pagnirtung Pass area, including large numbers of critical species of the genera *Poa*, *Draba*, *Salix*, *Luzula*, *Melandrium*, and *Antennaria*. In addition some mosses and lichens and a large number of epiphytic fungi were obtained.

The flora of the region consists of about 100 species. The small number is due to the absence of the calcicolous element and of species from coastal areas. The taxonomic work will be done in Canada and in Switzerland. Special studies were made of the ecology of vascular plants, especially of species which are absent in Greenland.

The writer spent the first four weeks assisting in the seismic work, but was able to fit in three field days in the region of Highway Glacier comparing the vegetation of isolated nunataks and determining the altitudinal limit of the vegetation. Two periods were spent at the Biological Camp. On the first, a detailed survey was made of the flora and plant communities, and a two-day reconnaissance trip taken to the upper lake in the June valley, thence across a 2,600-foot pass to the upper Naksakjua valley. Later, comparative studies were started. At the Base Camp ten days were spent studying ecological problems and making observations of the development of plant

¹Wynne-Edwards, V. C. 1952. "Zoology of the Baird Expedition (1950). 1. The birds observed in central and south-east Baffin Island." *Auk*, Vol. 69, pp. 353-91.

communities. On the second visit to the Biological Camp the changes in the vegetation since the earlier visit were noted and detailed work carried out on some species. A reconnaissance trip was made to the upper Naksakjua valley and thence to Tundra Lake, where a profile was taken of the vegetation from its limit at 3,600 feet to the birch belt at 500 feet around the lake. The remainder of the summer was divided between the Base Camp, where three vertical profiles were obtained of the vegetation and analyses made of the food of lemmings and birds for Watson, and the south Pangnirtung Pass area where the vegetation was studied.

The region to the east of the Pangnirtung Pass proved the most interesting. In the June and Naksakjua valleys the vegetation contained numerous relicts of a warmer period, which compare with relict vegetation found in the mountains east of the Penny Icecap. By contrast, the Owl River valley, only a few miles to the west, has a very young vegetation which must have invaded the valley during the last 150 years only.

The summer's work showed that the vegetation in the Penny Highland and in the mountains of east and north Greenland is basically the same, with only slight differences caused by local climate and local groups of species. The higher precipitation in the Penny Highland results in a relative dominance of cryptogams, and some special ecotypes in the genera *Poa*, *Potentilla*, and *Melandrium* deviate from the Greenland ecotypes. The altitudinal limit of vegetation in the Baffin area was about 3,600 feet on west-facing slopes, a low figure when compared with 3,300 feet in northeast Greenland north of 80 degrees.

Mountaineering and surveying. By J. Marmet

From the Base Camp the highest mountains of Baffin Island were accessible. In this region there were so many large peaks, some capped with ice, others sharp and outstanding, that it was difficult to select the most beautiful and interesting peaks for climbing. As part of the climbing program we planned to determine the heights of the highest mountains.

The time for mountaineering was limited by the progress of the scientific work. Baird and the Swiss seismic team had planned to stop work for two weeks during the best period for mountaineering, but were held up for some days at the Base Camp, and then by poor weather at the mountain cache (M on the map). After 5 days waiting in a small tent without being able to see more than a hundred feet through snow or rain, the group decided to return to the Base Camp and to continue the seismic work.

However, eight peaks were climbed between periods of scientific work. Mt. Battle (4,420 feet), above the Base Camp, was climbed first by Baird, and later by most of the expedition members. From the top there was an excellent view of all the glaciers round the Base Camp. Weber climbed a high flat snowpeak (c. 6,900 feet) to the east of Camp A2, and Marmet climbed a high snowpeak (c. 6,930 feet) to the south of A2 for survey work. Together, on June 27, Marmet, Röthlisberger, and Weber climbed a big rock tower

(5,180 feet) behind Camp A3 by a long gully and a rock face 300 feet high. The tower gave a wonderful view of Highway Glacier from the ice cap down to the snout.

Two days later they climbed Tête Blanche (7,073 feet), later shown to be the highest local mountain, by the northwest ridge, and had a difficult descent in poor weather. On July 13, a fine clear day, the four Swiss members climbed Mt. Asgard (6,596 feet), a very impressive rock tower. The rock climbing was extremely difficult, and the whole excursion took 25 hours. On August 5 Marmet climbed an outstanding peak (6,440 feet) to the southeast of A3. The most beautiful and second highest mountain (7,014 feet), which we called The Queen, was climbed by Baird and Marmet on August 25 in a 12-hour excursion by a long gully, snowfields, and a rock ridge, which necessitated some step-cutting and difficult climbing. Three days later this peak was climbed by three other members of the expedition.

