GLACIAL GEOMORPHOLOGY IN THE KAUMAJET MOUNTAIN AND OKAK BAY AREAS OF NORTH EASTERN LABRADOR

by

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CHAPTER 1

INTRODUCTION TO AREA AND FIELD WORK METHODS

Arguments concerning the nature and extent of the North American glaciation as a whole, and that of Labrador in particular, have been regularly appearing in print from 1883 until 1959. From the theories and reports presented it is possible to draw together several distinct lines of thought.

Early work by Bell (1882-84), Daly (1902), and Coleman (1921) suggested that the higher parts of the eastern edge of north east America had not been covered by continental ice. Coleman goes as far as to say that in the Nachvak area, "the unglaciated condition is known to reach at least 50 miles inland, giving a driftless area of perhaps 3,000 or 4,000 square miles", though he concedes that valley glaciers must have reached the sea in areas to the south of Nachvak.

Later work by Odell (1933), followed by Tanner (1944), and Flint (1943, 1947, 1952 and 1957), refuted the early work, and suggested - mainly on Odell's evidence - that the area had been completely inundated by ice at the Wisconsin maximum. In 1943 Flint correlated much of the evidence that was available at the time, and in particular coordinated climatic theory and geological evidence. His thesis embraced the complete growth and decline of the Wisconsin ice sheets. With regard to the Labradorean Ice he envisaged an initial accumulation on the eastern coastal mountains with early flow to the west. The accumulation of ice in the piedmont area, aided by climatic factors, gained continental proportions and the subsequent westward shift of the ice divide was accompanied by a reversal of flow to the east, through the coastal mountains. Flint further suggested that in the final stages of the Wisconsin these conditions were reversed, the last active glaciers being confined to the coastal mountains.

Ives (1957) has contributed extensively to the present understanding of the Labrador glaciation by means of his examination of Flint's hypothesis in the Torngat Mountain area during the summer of 1956. He concludes, first, that the Torngat Mountains were completely submerged by eastward-moving continental ice at the height of the last major glaciation; secondly, that local glaciers in the Torngat never reached significant dimensions; thirdly, that instantaneous glacierization of a large area of the Labrador-Ungava plateau was the most likely method of initiation of the continental ice. With regard to the regime of the ice itself, Ives recognizes two, possibly three separate glacial periods in the area, and proposes that the final stage of ice activity saw movement from the west followed by rapid downwasting of the ice in situ.

Clearly, the conclusions presented by Ives must be considered in conjunction with the theoretical approach of Flint. But it is equally clear that other areas must be analysed and fitted into the regional theory before any sound conclusion concerning the whole of the Labrador glaciation can be reached.

Significant systematic considerations may illuminate the regional features of the Labrador glaciation. Regarding the question of inundation or isolation of mountain-tops during the ice maximum, phytogeographic evidence may be examined. Early work, particularly by Wille (1915) and Fernald (1925), advanced the hypothesis that the plant communities at present in position on the summits of coastal mountains in areas that have been subject to widespread glaciation could exist in their present position only if the summits were ice-free during the glacial maximum. Later work by Abbe (1938) and Porsild (1922) suggested that the flora could return to the area from southern refuges after the glaciation had completely inundated the summits. Lőve (personal communication) suggests that the plants currently found in Labrador travelled along the continental shelf exposed by a lowering of sea level in glacial times, while the inland areas were covered with ice. A clearer understanding of these problems would result from a sound knowledge of glacial activity in the region. The question of summit inundation is critical both in the work of Dahl (1946) regarding the marginal slope of continental ice sheets, and in the work of Ives (1958) regarding the occurrence of mountain-top detritus. Dahl advances the hypothesis that the maximum marginal slope possible on a continental ice mass is 1:100, and that on the Labrador coast summits in excess of 3,000 feet would be left as nunataks at the ice maximum. Evidence from the Torngat mountains (Ives, 1957) suggests that both the inland and coastal summits were inundated by ice, and climatic considerations suggest that at the Wisconsin maximum ice was even thicker in the south. Further direct evidence regarding the state and height of coastal summits, coupled with the width of the adjacent continental shelf, would have to be considered before Dahl's hypothesis could be regarded as a sound contribution to the regional geomorphology of Labrador.

Ives, from work in an area in the Torngat that was subject to late-stage valley glaciation, suggests that mountain-top detritus occurs only on summits unaffected by the Koroksoak (Wisconsin) glaciation. This hypothesis may be perfectly sound with regard to the Torngat area, but, as Ives points out, it has not been critically examined elsewhere in Canada. Such an examination would be necessary before determining whether the distribution of mountain-top detritus can be used as an indicator solely in areas subject to late-stage valley glaciation, or whether it is valid as an indicator of upland areas isolated from continental glaciation.

To provide data on as many of these problems as possible, fieldwork was planned in the Kaumajet Mountain and Okak Bay areas of north eastern Labrador.

Figure I - SKETCH MAP SHOWING POSITION OF FIELDWORK AREAS IN NORTH-EASTERN LABRADOR

The Kaumajet Mountains (latitude 57°50' N., longitude 62°00' W.) have a maximum height of approximately 4,000 feet and are situated on the Labrador coast to the south of the Torngat Mountains (latitude 59°50' N., longitude 64°40' W.).

Such an area comes under what theoretically should be a thicker part of the Wisconsin ice sheet, and is thus critical with regard to the occurrence of nunataks.

Fieldwork was planned to attain the following specific primary objectives. First, and most important, the maximum level of inundation of the mountain mass was to be determined and the question was to be resolved of whether or not these relatively high coastal mountains were completely inundated by ice. The second primary objective was to determine the nature of ice movement in the area, and to resolve whether the ice affecting the area originated from the continental interior or from the mountains themselves. A series of secondary observations could immediately be appended to the primary objectives. Of these, an examination of the mountain-top detritus in relation to the inundation level was most pertinent, particularly in the light of Ives' work suggesting that such detritus could indicate areas subject to late-stage valley glaciation. Another important secondary objective was the manner of the disappearance of ice from the area at a part of Labrador remote from the source of continental glaciation.

Further inferences could be drawn from the establishment of the first primary objective, the level of inundation. If the minimum level of maximum inundation could be estimated at a point on the coast, additional quantitative data could be applied to Dahl's theory of the marginal slope of an ice sheet.

The understanding of the glacial activity in the area would bear directly on the phytogeographical theories regarding the movement of plants in Labrador. To this end it was planned to make a collection of plants in the Kaumajet Mountains.

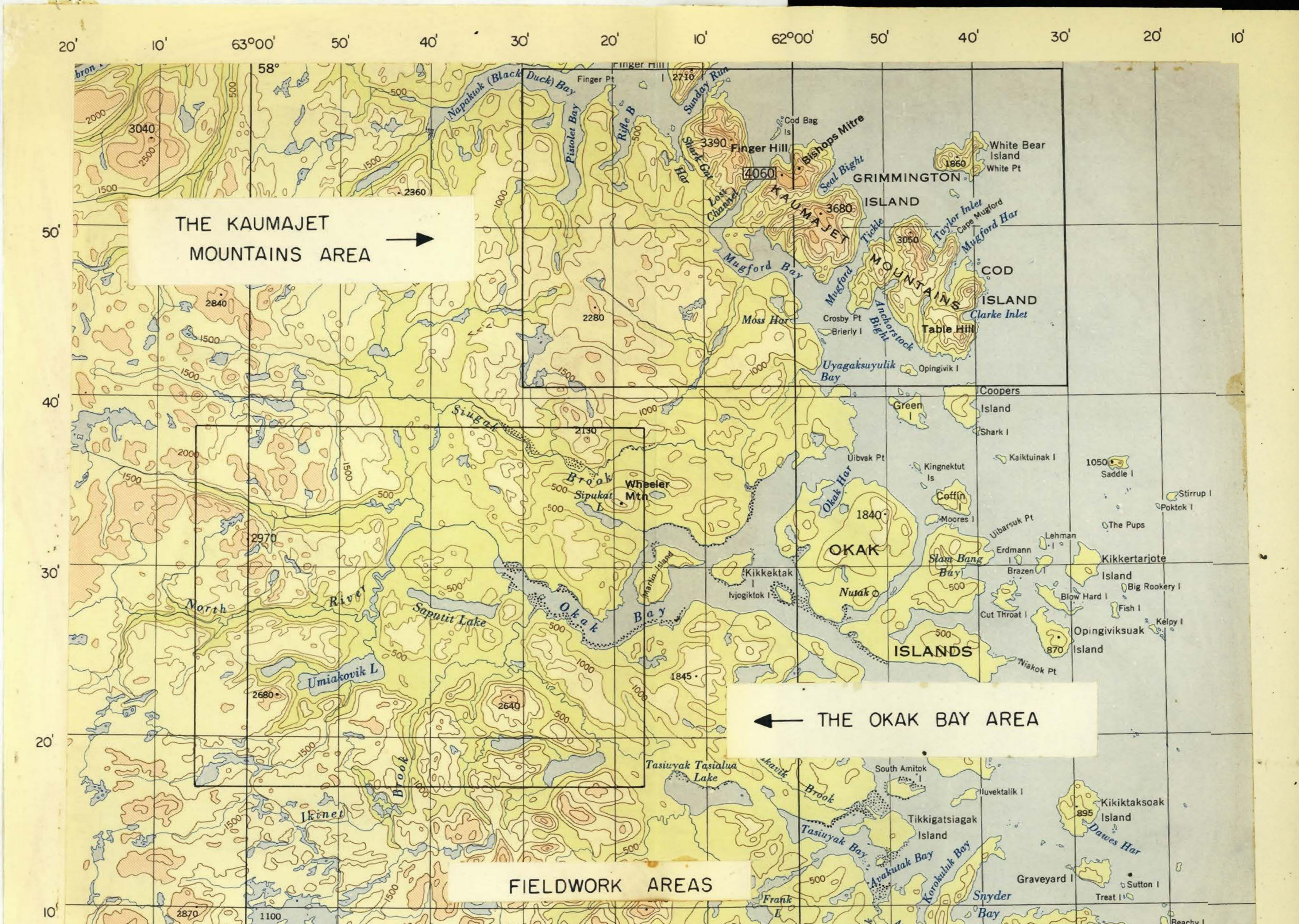

THE KAUMAJET MOUNTAINS AREA
THE OKAK BAY AREA
FIELDWORK AREAS
KAUMAJET MOUNTAINS
GRIMMINGTON ISLAND
COD ISLAND
OKAK ISLANDS
Finger Hill
Bishops Mitre
Table Hill
Wheeler Mtn
Mugford Bay
Okak Bay
Saputit Lake
Umiakovik L
North River
Kikkertarjote Island
Opingiviksuak Island
Kikiktaksoak Island
Tikkigatsiagak Island
White Bear Island
Coopers Island

Figure 2

One of the most important problems, however, was the possibility that there were separate phases of glacial activity in the fieldwork area. Careful pre-fieldwork examination of air photographs showed that the strong relief of the island blocks of the Kaumajet Mountains would not have facilitated the accumulation of the depositional evidence so important in resolving such a problem. This lack of depositional evidence also hindered both the assessment of the manner of disappearance of the ice and the documentation of the final stage of glacial activity.

To answer this requirement it was decided to extend the fieldwork into an area which, while it was close enough to the Kaumajet Mountains to be considered under the same climatic and regional effects of the Pleistocene period, presented a series of depositional forms which would allow the pattern of recession to be determined. A careful study of aerial photographs revealed an extremely prolific assemblage of depositional forms approximately 20 miles south of the fieldwork area in the vicinity of Okak Bay. This observation was supported by Wheeler, who had completed the geological survey of part of the area concerned. The extension of the fieldwork into the lowland area was thus planned to allow examination of evidence which was lacking in the Kaumajet area but which would have direct bearing on possible separate phases of ice activity, on the nature of the regional recession and on final stages of removal of ice from both areas.

Available large scale topographic maps of the Kaumajet Mountain and Okak Bay areas were limited to the 1:506,880 series produced by the Department of Mines and Technical Surveys, Ottawa, Ontario. This map provided a good outline of the areas concerned; but, as the scale was only 8 miles to 1 inch and the contours of the area were at best only form lines, they could not be used for preliminary terrain investigation or fieldwork planning. Air photographs from

R. C. A. F. 17,000 foot flight lines were available, and a stereoscopic cover of the Kaumajet Mountain area plus map cover of the Okak Bay area was obtained. From the air photographs an uncontrolled photo mosaic was laid down and a large scale field map was traced. The area was examined as a whole from the mosaic and in detail from individual photographs. From this investigation the areas containing distinct glacial evidence were determined. As well, the limited time available for fieldwork was planned so that the critical areas could be examined. A good estimation of the terrain types to be covered was also gained, and the method of travel and equipment to be used were planned accordingly.

The party was taken by air to Hopedale, and thence by coastal steamer to Nain. A fishing boat and crew transported the party, plus the equipment and a canoe, to the narrow isthmus separating Lost Channel and Neisser Inlet in the Kaumajet Mountains, where the party arrived on 9 July 1958.

The Kaumajet Mountain terrain differs markedly from that inland of Okak Bay. The former is characterized by treeless, sheer-faced mountain blocks, cut by steep-sided valleys, and accessible only from the open sea or from the fiord inlets. The latter consists of wide, densely-vegetated valleys cut into flat-topped rocky uplands, through which flow large and very swift rivers with numerous rapids.

In the Kaumajet area, the 18 foot canoe, powered by a $5\frac{1}{2}$ h.p. Johnson outboard motor, was used for transport around the islands and along the mainland coasts. Secondary camps were established at points on the coast from which the inland areas were accessible, and light camps were set up inland from which investigations were carried out in all directions. In this manner an extensive coverage was possible.

On 15 August, the party was picked up by pre-arrangement with a fishing boat and was taken to Okak Bay. A base camp was established at the head of the bay and from there investigations were carried out inland. The canoe was used on the major rivers and their tributaries, being portaged or waded past rapids, until the desired areas were reached. At these points a "canoe camp" or secondary base camp was established close to the main stream, and from the canoe camp the area was examined on foot, between light camps. It was found convenient to work out of canoe camps for up to seven days. By this method a close examination, even of the densely-vegetated features, was completed.

The party left Okak Bay on 12 September and returned to the McGill Sub-Arctic Research Station at Knob Lake via Nain and Hopedale.

The equipment that was taken and used had been determined by the terrain and method of travel, by the time available, and by the essentially reconnaissance nature of the fieldwork.

Visual observations were recorded in the form of field-notes and on film. Two 35 mm. cameras were used. Despite the loss of one complete roll of 36 exposures and several portions of other films, due to moisture damaging the emulsion of the black and white film, over 750 satisfactory colour and black and white photographs were recorded, each individually logged at time of exposure.

Surveying instruments comprised two Paulin 5 inch aneroids with thermometer and lens, one Brunton compass, one Abney level, one plane table and tripod, one 100 foot and one 8 foot steel tape. The surveying aneroids were most important instruments and were in constant use. They provided a readily transportable method of determining relative heights, and both consistently gave results within reading error. Several methods for use of surveying aneroids are suggested in the Paulin handbook which accompanies the instruments. The method found most suitable in the fieldwork area was the simplest way of correcting atmospheric fluctuations, that of rounding out the survey at fixed points. The air temperature was also taken at each reading, and the subsequent correction for air density was applied to the reading already corrected for atmospheric fluctuation, according to the values tabulated in the Paulin handbook. This method works well when surveys are made from standing camps or when fixed points can be returned to. A practice was made of using as many fixed points as possible, and rounding out to them, even when working from standing camps. A weakness in this method is apparent when a straight line traverse is made, as, for example, when one is travelling on a river in order to reach an inland area and the journey requires several days to complete. In this case, atmospheric and density correction would be meaningless, and in the event of fast barometric fluctuations, the readings obtained could be very inaccurate. When one has two aneroids, it is suggested that one leapfrogs, i.e., as one aneroid remains stationary the other is taken forward to a fixed point. However, in practice during fieldwork, particularly in conditions of terrain of high relief or dense vegetation, it is extremely hazardous to separate the members of the party, and often when transport such as a canoe is being employed, it is impossible. Thus, despite the accuracy of the aneroid instrument in most locations, its use in a few conditions as outlined above must be regarded as unreliable. For this reason, heights given in the report for inland areas will be relative rather than absolute, unless a known inland height has been available.

The Brunton compass was used in both Kaumajet and Okak Bay areas. It was found, however, that magnetic influences in the Kaumajet Mountains were locally very strong and fluctuated over short distances. This made the Kaumajet

Mountain readings unreliable and consequently few were recorded. This was a particular loss when the direction of striae had to be noted, and on the occasions when the party travelled across the upland surface in thick fog. In the Okak Bay area magnetic variation was more or less constant, and the compass was used frequently for sights and ground orientation of features. The compass was also used as a clinometer to a limited degree with satisfactory results.

The principle of the Abney level is well known and needs no explanation here. The level was used extensively, in all direct measurement of slopes, and in sketch surveying to determine comparative heights of inaccessible topography. A plane table was taken to provide for the possibility that a small area might require surveying in some detail. The widespread nature of the main features concerned and the element of time available on this preliminary investigation of the area did not make its use possible, or at this stage, necessary. Lateral measurements in terms of one or two miles were a difficulty, which was to some extent solved by the assumption of relatively uniform scale and measurement of distance in the centre portion of air photographs. For shorter distances, pacing, or tape, was utilized.

The method of work in the field concerns basically the observation of landscape features and the sound explanation of the genetic relationship between these features.

In the field, vertical air photographs were used extensively for preliminary recognition of major landscape features, and route location.

From this primary observation of landscape, observation of the features was carried out from the ground and the first record of the feature made. This record was made in notebook and on film. Annotated sketch maps were used extensively, and location was noted with reference to air photographs rather than to the topographic map. At this stage the consideration of the mental working hypothesis indicated whether detailed examination and detailed measurement were necessary.

Instrumental measurements were determined as described above. The results were again noted and recorded.

It will be noted that there is a reluctance to record the working hypothesis or hypotheses. This is because it was considered an unsound approach to state a definite hypothesis in explanation of a feature and then to work from hypothesis to hypothesis through the area. Rather, it was decided to record observations and later, when the relationship of feature to feature became apparent (or at least when the features could be thought of in relation to one another, through examination of other features in the area), to advance a hypothesis which regarded the area as a whole, the detail of the explanation being taken from the detailed observations recorded.

This method was found satisfactory in the field, and is the method which underlies the work and conclusions to be presented. The final conclusions are the result of considering the fieldwork hypotheses as a whole with regard to the body of knowledge of Labrador.

CHAPTER 2

GEOLOGY

The geological evolution and present lithology has markedly influenced the more recent glacial and geomorphological processes in both the Kaumajet Mountains and the Okak Bay area.

Previous work in the Kaumajet area by Daly (1902), Odell (1933), Kranck (1939), and Tanner (1944), with the more recent work by G. Vibert Douglas (1953), has led to the following understanding of the pre-pleistocene geology.

The basal gneissic complex underlying the Mugford Beds is highly metamorphosed, due to strong tectonic deformation and to granitization. G. Vibert Douglas suggests that the early sediments were depressed into a granitic magma, and in fact recognizes the basal complex in the north of Green Island as a biotite granite. Kranck tentatively correlates the gneissic formations with the Timiskaming or Keewatin series in Canada, but points out that this does not exclude the possibility of tectonic movement in these old gneisses which might be of comparatively more recent date.

The gneisses in the Kaumajet Mountain area are typically migmatic gneisses, but the basal material is quite calcareous (in a broad sense, to distinguish them from the gneisses further south). On the whole, however, they represent the undifferentiated basal rock known in every Pre-Cambrian area where denudation has removed the overlying, less altered formations of Huronian, or still greater, age. In aspect the gneisses are of the vein type, often consisting of a white pegmatite granite with dark interlayers. Flow structure is readily apparent, and deformation is strong.

Unconformably superimposed on the gneisses are the marine laid sediments forming the lower portion of the Kaumajet massif. The surface of this unconformity would, if produced, rise to seaward so as to pass completely over Nanuktut Island. On Cod Island, Odell found the gneisses overlain by a sheet of diabase about 50 feet in thickness, upon which were piled slates, quartzites, limestones and sandstones. Daly reports the same series from south west of Mugford Tickle on Grimmington Island. The sediments seem to vary from sandy mudstones to calcareous mudstones, and pass through a black mud facies. G. Vibert Douglas shows that the sediments are slightly folded, and have been subject to igneous activity, porphyrite, hornblende, porphyrite and diabase having been intruded in that order. The formation of slates was due to compression that followed these intrusions. The gneisses have participated in the folding of the sedimentary cover, and Daly suggests that it is because of this that they do not appear in the middle cliffs of Mugford Tickle. On the north west side of Mugford Tickle Daly recognizes a flat syncline with a north-west-south-east axis crossed further inland by a transverse warp, the latter feature being conspicuous in the morphology of the southern shore of Grimmington Island. The thickness of the sedimentary layers has been estimated as approximately 900 feet. The upper surface of the sedimentary series has undergone considerable erosion and presents an unconformable junction to the overlying formations.

The sedimentary rocks are overlain by series of volcanic outpourings which have a minimum thickness of 700 feet and which form the main mass of Brave Mountain (4,100 feet). G. Vibert Douglas counted more than twenty-five separate lava flows on the heights above the north eastern end of Anchorstock Harbour, and suggests that the total number may be considerably greater than that.

Several types of lava and volcanic products have been distinguished. Odell reports a trachytic tuff from the summit of Bishop's Mitre; Kranck details 600 feet of andesitic lava capping parts of Grimmington Island; G. Vibert Douglas demonstrates pillow lava in at least one of the flows and Daly recognizes varying thicknesses of volcanic breccia. The dominant lava is, however, a basalt, sometimes in the form of a basaltic agglomerate; these ferro-magnesian-rich rocks weather to give the characteristic rust-red appearance of the Kaumajet Mountains.

The source of these volcanic lavas is not definitely known. Kranck suggests that the structure of the sides of Mugford Tickle may indicate the existence of an old crater at that point, but this view has not been confirmed by other writers.

The lavas have an almost horizontal deposition, and provide the very resistant cap rocks of the mountains. They are not greatly folded, apart from the downwarping at the Mugford Tickle flexure, though major faulting must have occurred after their deposition. Kranck suggests that the Mugford formation as a whole consists of a block which has sunk down in relation to the formation of the present coast line. Both lavas and sediments are eroded down to their roots, and the cliffs now rise in almost vertical scarps, owing to the relatively fast weathering of the less resistant strata under the cap rocks. It is probable that this type of weathering isolated the Kaumajet massif prior to Tertiary times, but it is suggested that the dislocation of the mountain blocks was due to tectonic activity during the Tertiary period. Both theoretical considerations and field evidence lead to the conclusion that the present form of the major blocks and the broader elements of the topography in the Kaumajet Mountains existed in immediately pre-glacial times.

The present knowledge of bedrock geology in the Okak Bay area is due almost entirely to the work of Wheeler (1935, 1957 and personal communication).

The basal complex is composed of gneisses similar to those underlying the Kaumajet Mountains. In the gneiss areas the foliation as a rule trends west of the intrusive rocks around Umiakovik Lake. The gneisses vary slightly in lithology, and the hornblende gneiss and the acid garnet gneisses tend to be relatively hard and are often ridge-forming elements. Superimposed on the gneisses is the anorthosite group of basic igneous rocks, included in which are a few minor occurrences of ultrabasic rocks. The anorthosites are grey, and essentially monomineralic, though accessory minerals in the troctolite range characterize those in the south (Morse, personal communication) while a dark, often olivine-bearing series is common in the north. The main outcrop in the Okak Bay area is between Umiakovik Lake and Umiakoviarusek Lake, lying across Umiakoviarusek River to the east of Ikinet Brook.

Minor intrusives occur in the anorthosites: these include olivine gabbro, diorite, monzonite and granodiorite. They do not, however, form significant outcrops in the immediate area of Okak Bay.

Widespread outcrops of adamellite occur to the south of the gneissic complex. Umiakovik Lake is entirely within the adamellite series, as is the major part of Umiakoviarusek Lake. A further outcrop caps the ridge of the north east of Umiakoviarusek River. These biotite granites are distinctive rocks, being coarse-grained, and often having a well-weathered surface. When fresh, they would tend to be extremely resistant to mechanical erosion. They are, however, remarkably subject to chemical action and often present a crumbling, rotten exterior due to the breakdown of the feldspars. Despite this, the adamellite outcrops comprise much of the upland to the south of Okak Bay.

Joints and flow structures are common features in all the major rock outcrops and often influence minor topographic forms. Large scale faulting has been recognized, but is not widespread in the area. The largest fault is the one running from Tasiuyak Bay to Okak Bay, which is probably responsible for the north-west-south-east alignment of the westerly portion of the bay.

It is interesting to note that this fault is parallel to the one which runs along Mugford Bay, and that both of these faults are at right angles to the inferred fractures through Mugford Tickle, Lost Channel and Sunday Run in the adjacent Kaumajet Mountains.

While glacial action has been responsible for the detailed sculpturing of the Okak Bay area, the broad outlines of upland and lowland show a direct relationship between their geology and topography. Areas of granite and anorthosite tend to be higher than adjacent areas of gneiss: here, the coastal summits, composed of igneous material, are often higher than the summits on the watershed, which is largely composed of gneiss. Even disregarding the example of the Kaumajet on the grounds that they are composed of volcanic rather than plutonic material, one can point to the Kiglapait Mountains, Mt. Thoresby and Mt. Lister, which are all plutonic and have a height greater than 3,000 feet. On the other hand, the gneissic summits of the watershed rarely exceed 2,500 feet.

Within the immediate vicinity of Okak Bay, the anorthosites seem to form the higher parts of the upland, with their rounded summits in the region of 3,000 feet. The adamellite series is only a little lower, having the tops of many outcrops at approximately 2,500 feet. The gneisses at the coast form the lowland tracts, with often a sharply marked contact between gneiss and plutonic rocks. The lowland of Okak Bay is defined by the gneissic contact and its southern margin is indicated by the pronounced scarp to the south of Ikinet Brook. Minor relief does occur within the gneisses, as in the low hills around Saputit Lake, and in those to the north between North River and Siugak Brook.

The area immediately to the north of Okak Bay has not been geologically surveyed in detail. Nevertheless, field observation indicates that the relationship between upland relief and plutonic outcrops is essentially similar to that already described in the southern half of the area.

Differential erosion has been as significant a factor in the formation of the landscape under conditions of fluvial erosion as it has been under conditions of glacial erosion, and the Okak Bay area was subject to prolonged sub-aerial erosion before the onset of glacial activity. It is suggested that in this area the broad relationship of highland to lowland, as expressed in the present-day geology and topography, was established prior to its accentuation and modification by ice action.

Fig. 3

SECTION 2 - THE KAUMAJET MOUNTAIN AREA

CHAPTER 3 - BASIC PHYSIOGRAPHY AND PREVIOUS WORK

The Kaumajet Mountains form a distinctive group that Daly described as the "Himalaya of Labrador." From as far south as 50 miles on the sea approach the flattened tops of the group may be seen rising above the surrounding country, but only on close observation is the full form and size apparent.

The mountains fall into three major blocks, each about 10 miles square, the inland block being slightly smaller than the others. The blocks are separated by channels which at their narrowest points are less than a mile wide and at their entrances less than 2 miles wide. The central block is joined to the mainland by a small neck of land, and is itself properly mainland. Nevertheless it is referred to as Grimmington Island on the Admiralty charts and from the point of view of transportation has the characteristics of an island. Cod Island is the most easterly block and forms the southern extremity of the Kaumajet; it is separated from Grimmington Island by Mugford Tickle.

Each of the blocks reaches the height of between 3,000 and 4,500 feet. The summit area is a wide, undulating surface of rounded hills with a local relief rarely exceeding 700 feet. This surface is sharply and dramatically terminated by cliffs often falling 2,000 feet either directly to sea level or to the gneissic series which forms a basal raft. The blocks are further divided by deep valleys, such as Horr Valley, which crosses Grimmington Island from Horr Harbour to Seal Bight and has most of its floor below 600 feet. At the western extremity of the group a marked precipice separates the inland mountain block from the lower land to the west. This high, steep wall of sediments capped with basalt, with scree slopes covering its lower part, forms a barrier which is entirely characteristic of all three mountain blocks and which was to make access to the summit level difficult.

On the northern and eastern sides of the group, and to a lesser extent in the south, the mountain wall has been deeply sculptured into magnificent cirque forms occasionally extending from mountain top to sea level. The larger cirques on the headlands of Grimmington Island have eroded back into the tilted summit surface and have produced a number of razor-sharp arêtes and ridges. On one particularly high ridge a vertical dike of relatively soft material has weathered out, producing the pronounced cleft and well known landmark of Bishop's Mitre. Immediately south of the Bishop's Mitre on the same section of surface is the highest point of the group, the gently rounded summit of Brave Mountain (4,500 feet).

Elevation is the distinguishing characteristic of the Kaumajet Mountains, for their island form with branching fiords and channels on either side is very common on the Labrador coast. Immediately to the north of Cod Island is the small island of Nanuktut (White Bear Island), sculptured completely by cirque forms. Further north the fiords, rather than the islands, are the main coastal feature. To the south of the Kaumajet a whole series of islands and bays is characteristic of the coast, the nearest large island, Okak Island, having at least as much area as the greatest of the Kaumajet blocks. The Kaumajet massif is in fact just a large member of the "island zone" recognized by Wheeler (1935), though it can be noted that its position on the coast approximately marks the northern extension of the island and bay coast line and the commencement of the northern fiord coast.

Inland and to the west of the Kaumajet Mountains the character of the land changes markedly with the change in lithology. The gneissic complex and associated intrusive rocks give rise to a coastal lowland with wide valleys and low relief, in sharp contrast to the Kaumajet block. This low terrain gently rises toward the inland upland zone: the watershed is approximately 60 miles inland and 2,500 feet in height.

While the Kaumajet Mountains are a striking feature of the landscape of the Labrador coast and have been mentioned several times in geomorphological discussions of Labrador as a whole, little actual geomorphological investigation has been completed in the area.

The early geologists (Daly, 1902, Bell, 1882-84) produced a purely descriptive report of the mountain blocks and it was left to Odell (1933) to make the first ground observations. Odell's remarks were limited to Grimmington Island, and in particular to the Brave Mountain - Bishop's Mitre portion of the island. He did, however, note the presence of erratics and ice-polished rocks, the amount of weathering and the state of cirque glaciation, and he included these observations in a reasoned account of the glaciation of the area.

Tanner's comprehensive study followed in 1944. He was fully conversant with previous work, particularly the observations of Odell, and the photographs of the Forbes-Grenville expedition of 1933. He himself had both flown over the area, and paid it a short visit in 1939, accompanied by the geologist Kranck. With this background of knowledge, he incorporated the Kaumajet Mountains in his comparatively detailed consideration of the Labrador glaciation. He noted most of the major forms involved: for example, flat summit surfaces, deeply cut cirques and valleys, and he advanced a theoretical explanation connecting these features with a sequence of pleistocene events.

Wheeler (1958), having journeyed on the western side of the Kaumajet group since 1951, and also having examined the western side of Grimmington Island (this examination included an ascent of Brave Mountain by Peter Grimley), noted the distribution of erratics in this part of the region and added this evidence to that of Odell and Tanner.

These investigations still leave the major part of Cod Island, the eastern half of Grimmington Island, the entire inland block of the mountains, and the approaches to the west, in the main uninvestigated apart from aerial observation - which is at best superficial. Further, apart from the limited observations of Odell around Bishop's Mitre and the notes of Wheeler regarding erratics, no serious geomorphological work has been recorded, much less have the signs of glacial activity been carefully examined throughout the area. There is in fact little recorded evidence to support or challenge the theoretical considerations which have been advanced. It was with such a background of previous investigation that geomorphological observations in the Kaumajet Mountains were undertaken.

Fig. 4. Inland Lowland Area and Finger Hill Area from the East.

CHAPTER 4

INLAND LOWLAND AREA

The first area to be examined was that inland of the western block of the mountains. Access to the area is gained from the west shore of Lost Channel at the point where the mountain block gives way to relative lowland. A trough runs from this point to Shark Gut Harbour, parallel to, and at the base of, the precipitous flank of the mountain block. This valley is locally known as Cut Through Valley.