A small, light Wild T 0 theodolite, was taken for the mountaineering survey work. It was first used on the snowpeak to the south of A2, which Marmet climbed on a fine day with unlimited visibility, after three unsuccessful attempts because of poor weather. Some days later the theodolite was carried to the top of Tête Blanche, and the angles of 10 high mountains and Camps A1, A2, and A3 were taken before the weather suddenly changed while the party was on the summit. This survey showed that any one of three mountains might be the highest, but that the T 0 theodolite was not accurate enough to determine such small differences.

Therefore, towards the end of the expedition, a new base was measured at the Base Camp with the more accurate Wild T 2 theodolite. The angles of 25 mountains were taken with this instrument from the summits of Mt. Battle and an unnamed peak (4,950 feet) to the northeast of Glacier Lake, and it was found that Tête Blanche was the highest. The determination of the refraction was very difficult, if not impossible, during this short period which was broken by some days of bad weather. To get the absolute altitude of the base at the Base Camp another base was measured on Pangnirtung Fiord and the angles taken of four mountains that had also been measured from the Base Camp region.

Photography. By J. A. Thomson and J. R. Weber

The photographic coverage of the expedition included motion and still pictures. With a 16 mm. Cine K. Kodak and telescopic lens 3,700 feet of colour film were exposed, covering the arrival at Pangnirtung, setting-up of camps, living conditions, work at each camp, and transportation, including a dog-team trip up Pangnirtung Fiord. The opportunity also occurred to shoot scenes of a white whale hunt with Eskimo boats. A Busch Pressman $2\frac{1}{4} \times 3\frac{1}{4}$ plate camera was used for black and white photography. Film was provided by the expedition for those members who brought their own cameras. From all this material a collection of colour transparencies and black and white prints will be made for the Institute.

J.A.T.

A second cine camera, a Paillard H16, with a "Macor" reflex focussing device for micro-cinephotography, was provided by the Swiss Foundation for Alpine Research. With this camera, 2,200 feet of colour film were exposed, covering mainly the activities of the Swiss team, the flight to the ice cap, seismic work, biology (breeding birds, close-ups of flowers and insects), mountaineering, Eskimo life, and a seal hunt. The Swiss members also took still pictures, using 3 Exacta-Varex cameras for colour photography, and a Rolleicord 6 x 6 cm. for black and white.

J.R.W.

New Names

The following names have been approved by the Canadian Board on Geographical Names:

Coronation Fiord: Coronation Glacier flows into this fiord.

Coronation Glacier: First reconnoitred by us on the day of Her Majesty's Coronation.

Fork Beard Glacier: The ice of this glacier divides and falls in two rippled tongues to the valley floor.

Highway Glacier: The main expedition route from Base Camp to the Penny Icecap.

Maktak Fiord: Abbreviation of the local Eskimo name Maktartudjennak (Boas map), meaning the place where one eats white whale skin.

Mt. Asgard: Spectacular rock tower resembling the Norse gods' home illustrated by Van Loon.

Mt. Battle: After the late W. R. B. Battle, a member of the expedition.

Mt. Fleming: After the late Bishop Archibald Fleming, Anglican missionary.

Naksakjua River: Local Eskimo name, meaning Big Valley.

Owl River: Many snowy owls nesting here in 1953.

Penny Icecap: The general region here was named Penny Highland by Boas.

Rundle Glacier: After the late Nurse Rundle of Pangnirtung.

Tête Blanche: Ice-domed highest peak.

Turner Glacier: After the late Rev. H. A. Turner, for many years a missionary at Pangnirtung.

Weasel River: A tiresome number of weasels here in 1953.

The names above appear on Fig. 4, and are published for the first time. The following names were also approved by the Board, but are outside the area of the map:

Greenshield Lake: After Rev. E. W. T. Greenshield, Baffin Island missionary.

For the 17-mile-long lake on the west side of the Penny Icecap.

Kumlein Fiord: After Ludwig Kumlein, the naturalist with the Howgate expedition 1877-8. A colony of the gulls named after him nests on a cliff in this fiord, which is the large inlet to the north of Abraham Bay, east side of Cumberland Sound.