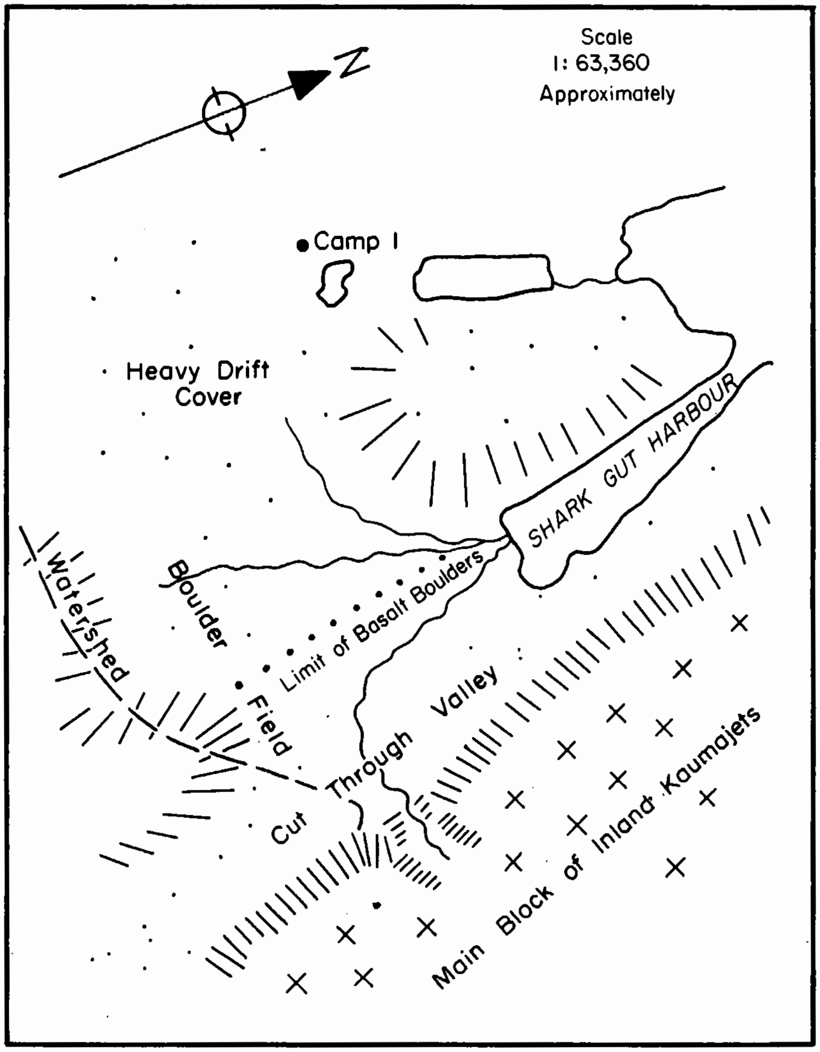
Ascending the valley from Lost Channel one crosses a complex of marine terraces among which are small deposition features, possibly small moraines or sub-glacially engorged eskers. These features are fragmentary and form no distinguishable pattern. No conspicuous marginal drainage channels or chutes were observed. On either side of the trough of Cut Through Valley are small hanging valleys an estimated 1,100 feet above stream level on the eastern side and some 400 feet above stream level on the western side. The valley itself is predominantly drift-filled. This drift filling reaches quite high up the valley sides, but at some 200 to 300 feet above stream level on both sides of the valley it gives way to glacially scoured bedrock.

From 300 feet above sea level up to the col at 520 feet above sea level an increasing amount of the fines are washed out from the drift, leaving the valley floor covered with a debris of rounded boulders which completely obscures the bedrock. This boulder drift consists predominantly of medium coarse grained white rocks. The rocks contain 50 percent of quartz, 30 percent of plagioclase, and 20 percent of biotite mica; it is in fact the easily recognized granite gneiss of the basal complex. Mixed with the granite gneiss are boulders of red rock which, when split open, reveal very fine-grained grey-blue basalt, the red colouring being the surface weathering characteristic of the basalts in the

Fig. 5 Cut-Through Valley from Lost Channel

Fig. 6 Photograph taken standing on Col of Cut-Through Valley, 520 feet above sea level. The washed boulder debris includes granite gneisses and basalts. The material has not been frost shattered in situ to any appreciable extent.

Fig. 7 Washed boulder debris to south of Shark Gut Harbour, and immediately west of Cut Through Valley. Photograph taken at 480 feet above sea level, facing west. Watershed appears as skyline on left of picture. Boulders in foreground are both granite gneisses and basalts. Basalts diminish to the rear of picture. Bedrock in the area is granite gneiss.



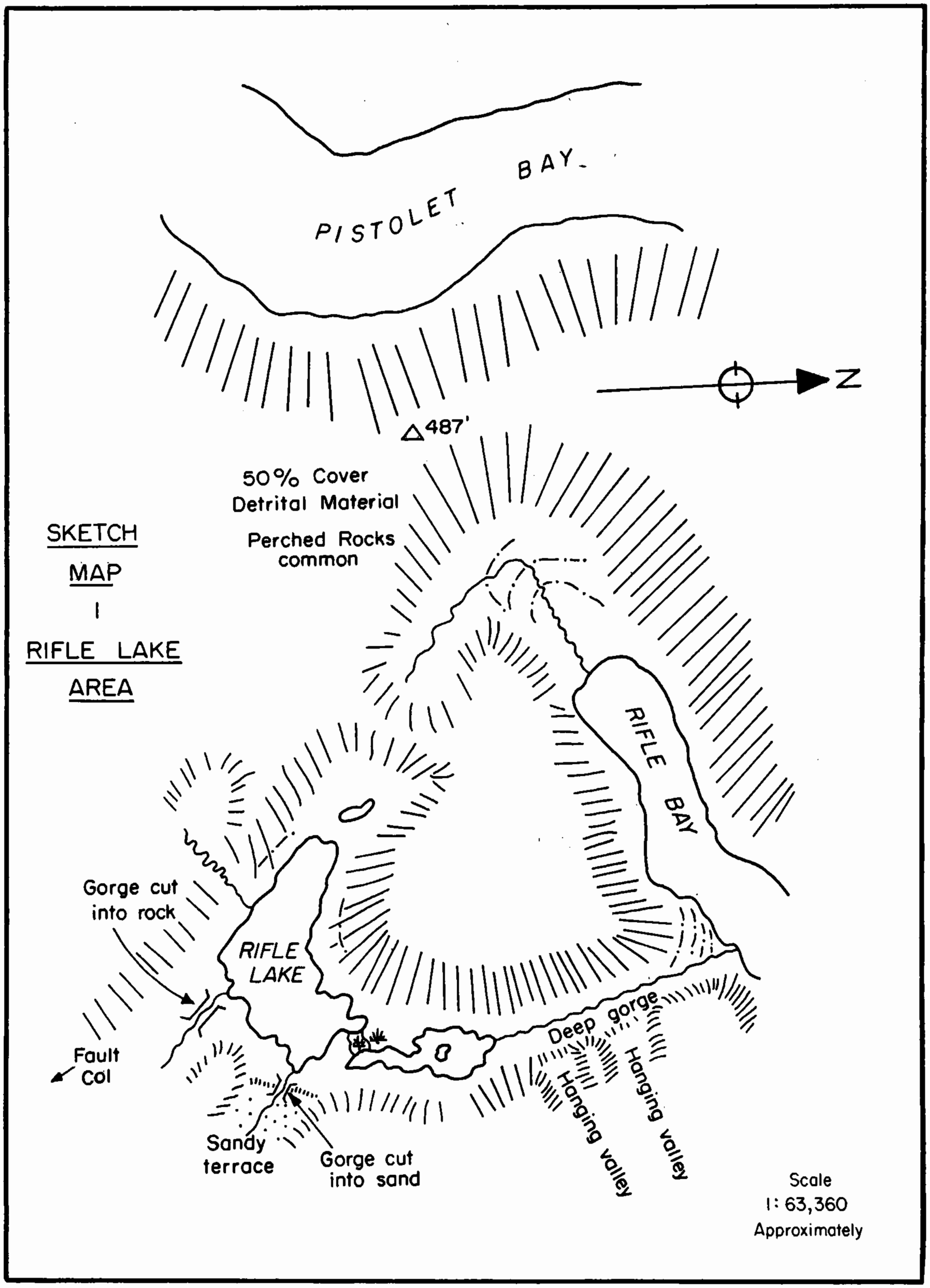
Scale
1: 63,360
Approximately
N
Camp I
Heavy Drift
Cover
SHARK GUT HARBOUR
Limit of Basalt Boulders
Boulder
Field
Watershed
Cut
Through
Valley
Main Block of Inland Kaumajets

Figure 8

area. These basalts represent the incorporation of rocks from the talus slopes into the drift. Of these boulders, the basalt rocks seem to be predominantly sub-angular, while the granite gneiss rocks seem to be predominantly well-rounded. None show evidence of frost shattering in situ and all seem to be sorted and carefully packed as if by water action. The sorting is particularly noticeable on the col itself, where the rocks form a relatively flat pavement with few boulders above the general level. This evidence of water action is interesting, as the present streams enter the trough from well-developed tributary valleys considerably below the level of the present col, which is dry, apart from small pools of melted snow occasionally trapped on the surface of the bedrock beneath the boulders.

The col in Cut Through Valley between the small streams flowing to Lost Channel and Shark Gut Harbour is one of a series on the watershed between the streams flowing north westwards to Napaktok Fiord and those streams running south eastwards to Mugford Bay and the open sea. First, the area to the north of this watershed as far west as Pistolet Bay was examined and on the return the area to the south of the watershed as far east as Mugford Bay was examined.

Leaving Shark Gut Harbour and travelling eastwards towards Rifle Bay, slightly to the north of the watershed, one crosses an extensive boulder field. This boulder field is impressive: the rocks are large and many are perched; occasionally small ridges of bedrock show through, but in most places it is hidden completely. The depth of boulder material is greatest on the watershed, and again exhibits water-lain characteristics. Down the slope, away from the watershed, it grades into an irregularly-dumped ice-lain material with abundant perched rocks and a higher proportion of small detritus. In the lower parts of the valleys this material grades into unwashed drift which has an abundant supply of fines. This distribution of washed and water-lain drift suggests



PISTOLET BAY
N
△487'
50% Cover
Detrital Material
Perched Rocks
common
SKETCH
MAP
I
RIFLE LAKE
AREA
RIFLE BAY
Gorge cut
into rock
RIFLE
LAKE
Fault
Col
Deep gorge
Hanging valley
Hanging valley
Sandy
terrace
Gorge cut
into sand
Scale
1: 63,360
Approximately

Figure 9

that ice-dammed water at some late stage in the glacial period was higher than the cols in the watershed and flowed through them, as it is unlikely that spring thaw water would flow in sufficient quantity across the cols to produce this water-lain effect. However, there is no evidence at all of shorelines in the area to the south of Shark Gut Harbour and north of the watershed.

The scattered outcrops in the boulder field are too weathered to preserve striations, though the outlines of even the highest rock outcrops appear to be ice-smoothed and have an abundance of perched rocks upon them.

The most significant observation in this area is that of the occurrence of basaltic rocks derived from the Kaumajet Mountains. These rocks, as has been noted, are common in the drift in Cut Through Valley, and they mix with the rocks of the boulder field in the drainage basin of Shark Gut Harbour. As one moves westward over the boulder field the proportion of basalt rocks decreases sharply and their outer limit is some $1\frac{1}{4}$ miles from the western front of the Kaumajet inland block. At no time in the examination of the lowland to the west of the block were basalt boulders or any trace of basaltic rock found further than this distance away from the western flank of the mountains.

The drainage basin of Shark Gut Harbour and that of Rifle Bay are separated by relatively high land which is cut by a fault forming a col at 1,200 feet. All the high land has been subject to ice action; boulder detritus covers much of the surface; the bedrock exposed is invariably smoothed or rounded granite gneiss, but weathering has removed all traces of possible striae. Again the col is partially covered by water-lain, washed drift, giving the appearance of a dried stream bed running across the top of the high land. Apart from this feature no fluvio-glacial features appear in the area.

Fig. 10 A relatively high point of land in inland lowland area at Fault Col, 1,200 feet above sea level, showing well-weathered outcrop of granite gneiss, masked on all sides by drift with rounded boulders. Production of frost shattered material at a minimum.

The drainage basin of Rifle Bay centres around Rifle Lake, a lake of approximately $1\frac{1}{2}$ miles length, a small distance to the south of the Bay itself. The small streams of the drainage basin flow down to this lake, and one large outlet stream cuts its way through a ridge of high land from the lake to Rifle Bay. In the Rifle Lake drainage basin there is evidence of lake shorelines at a higher level than the present lake; but it is too fragmentary to provide the basis of any hypothesis without additional support. However, two main rivers enter the south east end of the lake, and both flow in over what appears to be a high level tributary valley bottom and leave this high level valley bottom by cutting a gorge down to the present lake level; in one case the gorge is through detrital material and in the other it is through bedrock. These features would seem to suggest that at some point in the recent history of this area the lake level stood some 70 to 80 feet higher than at present. It may possibly have been higher still, but the steep rock walls of the valley are not conducive to the preservation of higher shoreline evidence.

From an investigation of several roche moutonnée type features, and one possible crag and tail formation in the vicinity of the lake, it seems that ice movement was topographically controlled and flowed from this basin toward Rifle Bay.

The valley between Rifle Bay and Rifle Lake is distinctly U-shaped. The bottom of this valley is filled with drift into which the river has cut a deep gorge extending down to bedrock. It has been cut in successive stages, as is evidenced by a series of river terraces which are particularly well-marked at the mouth of the river. The present nick point is at the place where the river leaves the lake. The valley sides above the terraces show glacial smoothing which indicates possible direction of ice flow towards the fiord. The wall on the eastern side is cut into by several small hanging valleys, each distinctly U-shaped, with an east-west trend. These so-called hanging valleys have the appearance, rather, of cols cutting through high land at right angles to the present valley and much above it, a possible inference here being that they were cut by high level ice while the major valley was filled with lower ice. At the mouth of the main valley, at the junction with Rifle Bay, there is a small bedrock peninsula protruding into the bay; on either side of this peninsula is a series of marine terraces. They are thought to be of marine origin rather than glacially-dammed lake shorelines, partly because of the nature of their material and partly because of the abundance of marine terraces observed elsewhere in the area and also by other workers along the Labrador coast. They are probably due to eustatic rise in sea level after removal of the ice, for they correlate well with similar terraces at the head of Rifle Bay, and these are cut in a gorge by a stream, suggesting that there has been recent rejuvenation in the area.

The drainage basin of Rifle Bay is separated from the drainage basin of Pistolet Bay by a col at 487 feet; the covering of boulder detritus is not as thick on this upland as it is closer to the Kaumajet Mountains. Nevertheless, 50 percent of the ground is covered with drift, boulders and perched rocks, among which are some excellent examples of smooth erratics, some of the more conspicuous being of quartz and limestone. No water-lain boulder patterns were observed in the col, the detritus exhibiting the irregular scattered pattern characteristic of ice-lain material.

The high land to the south, east of Pistolet Bay, forms the continuation of the watershed between the streams flowing to the north west and those flowing to the south east. The area is criss-crossed by fault patterns, each giving rise to small structural features; drift covers approximately 50 percent of the surface; perched rocks are numerous; erratics are common; the whole area has been covered with ice. The direction of ice flow is indicated, not by major features, but rather by many small imprecise details such as the rounding of bedrock, the wedged position of erratics and the moulding of deposition material, some of which could possibly be interpreted as crag and tail formation.

To the south of the watershed one main valley collects the small streams flowing to the south and directs them to the north western corner of Mugford Bay; this valley is wide and gentle, with many lakes and river expansions in the base; again the direction of ice flow is inferred by minor features as being from north west to south east along the valley; there are no moraines in the valley and no evidence of marginal drainage channels or other fluvio-glacial features. The lower end of the valley has a series of marine terraces cut by a gorge feature similar to those described in Rifle Bay. Crossing the relatively low upland between the valley to the south of the watershed and Cut Through Valley is a small hanging valley. This valley opens at each end, hanging into both Cut Through Valley and the large southern valley. Its slope is gentle but distinctly descends from north to south; crossing it is a small, ill-defined moraine which, hardly recognizable as a geomorphic feature, is sufficient to dam a small lake in the hanging valley. The lake has cut its outlet through the higher land between itself and Cut Through Valley. This small feature could be explained by the presence of ice filling the valley to the south, overflowing into the hanging valley, and damming the lake there until it cut itself a path through bedrock to Cut Through Valley. The receding ice then left a small amount of debris behind, which is sufficient to dam the present lake and make it continue to flow northwards to Cut Through Valley.

CHAPTER 5

FINGER HILL AREA

The mainland portion of the Kaumajet Mountains, here termed the Inland Block, is bounded by Lost Channel to the south east, Cut Through Valley to the south west, Sunday Run to the north west, and the open sea to the north east. The mountain block is dissected by two main valleys, both cutting back to the centre of the mass, one opening on to the coast at Sunday Run, the other (Finger Valley) opening into Cut Through Valley. The main prominence of the inland block is Finger Hill, a part of the undissected surface that rises to 3,428 feet above sea level. Access to the centre of the inland block and the summit surface was gained up Finger Valley.

Finger Valley itself is a U-shaped valley, having in its lower portion practically vertical walls with the characteristic 200 to 300 feet of talus slope grading down into the drift-filled valley bottom. The vertical valley sides show glacial smoothing, which is more pronounced on the lower levels of the wall. The valley floor is 100 feet above the floor of Cut Through Valley at the point where the two meet. Across the mouth of Finger Valley a moraine can be distinguished. Through this moraine and the drift below it the river leaving Finger Valley has cut a gorge down to bedrock before it meets Cut Through Valley and flows northward to Shark Gut Harbour. Behind the moraine which rises 60 feet above the floor of Finger Valley is a distinct terrace feature which stands 15 feet above river level. This terrace is continuous with the upstream side of the moraine but has its own distinct surface level and terminates abruptly in a reverse arcuate slope a hundred yards into the valley. It is possible that this reverse slope is an ice-contact slope and that the terrace represents moraine fill between an ice front and the terminal moraine some yards in front of it, or possibly it is the terrace of

Fig. 11 Finger Valley, from Col above Finger Lake. Photograph taken at 2,442 feet above sea level.

a lake formerly dammed between the moraine and ice or higher land upstream.

Approximately 1 mile up Finger Valley and 115 feet above the mouth is a second moraine. This is a distinct feature rising quite sharply 30 feet from the valley floor, arcuate from valley side to valley side, and cut only by a river running through its centre. It is composed of assorted debris: sub-angular and angular blocks, some of considerable size (10 feet by 20 feet by 15 feet) which have been derived by free fall from the free face. There is a concentration of these large blocks at either end of the moraine. There is the occasional rounded and smooth rock amongst the usual angular debris. The occurrence of these moraines would indicate glaciation, probably of a cirque nature, from local sources after the last glacial maximum.

The upper portion of Finger Valley is a series of coalescing cirques. They are all flat-based, with large waterfalls spilling over the headwalls, which average 300 to 400 feet in height. The highest and largest cirque has a headwall of 1,000 feet, the top of which is a broad arête backed by a very large cirque on the north side of the mountain block. The highest cirque in Finger Valley contains a lake some 3/4 mile in diameter, called Finger Lake. The back wall of the Finger Lake cirque is cut into on the north west side by a small cirque whose lip is some 500 feet above lake level. This cirque reaches the wall between the Finger Lake cirque and the highest part of the major valley leading south westwards to Sunday Run, forming a col 804 feet above Finger Lake.

The lip of Finger Lake is composed of smooth, glacially polished and striated rocks. The striations are parallel to the trend of the main Finger Valley and were found well-preserved up to a point 573 feet above lake level. Above this point no well-preserved striations were found in the valley.

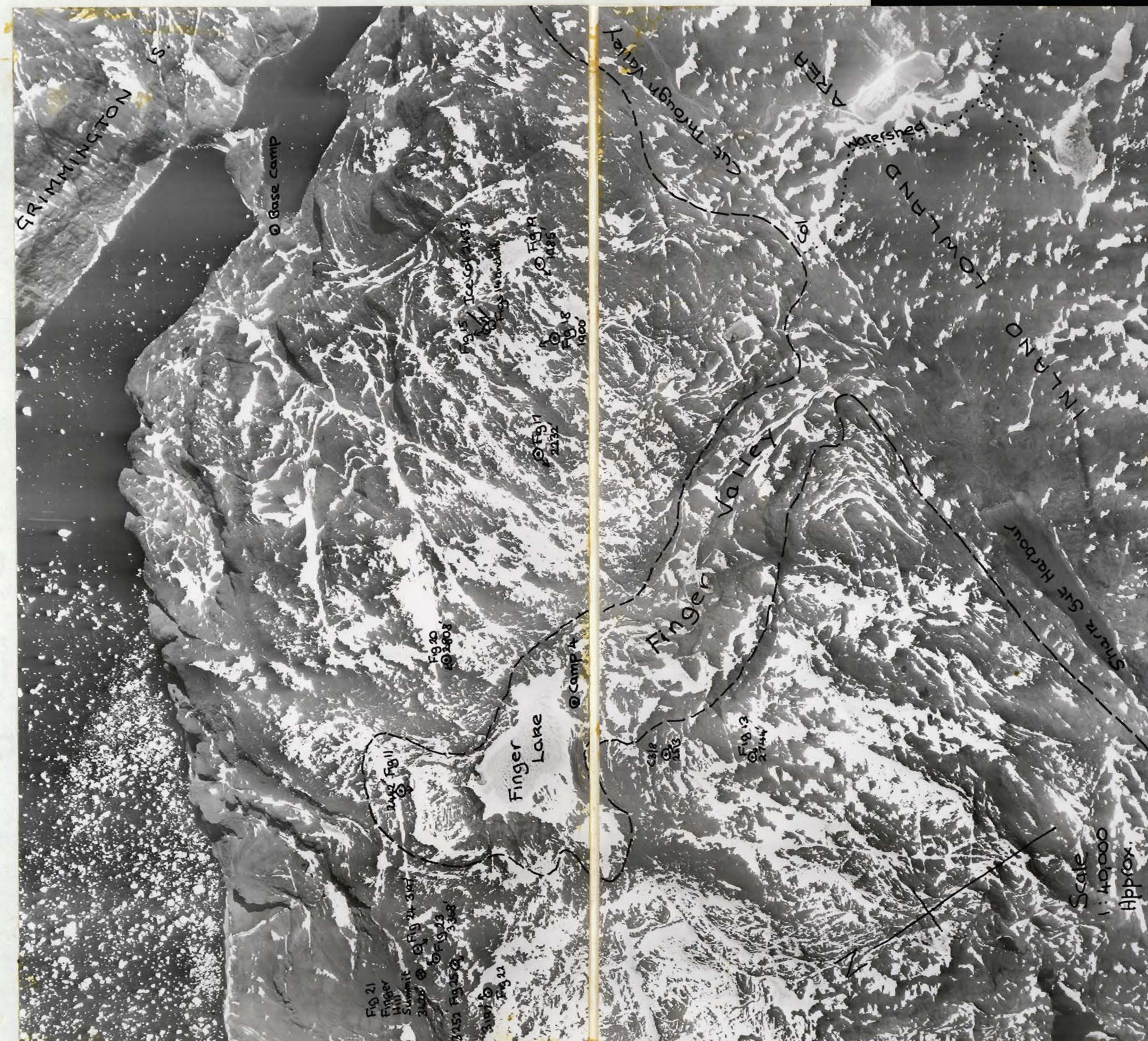


Fig. 12 Aerial Photograph showing approximate position of ground photographs in the Finger Valley and Finger Hill area. Heights indicated are from aneroid measurements with the exception of those for Figs. 13, 17, 18, 19 and 20, which have been determined photogrammetrically by Spartan Air Services Ltd., Ottawa using aneroid points for vertical ground control. Accuracy of the photogrammetric points is to plus or minus 50 feet.

Well-marked dry channels parallel to Finger Valley, cutting across small spurs, were found at 730 feet and 954 feet on the western slope above Finger Lake, the uppermost of these channels being approximately level with the top of the cirque headwall. Above the highest striation in Finger Valley, frost-shatter of the rocks increases considerably; large areas of weathered bedrock occur, though approximately 50 percent of surface is detritus-covered.

The upland area of the inland block was examined radially from Finger Lake. The arête separating the two drainage basins of Finger Valley and West Valley has already been described. West Valley has a composite head in several cirque forms, their position being determined by differential erosion of structural variations of the bedrock. The Valley itself is similar to Finger Valley in its step-by-step descent; the steps seem determined in some part by structural ridges, one ridge in particular stretching across the valley from side to side and being cut by a gorge. No moraines were observed in West Valley. The col separating Finger Lake and West Valley has definitely had ice over it; erratics of granite gneiss abound and rounded rock surfaces are common. On the whole, however, the rocks are weathered and any striae have been removed. Fresh striations do occur in the bottom of West Valley. It is suggested that cirque glaciation took place, but that it filled Finger Lake no higher than 500 to 600 feet above the Finger Lake lip level, as the highest striations found were 573 feet above Finger Lake lip. In the main the ice was probably below 400 feet. It is further suggested that the col separating West and Finger Valleys at 804 feet above Finger Lake was not crossed by ice during the cirque glaciation, but was possibly crossed by ice from west to east (this direction being suggested by the rounded forms and the occurrence of erratics from the west) during a former, higher glaciation. On either side of the col between West Valley and Finger Valley were found terraces,

Fig. 13 Frost-shattered volcanics on Summit surface to south of West Valley and west of Finger Valley. Photograph taken at altitude of approximately 2,744 feet above sea level.

Fig. 14 Ice-flow path across Ice Col at 2,433.7 feet above sea level. Position located on Photo Key (Fig. 12). Photograph of striae below taken to left of this picture just out of immediate foreground.

Fig. 15 Striations on side of above flow path.

Fig. 16 Incipient break-up of surface due to frost action.

the highest 238 feet above the level of the col, and less distinct ones forming a flight down into the col; an unusually high pile of shattered material, possibly the residue of a lateral moraine, was found 70 feet above the north side of the col. The summit surfaces to the south and north of West Valley were briefly examined. These surfaces are above 2,000 feet and below 3,000 feet and are undissected or gently undulating. Frost-shattered material covers approximately 60 percent of them; bedrock protrusions are rounded in some instances and frost-shattered in others. The bedrock is the red weathered basalt, but erratics of white granite gneiss abound on the surface.

The surface of the highland to the east of Finger Lake was examined. Erratics are common on all surfaces of this highland. Nearly all bedrock exposures show considerable weathering; angular debris covers approximately 50 percent of the bedrock. Drainage is affected by a series of valleys radiating to the coast. These valleys show little or no sign of cirque glaciation, but have erosional features suggesting névé action without the formation of a cirque glacier.

One distinct and significant feature on this surface area is a definite ice flow path at approximately 2,433 feet above sea level, (Fig. 14). This ice-flow path is in the form of a saddle cutting a ridge from east to west, the ridge running from north to south. The saddle has undoubtedly been ice-eroded: several plainly marked striations were found, and the rocks are smooth and polished. Those on the saddle bottom, though smoothed, have been frost shattered in situ and striations have been practically weathered away on the horizontal surfaces. It is suggested that the col was cut by the main ice-stream flowing in a west to east direction; the lowest part of this feature is nearly 1,000 feet above the highest evidence of cirque glaciation, is

Fig. 17 Frost-shattering on basaltic surface at approximately 2,232 feet above sea level on upland surface of Inland Block. Position located on photo key (Fig. 12).

Fig. 18 Frost-shattered upland surface of volcanics with prominent unweathered erratic of granite gneiss. Taken at approximately 1,900 feet above sea level on east side of Inland Block. Position located on photo key (Fig. 12).

Fig. 19 Taken at 1,985 feet above sea level in south eastern part of upland basaltic surface of Inland Block. Lowland granite gneiss area in distance to south.

Fig. 20 Frost-shattered basalts with frost heaving and polygon and ring formation in the detrital material. Taken at 2,808 feet above sea level on eastern side of Inland Block. See photo key (Fig. 12).

Fig. 21 Frost-shattered material on actual summit of Finger Hill, 3,426 feet above sea level. Small erratic indicated in foreground.

Fig. 22. Erratic on frost-shattered basaltic surface of summit level, immediately west of Finger Hill. Note the relative degree of weathering of basaltic bed-rock and granite gneiss erratic. Taken at 3,197 feet above sea level.

above much of the summit surface, and is above at least one third of the boulder detritus material.

Also in this area of the inland block is the saddle between the head of the Finger Lake cirque and the northern wall of the mountain mass. The lowest point of this saddle is approximately 2,300 feet above sea level. No fresh striations were found crossing this feature and all surfaces were either rounded or frost-shattered. This fact adds weight to the suggestion that the cirque glaciation was confined to the cirque valleys.

The summit of Finger Hill (3,426.7 feet above sea level) was examined. Erratics of granite gneiss were found on the very top of this summit. Frost shattering is dominant. Angular debris masks the sides, the percentage of debris over bedrock increasing with height. In this region several distinct terraces were found on both the east side and the west side of the summit, both sets of terraces dipping to the south. The flat surface of the terraces is normally 8 to 10 yards wide and frequently between 20 and 25 yards wide; they themselves curve round the hillside for some $\frac{1}{4}$ mile. The material is angular or sub-angular, varying in size from $\frac{1}{2}$ inch diameter to blocks of 2 to 3 feet diameter. Clay, silt and sand fraction is absent. Material is essentially the same as the bedrock in the area, though it has a number of conspicuous erratics. Interpretation of these features is difficult, and at best extremely tentative. Two possibilities suggest themselves. Similar features worked into drift material elsewhere have been recognized as kame terraces formed by the fluvio-glacial action of water at the ice margin. If this were the case concerning these terraces, they must have been formed by the re-working of the boulder detritus.

The position and aspect of the terraces, however, cause one to think in terms of frost action: possibly the forms are in fact solifluction terraces.

Fig. 23 Terrace, cut into boulder detritus, south side of Finger Hill, at altitude of 3,368 feet above sea level.

Fig. 24 Detrital material on upper slopes of Finger Hill, altitude 3,197 feet above sea level approximately.

Fig. 25 Detrital material on upper slopes of Finger Hill, taken from altitude of 3,252 feet above sea level. Terraces in boulder material indicated.

The size of the features seems very great if the frost heaving process alone is responsible, though the nature of the material favours this suggestion.

No definite conclusion is possible regarding the origin of the features, and their interpretation must await correlation with similar features elsewhere.

Time and weather conditions imposed strict limits on the examination of this area. It is greatly regretted that it was impossible to complete a systematic study of the overall relationship between the degree of frost action and the elevation, or between the degree of frost-shatter and the individual rock types within the volcanic series.

An attempt has, however, been made to present ground photographs within the area, showing surface conditions and materials. These photographs have been located as closely as possible on an air photograph of the area (Fig. 12) and the height of each point indicated.

The following observations were also made and may be considered:

The summit surface of the inland block varies in height from approximately 1,800 feet (at the top of the cliffs in the volcanic series) to a maximum of 3,426 feet (summit of Finger Hill). The greatest part of the surface is nevertheless below 2,800 feet above sea level. The dominant form of weathering in the areas examined is mechanical destruction of bedrock by frost action. In general, the percentage of the surface covered with frost-shattered material increases with height. There are areas of the summit surface that are relatively clear of deep debris, but most show evidence of incipient frost action and disintegration, and frost-shattered material is common at even the lower levels of the summit surface. It is felt that the whole of the summit surface comes within the range of altitude in which frost-shattering is active. The degree of frost shatter can vary markedly over quite small areas. On the summit of Finger Hill (Fig. 21) the boulder detritus comprises a considerable proportion of large angular boulders (2 feet by 1 foot by 18 inches). Immediately to the west of the summit (Fig. 22) at an elevation of 3,197 feet above sea level the material is predominately small broken fragments, frequently smaller than an orange and rarely exceeding 10 inches by 10 inches by 10 inches. The latter material definitely shows that the basaltic material can be readily reduced to small fragments and is not necessarily resistant once initial break-up has occurred. A similar area of well-fragmented basalt is shown in Fig. 20.

The relationship between the weathering of the granite gneiss erratic material and that of the bedrock on which the erratic has been deposited is quite striking. In nearly every case the granite gneiss erratics are fresh and unweathered, and certainly are not highly frost-shattered. This is often in complete contrast to the bedrock on which they have been placed. (See Fig. 22).

Several hypotheses may be advanced to account for these differences in degree of frost action, including differences in micro-climate, differences in surface configuration conducive to a water regime favourable to frost action, or differences in bedrock.

The extreme north east portion of the inland Kaumajet block comprises a narrow extension of the granite gneiss complex below the level of the high sediment and basalt mass. The area is delimited to the east by the coast and to the west by the main wall of the Kaumajet series. This is, then, an examination of the cirque features which appear to form a connected chain, aligned approximately north-west-south-east, around the north east corner of the inland Kaumajet block. The cirques share common head-and side walls, formed by the sediment and basalt wall of the Kaumajet Mountains.

The headwall of the highest cirque in this series is at approximately 2,300 feet above sea level at its highest point (a small lake in the cirque is 840 feet above sea level). The headwall is in the order of 1,400 feet high, of which an estimated 900 to 1,000 feet is free face. The seaward retaining wall measured in the top cirque is some 50 to 60 feet above its base. That ice flowed directly out to sea over this relatively shallow lip is undoubted; in fact, several gigantic clefts in the seawall form natural outlets; but definite, well-preserved striations show movement of the ice from the top cirque down over its lip into the lower cirque. This direction of ice-movement is parallel to the main wall of the Kaumajet block and restricted by the 50 to 60 foot high seaward wall. There is also a distinct moraine feature below the lip of the top cirque in the series. This moraine is cut through by the river now flowing from the top cirque: it has a maximum height of 60 feet above river level.

The second cirque in the series is practically a continuation of the top cirque, with its present drainage directly to the sea. This drainage, however, appears to be a recent innovation; a terraced floor indicates that the sea-cut is postglacial in part at least, and if ice did flow directly seaward, it was at a higher level than the present path of water.

The third cirque in the series is a minor feature containing a small lake. Between the second cirque and this small lake is a ridge of rock 30 feet high crossed by clear and distinct striae, which give strong evidence of ice movement from the second cirque to the small lake.

Below the small lake is the final major cirque of the series. A striking feature is a channel between the lake and the lowest cirque. This channel, 25 feet deep and 25 feet wide, is cut into solid rock, with vertical walls, and is part-filled with large and small boulders; there are no striations on

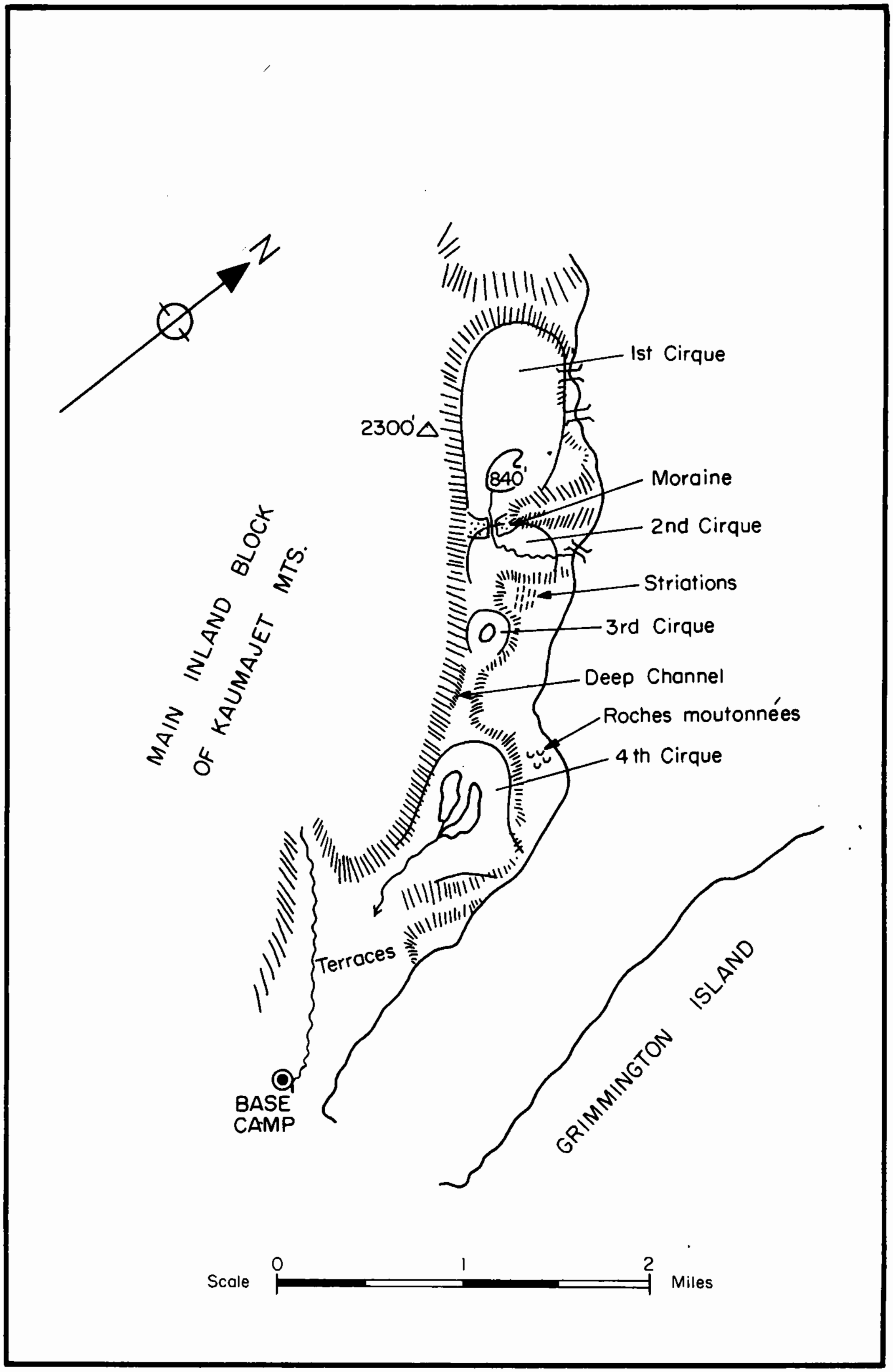

N
1st Cirque
2300' △
840'
Moraine
2nd Cirque
Striations
3rd Cirque
Deep Channel
Roches moutonnées
4 th Cirque
MAIN INLAND BLOCK
OF KAUMAJET MTS.
Terraces
BASE
CAMP
GRIMMINGTON ISLAND
Scale
0
1
2
Miles

Figure 26

the side of the channel: it definitely appears to be a water-cut feature. The lowest cirque appears to be self-contained. Definite striations downstream indicate overflow from it: if ice filled the cirque completely, its surface would be raised, with relation to the seaward retaining wall, sufficiently to find egress through a second overflow channel. Fresh striae do not extend far below either lip.

Other observations in this area include striations on the higher outer rocks forming the seawall, which cross, and are more nearly parallel to, the main valley than those within the cirques. On the same seawall, roche moutonnée features are found, as are structural cracks, also rounded on one side only. These features all suggest ice flow in the main channel between the Inland Block and Grimmington Island in a south to north direction, opposite to that of the local cirque glaciation. Erratics of white granite gneiss and red basalt are common at all levels.

A tentative interpretation of the cirque glaciation in this area may be made. It is suggested that it came after the glacial maximum, as is indicated by the fresh striae and the existence of moraine in the top cirque. The ice flowed from the top cirque down the small valley between the seawall and the inland wall. At the maximum extent, the top valley cirque pushed a glacier into the second cirque; the ice possibly extended as far as a small lake, but overflowed to the sea at that point. The lowest cirque had its own small cirque glacier, of no great importance. With the waning of the cirque glaciation the lowest cirque emptied and the top cirque glacier retreated, leaving in the second cirque an ice block and a lake, which overflowed to the south into the lower cirque via the gorge cut between the small lake and the lower cirque.

Further retreat of the ice saw the ice block in the second cirque diminish and water drain to the sea directly from this cirque. The final stages saw a minor advance, forming the moraine at the lip of the top cirque, and a final retreat and disappearance of the ice. This cirque action must have taken place after the retreat of ice not only from the tops but also from the fiords.

Below the lowest cirque in this series and above the base camp on the isthmus is a series of well preserved terraces: these terraces are properly river terraces from the small stream flowing onto the isthmus from the inland block, but the flat surface on the edge of each terrace must have represented a higher sea level and thus can be taken to indicate the approximate height of a series of sea levels.

Fig. 27 Cod Island from the west.

CHAPTER 6

COD ISLAND AREA

The examination of Cod Island was carried out from a base camp established at approximately the mid-point and on the eastern side of Mugford Tickle. Examination of Cod Island and Grimmington Island was seriously hampered by nineteen days of continuous fog, which made travel slow and hazardous. The following observations, made under these conditions, are presented.

Mugford Tickle itself is a channel some 8 miles long, rarely exceeding $1\frac{1}{2}$ miles in width, except at the entrances at either end, and decreasing to approximately $\frac{1}{2}$ mile in width at its narrowest point in the centre. Approaching Mugford Tickle from the south one enters the channel between low headlands of basal granite gneiss, Crosby Point of Cod Island to the east and the south eastern tip of Grimmington Island to the west. Slightly further north, the character of the walls changes markedly. The low granite gneiss of Grimmington Island gives way to a sediment and basaltic series which forms a sheer cliff rising an estimated 1,500 feet up from sea-level. This cliff gives way in turn to a slightly lower, cirque-dissected wall as one leaves Mugford Tickle to the north. The Cod Island side of Mugford Tickle has a gentler aspect as the surface of the basaltic mass in the centre of the Tickle is tilted towards the Tickle, so that the cliffs are lower than those on the western side and the upland surface rises gradually from them. It can be seen, however, that the sides of Mugford Tickle are not readily accessible for surface geomorphological investigation, as landings can be made only in a few places.

The sides of Mugford Tickle and the coast of Cod Island as far as Camel Inlet were, however, examined from the sea. The coast is irregular,

Fig. 28 Camel Inlet - From storm beach showing fragmentary raised beaches (indicated by arrows). Storm beach in foreground.

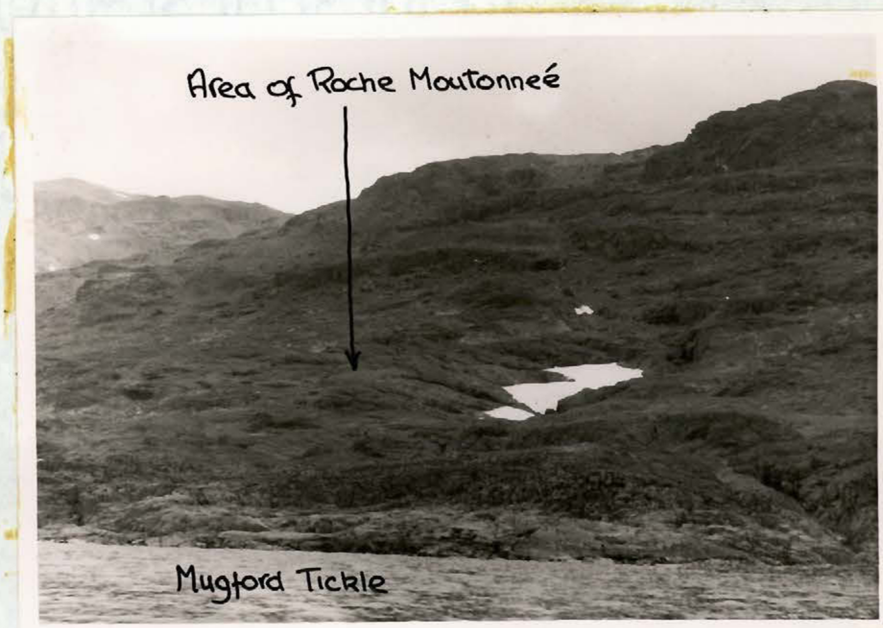


Fig. 29 Incipient roche moutonnée area, immediately north of base camp on Mugford Tickle. Location of base camp shown on Fig. 27 and Fig. 33.

with tectonic structures influencing most of the protuberances. A series of small cirques cut into the walls of Mugford Tickle was noted; it was estimated that the lips of these cirques rarely came below 400 feet. This is in contrast to the cirque forms on the northern sides of the island, which often descend to sea level.

Camel Inlet is the bay formed at the head of a fault zone that runs north west to south east from the head of Anchorstock Harbour. The bay itself is approximately 3/4 mile wide. Its back wall is breached to the south by a high level valley following the fault zone. Crossing the head of Camel Inlet is a large storm beach, approximately 40 feet above sea level. Behind this beach a lake has been ponded back against the back wall, fed by a waterfall from the hanging valley above and cutting its way to the sea through the storm beach. A series of fragmentary marine terraces was noted and measured behind this lake, though the scree from the headwall and the nature of the headwall itself are not conducive to the preservation of high level features.

Further examination of the northern coasts was not possible, due to high seas.

Examination of the rocks to the north and south of the base camp established in Mugford Tickle revealed numerous small features indicative of ice flow and direction. To the south of the base camp are smooth, rounded and striated rocks, the striations being parallel to the fiord-side. To the north of the base camp is an area some 3/4 mile long by ½ mile wide which is a composite of small roche moutonnée features showing that the ice flow direction through the Tickle in the later stages of glaciation was from south to north. This evidence is supported by similar observations on the western side of the Tickle. It can be noted, however, that all the recent striations and roche moutonnée features seem to be below the level of 400 feet above sea level. At this

Fig. 30 Terrace feature at high point on col between Sutherland Inlet and base camp on Mugford Tickle. Top of terrace 658 feet above sea level.

Fig. 31 Sutherland Inlet Col, showing suggested moraine crossing north side of col.

Fig. 32 Sutherland Inlet Col. Close-up of stream cut through suggested moraine feature on north side of col.

point there seems to be a distinct "trim line" above which the weathering processes have eliminated the fresh striae and obscured the rounded forms. The evidence observed would suggest that ice passed through Mugford Tickle from south to north up to 400 feet above present sea level at a later date than the glaciation of the summits, though the evidence for this is far from conclusive.

Cod Island itself does not have the same block form and undulating summit surface as Grimmington Island and the Inland Block of the Kaumajet Mountains. Rather, it is a composite of six or seven blocks faulted against one another, each with its surface tilted and sloping to a varying degree to the north west. This can be plainly observed on the eastern side of Mugford Tickle and also on the eastern side of the island, where the block forming Table Hill and the block between Clark Inlet and Mugford Harbour are also tilted to the north west. Other units in the centre of the island show the same inclination. This has produced a disjointed summit surface, and weathering and erosion of all kinds have acted on the weaknesses between the small blocks to create a series of large and small valleys which cut into and dissect the island to a greater extent than either Grimmington Island or the Inland Block.

Immediately south of the base camp on Mugford Tickle is a fault zone which turns north north west to south south east from Mugford Tickle to the coast at Sutherland Inlet. This valley forms a convenient crossing point from Mugford Tickle to the southern shore of the island. The valley bottom is filled with drift into which has been cut a steep sided gorge extending from the col at 658 feet above sea level down to the coast. The col itself is flattened, and on it there are quite distinct terrace features, with flat surfaces of well-sorted material (much of it about fist size or less), quite clearly water-lain. On the north side of the col the river cuts its gorge

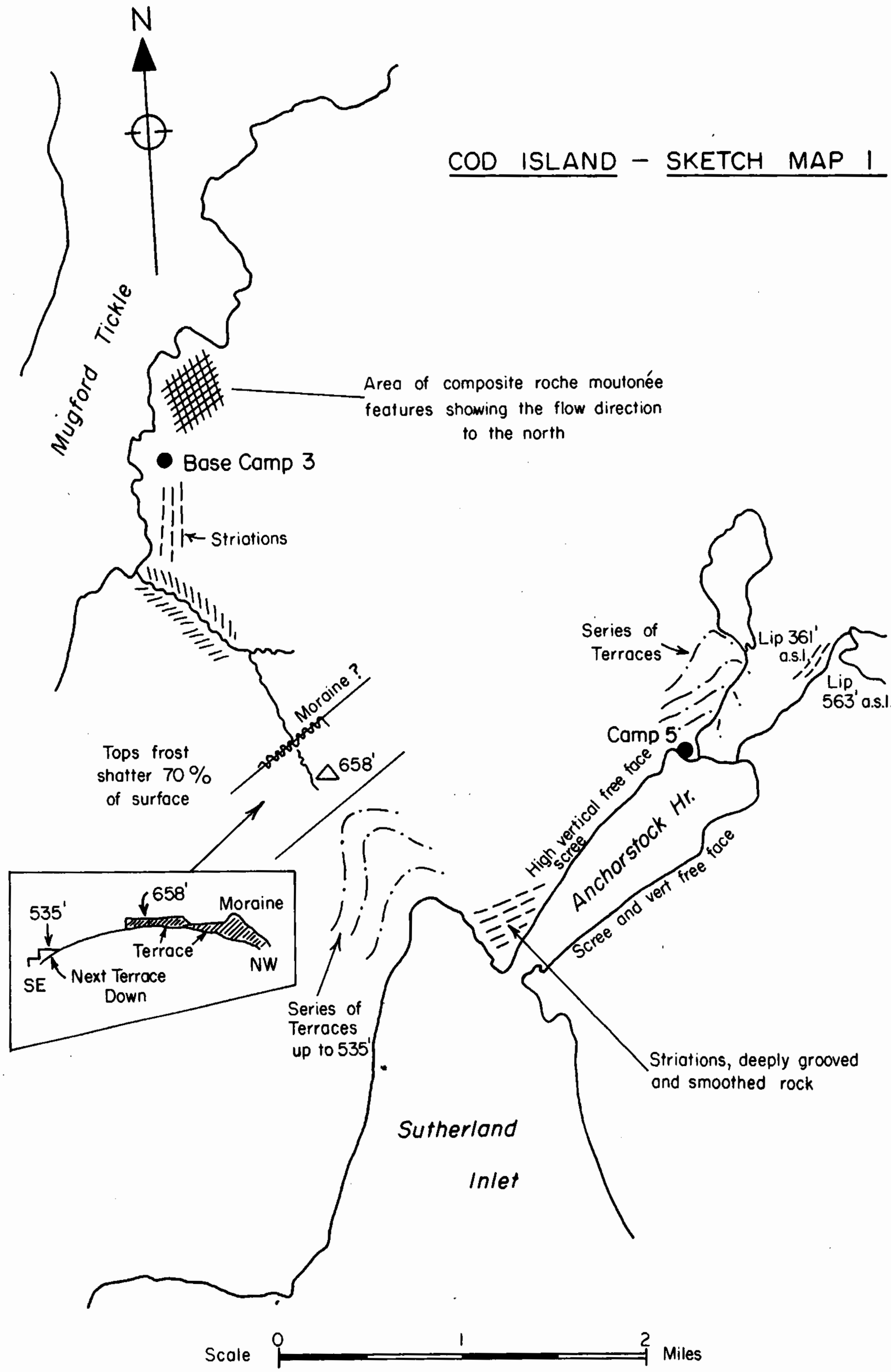

N
COD ISLAND — SKETCH MAP I
Mugford Tickle
Area of composite roche moutonée features showing the flow direction to the north
Base Camp 3
Striations
Moraine ?
658'
Tops frost shatter 70 % of surface
535'
658'
Moraine
Terrace
SE
Next Terrace Down
NW
Series of Terraces up to 535'
Series of Terraces
Lip 361' a.s.l.
Lip 563' a.s.l.
Camp 5
High vertical free face scree
Anchorstock Hr.
Scree and vert free face
Striations, deeply grooved and smoothed rock
Sutherland
Inlet
Scale 0 1 2 Miles

Figure 33

through a high pile of material stretching from valley side to valley side: this could be interpreted as a moraine.

A brief examination of the summit surface to the south of the col at the level of approximately 1,300 feet was made. The surface is not that of a gently rounded summit plateau, but rather that of a highly irregular, dissected and faulted mountain top, the dominant forms being controlled by fracture and fault lines in the bedrock. Glacial action has, to some extent, rounded the minor forms and it is estimated that boulder detritus covers 70 percent of the surface area. In general, the ice action modified in detail the preglacial, gently undulating basalt capping of the mountain blocks: where this capping was unbroken, it left gently rounded plateau surfaces; where the basalt was fractured and displaced, it accentuated, rather than diminished, the irregularities. Indeed, on the summit surfaces the modifying effect of frost-shattering has probably contributed as much to the reduction of major angular features as has ice erosion.

South of the col the valley widens and descends to the head of Sutherland Inlet. Down this valley a small stream cuts a V-shaped notch into the drift from the col to sea level, and from immediately below the col there is a flight of well-preserved terraces. The terraces are horizontal, following the contour lines from one side of the valley to the other. The highest terrace that could be observed, apart from those on the col, is at 535 feet above sea level. An exceptionally well-preserved group occurs between 409 and 438 feet. In fact, no less than seven well-defined features were found above 400 feet. The origin of the terraces is not immediately apparent. Their form, particularly their horizontal nature, suggests that they are not river terraces. Their proximity to the sea would imply a marine origin, though confirming evidence of other raised beaches at this height was not found. Of the lower terraces, the height of the six most distinct examples was taken, and it correlated well with similar features elsewhere in the Kaumajet area.

To explain this sequence of features one must envisage two possible factors responsible for their formation. There is no doubt that ice totally inundated this whole mountain area, as the evidence of erratics on all the summit surfaces indicates clearly. There is further evidence that the last ice maximum certainly reached summit level at least. One could then suggest eventual downwasting which exposed the col before lower levels were clear of ice. Possibly the ice retreated from Mugford Tickle before it retreated from Sutherland Inlet, leaving a tongue of ice lying across the col to the limit of the small moraine on the northern side of the col. Its melt water would cut deeply through the drift and form the gorge down into Mugford Tickle. The retreat of this tongue would leave water dammed against the moraine to form the small terraces on the col. As the ice retreated down the hillside, exposing greater areas of the valley, it is easy to imagine water dammed between the high land and the ice front, forming the higher terraces as a succession of pro-glacial lake shorelines. But at lower levels, as the valley broadened, perhaps the ice dam was no longer effective and the water, hitherto trapped between ice and valley walls, could leak away elsewhere. Another possibility is that the sea level was higher at that time and the ice had melted back to it. Later eustatic changes in sea level would produce a series of marine beaches similar in form to those produced at a higher level by the pro-glacial lake shorelines.

As has been stated, a fault is the main reason for the valley already described between Mugford Tickle and Sutherland Inlet. This fault carries on south south eastwards and is probably responsible for the position of the coastline south east of Sutherland Inlet. Parallel to this fault and slightly to the north of it is another fault zone lying between Camel Inlet and the

Fig. 34 Striations at water level, Anchorstock Harbour mouth.

Fig. 35 Head of Anchorstock Harbour, showing lip of lake ponded in high level valley leading to Camel Inlet.

head of Anchorstock Harbour, again responsible for a major feature on the island. Anchorstock Harbour itself is approximately $1\frac{1}{4}$ miles in length, $\frac{1}{2}$ mile wide at its widest point and 200 yards wide at its mouth, where it meets Sutherland Inlet. It is a deep trough with 900 foot vertical walls on either side from the bases of which scree slopes extend to sea level. Where the harbour narrows near its entrance, rocks of the basement complex come out from under this scree, and it can be seen that they are smooth and polished and deeply striated in a north-east-south-west direction approximately parallel to the sides of Anchorstock Harbour.

At the head of Anchorstock Harbour is a series of terraces between sea level and 400 feet. These terraces lead up to the lip of a lake which is situated at the mouth of a high level valley extending between this point and Camel Inlet along the fault zone already mentioned. The valley is predominantly a structural feature, but the rocks in it have been smoothed and rounded by ice action, and striae were found on some surfaces, though weathering has affected most rock exposures.

The drainage has to some extent been modified by glacial action, but the major form of the valley is of pre-glacial origin. The lip of the lake shows clear signs of recent ice-polishing and striations, as do the twin cirques which cut back into the mountain mass to the east of the head of Anchorstock Harbour. It is probable that late-stage cirque glaciation ice filled these hollows, flowed into Anchorstock Harbour and probably reached as far as the coast at Sutherland Inlet. From the evidence of striae at the mouth of Anchorstock Harbour, and from fragmentary evidence of the limit of recently smoothed rocks on the walls of the harbour, it is doubtful that this cirque glaciation ice exceeded 300 feet in thickness at the mouth of the harbour.

The highland of the centre of Cod Island has surface characteristics

Fig. 36 Highland in centre of Cod Island, showing frost-shattered material, and conditions of limited visibility that were continually encountered.

similar to those already described between Mugford Tickle and Sutherland Inlet. This surface is faulted and irregular, and erratics of granite gneiss are to be found in the boulder detritus, produced by frost-shattering that covers a high percentage of the surface. This frost-shattered material has been re-worked into broad terraces that in the very highest parts of this area form a series of flat steps on which progress was relatively easy. Unfortunately, this area was not examined in detail: though it was traversed in both directions, each time was in fog with 25 to 30 yard visibility, and while the terrace forms could be noted, their regional distribution could not be studied satisfactorily. Striae in fresh condition were preserved on this surface at the height of 1,358 feet trending in an east-west direction. Again these relatively fresh striae were above a considerable quantity of frost-shattered material.

Long Lake is situated approximately in the centre of Cod Island. Its long axis is about $1\frac{1}{2}$ miles long, parallel to the long axis of Anchorstock Harbour and Mugford Harbour. From the southern end of Long Lake a valley makes an about turn directly south and runs straight to the sea. Both Long Lake and the valley leaving it are predominantly structural features. To the north east of Long Lake a valley, whose lower drowned portion constitutes Mugford Harbour, is cut back until its head is within 1 mile of the head of Long Lake. The high land between the two valleys is breached by a col whose lowest point is 564 feet above sea level. To the east of Long Lake and Mugford Harbour valley are two large blocks of the sediment basalt complex. The northern block is between Clark Inlet and Mugford Harbour. Its walls are precipitous and on the inland side are sculptured into magnificent cirque forms. The top of this block is in excess of 3,000 feet and is gently tilted toward the west.

Fig. 37 Striations on Col between Long Lake and Mugford Harbour.

Fig. 38 Part of former lake shoreline, 62 feet above lake level at north east end of present Long Lake.

The second block is south of Clark Inlet; its eastern face presents the 3,000 foot cliffs of Table Hill to the Atlantic. Its summit surface slopes quite markedly to the west until it is terminated by Long Lake Valley.

The north western side of Long Lake is bounded by precipitous slopes over 1,000 feet high. These slopes are smoothly polished, with fresh striae, the highest at 900 feet, running parallel to the long axis of the lake. Fresh striae are also abundant on the col separating Long Lake and Mugford Harbour Valley, and were found up to a level of 830 feet above sea level. These striae cross the col from east to west. To the north and north west of Long Lake at approximately 900 feet above sea level is a series of gullies and marginal drainage channels curving round the hillside and sloping gently to the south and east. Erratics of white granite gneiss are common on all the surfaces in this area.

Around the head of Long Lake is a series of lake shorelines. The three most distinct of these are at 33 feet, 55 feet, and 62 feet above present lake level (473 feet above sea level).

That the ice at the maximum of the glaciation covered this entire area is evidenced by the number of erratics on all surfaces. The fresh striae around Long Lake indicate that ice has filled this valley at a comparatively recent date and overflowed the col into Mugford Harbour Valley. This ice reached a height of at least 900 feet at the head of the valley. The marginal drainage channels and gullies cut just above this level could possibly have been produced during a waning stage of the maximum glaciation or at the maximum of the later minor glaciation. As the final ice downwasted, the melt water probably flowed over the col and into Mugford Harbour Valley. This overflow of water from Long Lake Valley caused a vertically sided channel 20 feet deep by 8 feet wide to be cut through the col between Long Lake and Mugford Harbour.

Figure 39 - COD ISLAND - SKETCH MAP 2

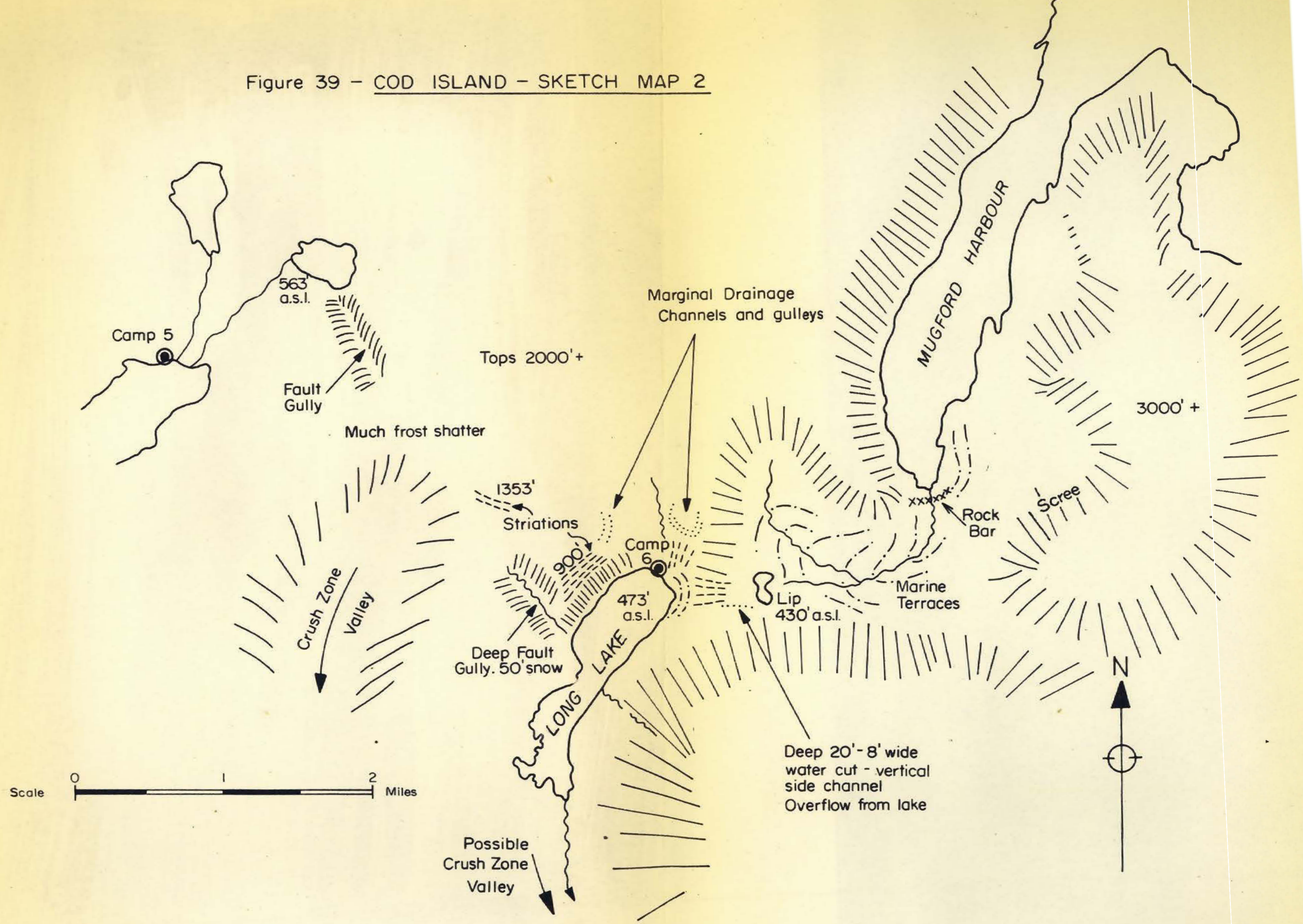


Fig. 40 Granite gneiss erratic sitting in glacial drift over basaltic bedrock on col between Long Lake and Mugford Harbour. Note difference in weathering between granite gneiss erratic, and incipient frost-shattering on basaltic bedrock in background.

Further receding of the ice and lowering of the water level ponded water at the head of Long Lake below the level of the col. The ponded water formed the successive shorelines noted above Long Lake.

The col between Long Lake and Mugford Harbour Valley has its eastern slope cut into by a small cirque containing a lake whose lip spills out into Mugford Harbour Valley at a height of 430 feet above sea level. Mugford Harbour Valley is a relatively wide valley delimited by the vertical walls of the basalt blocks. Its fall shows a succession of well-marked marine terraces, the highest being 353 feet above sea level. The bottom of the valley is U-shaped and drift-filled. A pronounced rock bar or riegel crosses the valley immediately above sea level. The river cuts through this rock bar before reaching the sea. To the east of the rock bar along the valley side are three further marine terraces at a lower level than those noted above.

It seems clear that Mugford Harbour Valley has been filled with ice during the period of major glaciation and also has received ice both as the overflow from Long Lake Valley and from its own small cirque glacier in more recent times. The marine terraces are the result of isostatic uplift at the end of the glacial period. But in the prevailing weather conditions it was unfortunately not possible to examine the upland surfaces to the east of Long Lake and Mugford Harbour. From a brief examination of their lower levels and an examination of air photographs it would seem that they follow the same pattern as the upland surfaces of this island already described.

CHAPTER 7

GRIMMINGTON ISLAND AREA

Grimmington Island is the centre-most unit of the Kaumajet group. It is higher than the surrounding mountains, having Brave Mountain at over 4,000 feet at its western side, and an elevation of 3,680 feet on its eastern side. The island is divided into two mountain blocks by Horr Valley which dissects it on a north-east-south-west line between Horr Harbour and Seal Bight. The block to the north of Horr Valley contains Brave Mountain and Bishop's Mitre. This block is sculptured by cirque forms on all sides, the most magnificent examples occurring on the northern side exposed to the open sea. The largest of them is the single cirque below Bishop's Mitre, whose headwall curves down from the very summit (3,900 feet above sea level) to sea level. Most of the others are composite features, usually one cirque above another. These seaward facing cirques cut back until they form arêtes with those which are cut into the northern wall of Horr Valley. Thus, the block to the north of Horr Valley is almost entirely cut away by cirque forms, relatively small patches of the summit surface being left undissected. One such area, however, is the gently rounded top of Brave Mountain. It is this block that has been examined by Odell and Wheeler.

To the south of Horr Valley is the larger of the two mountain blocks on the Island. This block itself is cut into and dissected by cirque valleys, but the greater portion of the upland surface remains.

Heavy seas on the northern shores and a low cloud base effectively prevented examination of the northern coast and the summit surfaces on Grimmington Island in the time available. An examination, was, however, made of the southern part of the island and also of Horr Valley: these results are presented.

Fig. 42

Fig. 43

Fig. 41

On the south side of Grimmington Island the basal gneissic complex projects from under the basalt-sediment complex to form the shoreline. Thus, the vertical wall of the mountain blocks stands back from the shore. The southernmost point of Grimmington Island is a projection of granite gneiss that was once covered by the basalt series, the two hills on the projection being capped with erosion remnants of basalt.

Immediately to the west of this point is Eskimo Cove. Between Eskimo Cove and Horr Harbour are two major cirque valleys cut into the mountain block, both of which have rivers flowing directly to the sea. Eskimo Cove itself is a small bay to the south east of the entrance of the first cirque valley, divided from it by a low ridge of gneiss. At the western end of Eskimo Cove are two streams, both flowing in gorges deeply cut into drift material, which extend back over the crest of this ridge. The water now flowing in the stream channels is gathered from the mountain wall and the sides of the ridge below the crest, but water must have flowed across the crest to cut the gorge there. Such water could have been derived only from a lake ponded in the head of the cirque valley, most probably by an ice dam at its mouth, or else from melt water flowing along an ice-rock contact, to a point where it could drain away over the ridge to Eskimo Cove. Thus, the features are properly overflow channels now being utilized as minor stream courses.

A series of marine terraces was noted and measured on the sides of Eskimo Cove. In Eskimo Cove the line of boulder debris formed at the junction of land-fast ice and moving pack-ice is particularly noticeable and constitutes an arcuate barrier parallel to the shore.

An examination of air photographs shows that the first cirque valley is basically a simple cirque with its valley leading directly to the coast. The second cirque valley stretches further back, probably along a fault zone, and

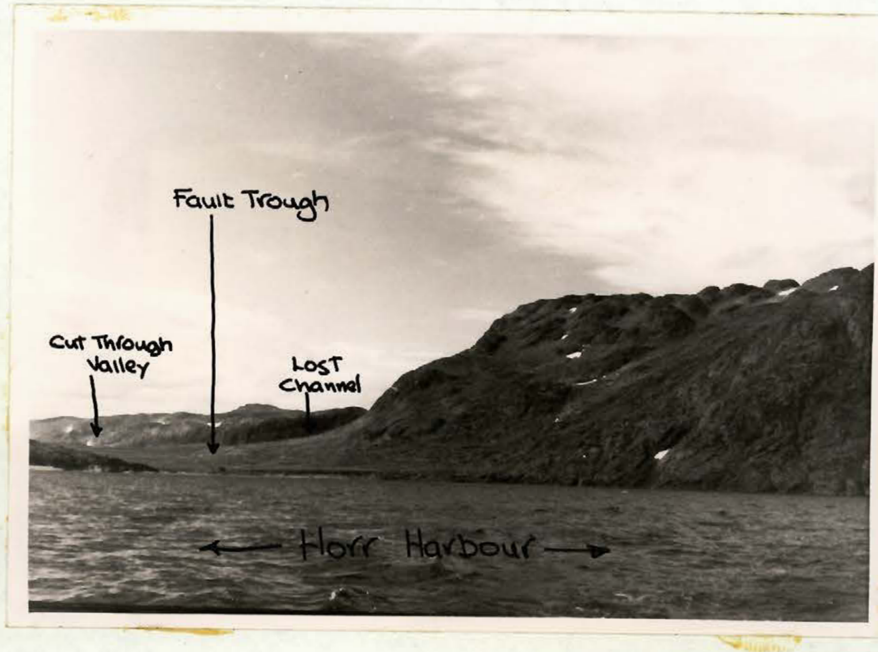


Fig. 44 View to west from Horr Harbour showing fault trough.

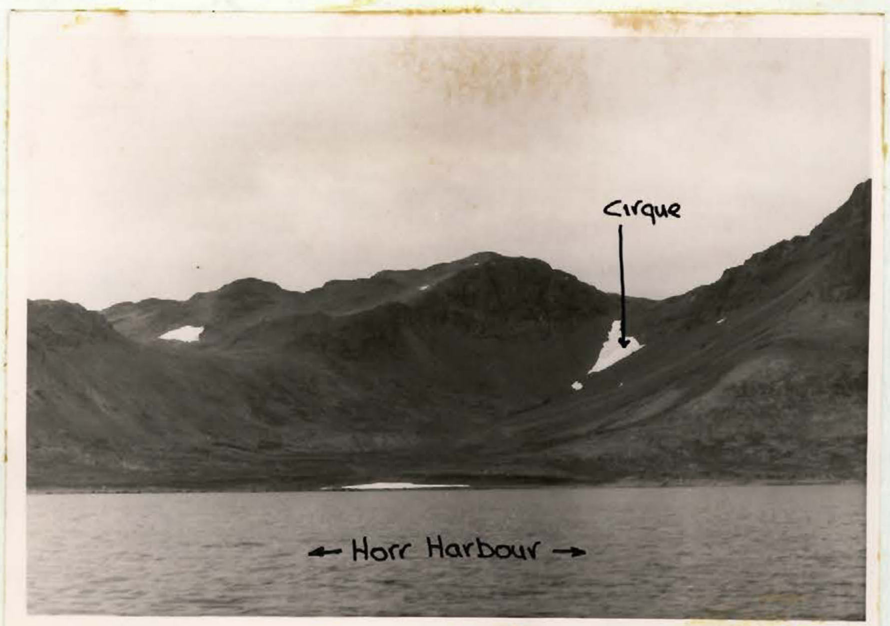


Fig. 45 View to west from Horr Harbour showing cirque.

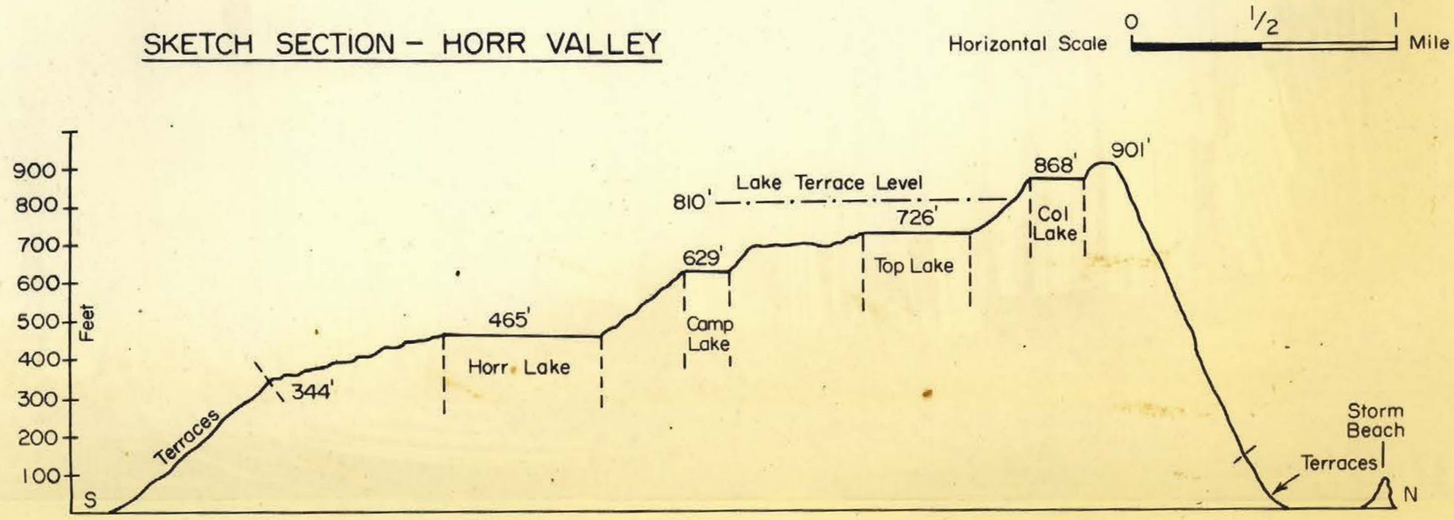
its head consists of a series of cirques forming steps to the summit surface. It was noted from the shore that the valley bottom has a marked break of slope at about 400 feet above sea level. Below this point the river cuts in a gorge down through a series of marine terraces. This suggests that glacial erosion and more important, glacial deposition, were related to a sea level 400 feet above the present sea level. Between the second cirque valley and Horr Harbour is a small island connected to the coast by a tombola. The highest point of this tombola is 44 feet above sea level which correlates well with a distinct marine terrace in Eskimo Cove.

To the south west of Horr Harbour is an extension of gneissic basal complex that separates Horr Harbour from Lost Channel. The granite gneiss is dissected by a trough which extends from Lost Channel to Horr Harbour and is parallel to the trough of Cut Through Valley. It is probable that the same fault system responsible for Shark Gut Harbour and Cut Through Valley is also responsible for this trough, and indeed for the main coastline of Grimmington Island south of Horr Harbour. The mountain block north of Horr Valley is terminated by this trough. On the west side of Horr Harbour is a major cirque cut into the mountain block.

Horr Harbour itself is primarily the drowned southern part of Horr Valley. This valley is essentially a structural feature which has undergone three stages of glacial modification; first, before the glacial maximum, it was widened by cirque cutting; secondly, under the influence of major glaciation, a U-shaped trough, structurally modified,was created; thirdly, both erosional and depositional features were added by final cirque glaciation.

Ascending Horr Valley from the south one crosses a series of raised beaches and river terraces. The river terraces are very close to the sea and can almost be regarded as marine terraces. Certainly this applies to the flat

Figure 46



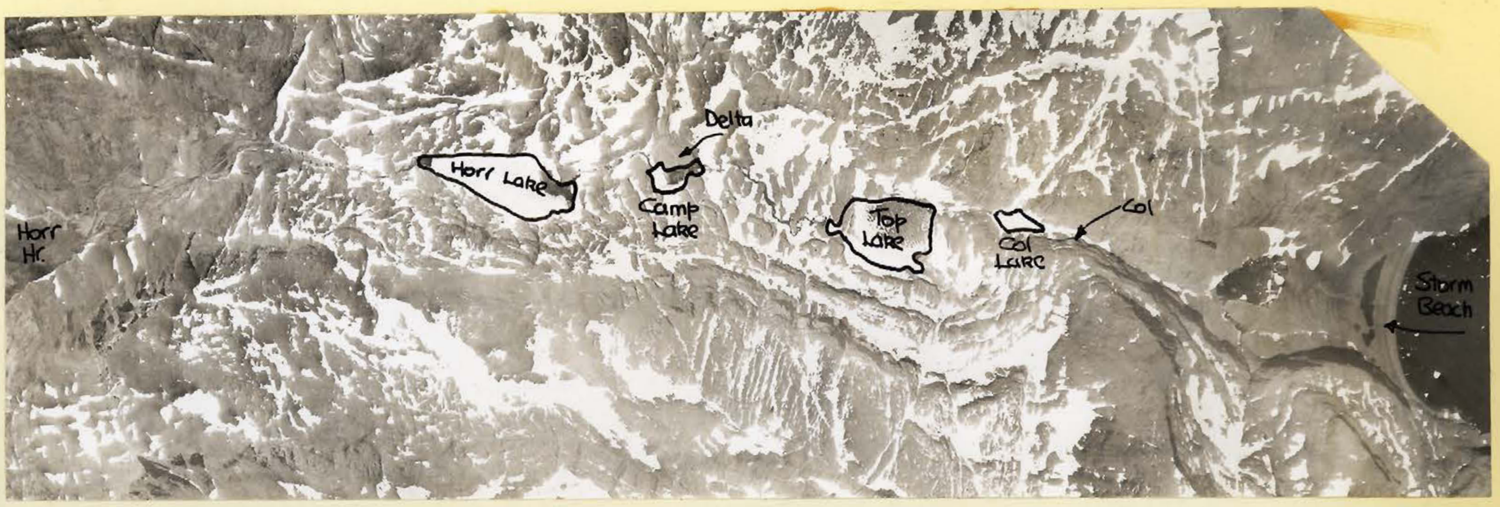


Figure 47

lower limits of each river terrace. The terraces are beautifully preserved and are dissected in a gorge by the present stream. The highest terrace was found at 344 feet above sea level. Above this height, the river falls in an even cascade over open structural steps from Horr Lake (465 feet above sea level) to the top terrace, these structural steps being 6 to 10 feet in vertical dimension. The lip of Horr Lake flows over a similar rock ledge.

Horr Lake itself is not deep (its estimated depth is 40 to 50 feet), but it has a vertical east wall, and a scree slope leading from a free face composes its west side. Fresh striations were found on the lip of Horr Lake and on the exposed rock surfaces in the valley bottom. The valley below Horr Lake has been filled with drift but the river has cut away most of it, exposing the bedrock already mentioned. No moraine features were found in the lower valley.

Above Horr Lake the trough form of the valley becomes particularly apparent. To the north west a major cirque hangs to the trough, with its headwall immediately below Brave Mountain. Half a mile above Horr Lake is another small lake named Camp Lake at 629 feet above sea level. On the western side of this lake is a large raised delta, whose area is larger than the area of the present lake. Above the lake the structural influence can be seen on the southern side of the valley. Here, ice erosion has been controlled by the lithological differences in the basalt sediment complex, and has given rise to a series of ledges at approximately 400 foot intervals on the valley wall. Above Camp Lake the amount of drift in the valley bottom diminishes; smooth striated bedrock forms the valley floor. At 720 feet above sea level a rock ledge dams a relatively large lake in a local widening of the valley floor. This lake was named Top Lake. Above it, at a height of 810 feet above sea level, is a fragmentary lake shoreline worked into scree material. Above Top

Fig. 48 Lake shoreline above Top Lake, at 810 feet above sea level.

Lake the valley narrows and approaches the col (901 feet above sea level). Immediately south and 33 feet below the col is a small lake named Col Lake. At the col the walls of the valley are very high and close together, forming a narrow cleft between the two mountain blocks, the bottom of which has been eroded into a U-shaped trough. The bottom of this trough has in turn been cut into by a small deep cleft whose sides show evidence of water action rather than of glacial striation and whose base is only 20 feet above the present level of Col Lake. On the north side of the col a steep slope descends between near vertical 3,000 foot walls, to sea level. At the bottom of this slope, which is covered in talus material, is Seal Bight, a major bay in the northern coast of Grimmington Island. At the head of the bay a storm beach, some 60 feet above sea level, stretches from side to side. Behind the storm beach is a linear series of small lakes, and behind the small lakes a series of previous shorelines. These raised shorelines in turn pond back a large lake against the backwall of the bay. The raised beach features in Seal Bight were examined and measured.

From the evidence presented a tentative description of the glacial events that have influenced the form of Horr Valley may be advanced. The very large cirques cut into the north of Grimmington Island, particularly those which cut below sea level, suggest cirque glaciation in excess of that postulated in post-glacial maximum times from evidence of fresh striae and moraine features. It is probable that the pre-glacial maximum cirque glaciation responsible for these features also initiated the cirque development in Horr Valley. This is supported by the fact that some of the cirques appear to have been smoothed, and even truncated, by the trough development in the valley, and that none cut down into this trough. The ice at glacial maximum completely filled the valley, the erratics found on the summit of Brave Mountain by Wheeler being ample evidence of this. The direction of this flow is not immediately apparent as the rounded features and striations in the valley itself are not conclusive indicators. However, if the direction of flow was similar to that in Neisser Inlet and Mugford Tickle, it would be from south to north. Certainly the ice of the major glaciation was responsible for the trough form which is particularly noticeable in the higher parts of the valley. The water-worn channel cut through the col, only 20 feet above the present level of Col Lake, strongly suggests that Col Lake has been at a higher level than at present, and overflowed northwards to Seal Bight. Such a rise in lake level could be explained only by a dam at the southern end of Col Lake. There is no evidence to suggest that a rock ridge could have formed this bar, only to be cut through subsequently by water action. Hence it is reasonable to advance the concept that the waning stage of ice was one of downwasting which exposed the higher land first, trapped melt water against the col, and thus gave rise to a higher lake level.

As downwasting continued, it might be expected that the ice front would form further pro-glacial lakes at lower levels. There is evidence for such a supposition in the shoreline feature, which postulates a water level at least 84 feet above Top Lake, and in the large raised delta above the middle lake, which would also require a substantially higher water level than the present configuration of the valley could contain.

Coincident downwasting on the northern side of the col would presumably give rise to similar melt water conditions, though the precipitous rock walls and steep slope covered with recent talus are not favourable to the formation and preservation of depositional evidence.

The final stages of downwasting probably saw melt water, no longer retained by the ice barrier, draining directly to sea level.

The fresh striae observed on Horr Valley floor suggest that the valley was in part occupied by late stage cirque glaciation ice. It must be pointed out that cirque glaciation was not a major factor in the sculpturing of the valley floor. Fresh striae were not observed on the valley walls higher than 200 feet above stream level. The headwalls above each of the lakes in the valley are not the steep vertical headwalls of cirques. They are, rather, an irregular slope from lake lip to lake head, over which the river cascades in a series of small steps. It is possible that the higher cirques on the valley walls were partly filled with ice during the cirque glaciation and spilled their ice into the valley bottom, where it gently modified the already rounded features and left fresh striations behind.

The final event influencing the present form of Horr Valley was undoubtedly isostatic uplift. The series of well-preserved raised beaches up to 344 feet above sea level at the head of Horr Harbour, and the series of raised strand lines in Seal Bight, tend to substantiate this suggestion. The very recent gorge cutting down through the marine features to Horr Harbour adds further support to this hypothesis.

CHAPTER 8

CONCLUSIONS

Extent of Wisconsin Glaciation

The problem of maximum vertical extent of ice is solved by the presence of unmistakable erratic blocks on all the summit surfaces that have been examined in the Kaumajet Mountains. The difference in lithology between the Kaumajet summit surface and the surrounding lowland area is particularly fortunate in this respect. The erratics of white coarse-grained granite gneiss cannot be mistaken for the fine-grained blue-gray basalt bedrock with its distinctive red, weathered surface.

As noted in the text, the highest point examined by the party - the summit of Finger Hill (3,428 feet) - had numerous examples of these erratics. At one point on the summit surface it was possible to pick one's way over the ground by stepping from erratic block to erratic block. Wheeler, in his examination of Brave Mountain (4,026 feet), found similar erratics on the summit surface at a level of 3,850 feet where he "could see no change in the form of the summit slopes that might suggest they had not been overridden by the ice that brought erratics from the west to the 3,850 foot level." Erratics were as numerous on the summit surfaces of Cod Island. Quite frequently erratic blocks were very large (10 feet by 10 feet by 8 feet): one such block was found at over 2,000 feet on Cod Island.

Any gneissic erratic material found at a level of over 2,000 feet in the Kaumajet Mountains would presuppose a vigorous flow of ice across the summits, which in turn implies that the summits in question were submerged beneath a considerable thickness of ice.

The morphology of the mountain blocks of the area is interesting in this connection. As has been described, the volcanic series forms a precipitous wall between 1,000 and 2,000 feet in height around each mountain block. Ice flow sufficient to place a considerable amount of gneissic material on the surface of the mountain blocks would have to have a thickness and a surface gradient sufficient to overcome this barrier. It is reasonable to suggest that ice flow of this nature over the mountain group would require at least 1,000 feet of ice over the highest summits.

The necessarily reconnaissance nature of observations made in the Kaumajet Mountain area does not allow definite conclusions to be formed regarding the rate of break-up of the volcanic series by frost action, or the time of deposition of erratics on the summit surface. In particular the degree of weathering of erratics cannot be directly compared to that of the bedrock. One is, however, tempted to advance some hypothesis for the striking difference, and while it must be realized that there are areas of bedrock on the summit level which have only incipient frost-shattering, it is clear that some types of the volcanic series are more susceptible to frost action than the granite gneiss.

While considering the degree of frost-shattering found in various rocks on the summit surface, one must mention the well-preserved striations observed on the summit surface of Finger Hill at about 4,000 feet above sea level. These striae are nearly 1,000 feet above the highest limit of fresh evidence of cirque erosion, and also trend in an east west direction. It is suggested that they were formed by ice crossing the summit surface in an east-west direction, and, bearing in mind the morphology of the area, one might conclude that an ice mass of sufficient thickness and surface gradient to cross the summit surface must have at least approached the top of the highest summit.

As striae are not enduring features, the presence of the well-preserved striae on the summit surface argues that either they are of recent origin, or they have been in some way preserved. It has been suggested that the striations were fortuitously preserved beneath a protective cover which has been recently removed. In this manner the striations could have been protected since a pre-"classical Wisconsin" maximum. Similar fresh striations on the summit surface were found on Cod Island at the much lower level of 1,358 feet above sea level. Again the striae must have been formed by ice crossing the summit surface, above and moving at right angles to the local later cirque glaciation. It is possible that these too were fortuitously preserved under recently removed debris.

The general scarcity of striations observed on the higher summits must not be over-emphasized. In the very limited time available for summit investigation, probably less than 10 percent of the total summit area was examined in sufficient detail to allow the recording of striations. Further, it is not reasonable to expect large areas of freshly striated rocks, even of striae related to a hypothetical late Wisconsin maximum glaciation, to be preserved in an area subject to the vigorous weathering and the sub-aerial erosion that characterizes the Labrador coast.

An alternative to the hypothesis of fortuitous preservation might be that the striae observed are in fact some of the few unweathered ones remaining from a post-Sangamon glaciation. This observation does, however, fit with the unweathered state of the granite gneiss erratics, and supports the hypothesis that certain types of volcanic rocks are very susceptible to frost action, and may have disintegrated relatively rapidly, as would be required if the glaciation that caused the striae and deposited the fresh erratics were indeed post-Sangamon. This suggestion must await further evidence for confirmation or rejection.

Direction of Ice Movement in the Kaumajet Mountains

The main movement of ice through and over the Kaumajet Mountains was from a westerly direction, and at no time during the Wisconsin period did the mountains form a major centre of ice dispersal to the west.

This conclusion is prompted by the distribution of erratics in the area, by the summit surface striations, and by a consideration of the position of the mountain group.

The presence of granite gneiss erratics on the highest levels of the Kaumajet Mountains implies that ice passed across the summit surface. While the granite gneiss basal complex surrounds the volcanic series on all sides, it is doubtful that a centre of ice flow large enough to force ice over the mountains was established on the relatively narrow continental shelf to the east of the group. Emplacement of erratics was thus by ice flowing from a centre inland of the mountains. The limited evidence of striae on the summit surface indicates movement in a directly west to east direction. This is supported by innumerable minor indications deduced from rounded bedrock forms on the upper surfaces. The conclusion is reached that the main supply of ice affecting the Kaumajet originated in the west and crossed the summits in a due west to east direction.

This conclusion is supported by the evidence of Wheeler (1958), who made a similar examination of the watershed in the country west of the Kiglapait Mountains. Here chatter marks and indicator erratics show a distinct movement of ice from the south west.

The axes of drumlins and drumlinoids plotted on the 8 inch to 1 mile Nain-Nutak sheet by Douglas and Drummond conform to this west to east trend of ice movement.

That the lower levels of ice movement were topographically controlled is beyond doubt. The observations in Neisser Inlet, Horr Valley, and Mugford Tickle clearly show that the ice flowed through them from south to north. In the inland area the valley between Rifle Lake and Rifle Bay indicates movement directly south to north at right angles to the main ice movement. If this is so, it suggests a circuit movement of the bottom ice conditioned by major topographic forms.

If the Kaumajet Mountains had been a centre of outward-flowing ice, one would expect such movement to be indicated by the occurrence of basalt erratics on the lowland area affected by the ice flow. The only concentration of volcanic blocks occurs where talus material has been washed down into the drift covering the floor of Cut Through Valley. Only scattered occurrences of basalt material occur in the boulder field immediately west of Cut Through Valley, the furthest away from the mountains front being some $1\frac{1}{4}$ miles. No trace of basaltic material was found during the careful examination of the lowland inland area. This evidence is supported by similar observations by Wheeler (1958) after a careful search over the first gneiss hill south west of a contact on the isthmus between Horr Harbour and Lost Channel.

The conclusion is reached that ice originating in the Kaumajet Mountains in the Wisconsin period did not significantly influence the glaciation of Labrador as a whole.

Recognition of Separate Phases of Major Glacial Activity

The precipitous sides of the Kaumajet Mountains are not conducive to the preservation of such evidence as lateral moraines, differentiated drift, or other depositional features that would readily indicate a greater and lesser stage of Wisconsin glacial activity. Nevertheless, there must be a consideration of the land forms that have been noted in the text for possible correlation or indication of such separate phases of glacial activity. It is tempting to suggest that after a glacial maximum overflowing the summits, a second incursion of continental ice partly engulfed the Kaumajet group, that it was not vigorous enough to place erratics on the summit surface, yet that it gradually covered most of the plateau, possibly incorporating or overriding a minor sympathetic icecap already in place on the plateau surface. Such an ice condition would probably only briefly cover the summits and for most of its duration would only surround the summits, which would project as nunataks. Minor local movements of the base of this ice at plateau level would be sufficient to produce striations, but on the whole little disturbance of the broad surface areas would occur and the main mass of boulder detritus would be left in place. The lower levels - particularly those confined to narrow channels - might be expected to have more erosive power and produce relatively fresh roches moutonnées and striations.

However, other hypotheses are equally possible. If the ice flow that placed the abundant erratics on the summit surface was of Wisconsin age, and the unweathered state of the erratics would seem to suggest this, then, as tentatively put forward, production of mountaintop detritus might also have occurred at some time during the Wisconsin. Certainly it is difficult to subscribe to the view that mountaintop detritus could have stayed in place during such ice activity.

Insufficient is known about the disintegration rate of bedrock with relation to variations in lithology and macro-climate to differentiate between detritus whose shattering began at different times during the Wisconsin, and there is not sufficient evidence in this area to place the start of disintegration at either a first or second phase of Wisconsin glaciation.

Disintegration could well have begun after the formation of the striae observed on the upland surface. If the disintegration began after a single Wisconsin covering the summit surface, the terrace forms wasted into the detrital material cannot be explained as ice margin terraces. It could be suggested that they are the result of peri-glacial activity and possibly are very large solifluction terraces. The rather well-preserved roche moutonnée features and striae in Mugford Tickle could owe their good state of preservation to protection during marine submergence rather than to a low-level recent major glaciation. That the sea level was effectively higher than at present is evidenced by the occurrence of marine beaches around 350 feet above sea level in parts of the area favourable to their preservation.

While it is important to give careful consideration to these hypotheses it must be concluded that the evidence does not form a sound basis to prove the existence of two distinct phases of major glacial activity. One is compelled at this stage to assume a working hypothesis of one major glacial incursion during the Wisconsin period, having, perhaps, a long waning period during which a stage of partial submersion existed for a considerable time.

Cirque Glaciation in the Kaumajet Mountains

Several interesting cirque forms were examined in detail in Finger Valley, Neisser Inlet, Horr Valley, Anchorstock Harbour and Mugford Harbour Valley. Further observations were made in Mugford Tickle, the south coast of Grimmington Island and on the north west side of Grimmington Island. Cirque forms in the whole area have been carefully studied on air photographs.

No active cirque glaciation is noted in the Kaumajet area. However, the freshness of the evidence, particularly the very fresh nature of the inner moraines (whose boulders show not the least sign of chemical weathering, or lichen growth), indicates that cirque glaciation has occurred in recent historical time. It is estimated that cirque glaciers have existed in the Kaumajet

Mountains in the last two hundred years.

This cirque glaciation was not of great extent. The glacier in Anchorstock Harbour reached the sea, and the moraine at the mouth of Finger Valley probably represents the terminal moraine of the Valley glacier. The Neisser Inlet series briefly spilled into the sea but others were wholly contained in their valleys.

The contrast between the unweathered evidence of cirque glaciation and the weathered nature of the surrounding terrain in the area of maximum extent of cirque glaciation prompts the conclusion that the more recent cirque glaciation has developed since the post-glacial Thermal Maximum and is primarily a product of the "Little Ice Age".

This conclusion, and the relative insignificance of the recent cirque glaciation, is in complete contrast to the size and magnificance of some of the cirque forms. Clearly, one must come to the conclusion reached in the examinination of Horr Valley, that the main body of cirque erosion predates the fresh evidence and in some cases predates the Wisconsin glacial maximum.

Tanner noted that the Island of Nanuktut immediately north of Cod Island has its surface completely dissected by cirque forms. Careful study of air photographs supports his observation that most of the arêtes are smoothed and rounded, suggesting the passage of continental ice, and hence the premaximum origin of the cirques. Cirque forms cut below sea level suggest that downcutting occurred during the lower sea level of the glacial period before total inundation and again, immediately after the wasting of ice from this marginal area, before the subsequent marine transgression. Certainly it is difficult to conceive that the Bishop's Mitre cirque (3,900 foot headwall) was sculptured either by cirque activity below sea level at the end of the Wisconsin maximum or by recent cirque glaciation.

In summary, one can postulate that the present cirque forms are a product of: (a) pre-Wisconsin cirque glaciation; (b) post-Wisconsin maximum action; (c) recent cirque glacier activity.

Late Wisconsin Conditions

There are three basic methods by which a continental ice cap can wane. In the first case, ablation at the ice front exceeds accumulation and dispersal from the source areas, causing the gradual retreat of an active ice front. In the second, the snow line rises, the accumulation zones are starved, and there is downwasting in situ of the ice mass. In the third case, the two above mentioned methods combine, the first usually being a primary phase of the second.

Following Tanner (1944), Ives (1959) advanced evidence supporting theoretical considerations that the final stage of the Wisconsin ice sheet in north east Labrador was one of starvation of the accumulation zones and downwasting in situ.

Evidence tending to substantiate this concept was found in the Kaumajet area. The higher terraces on the ice diffluence col to the north west of Sutherland Inlet and the terraces above 400 feet on the upper slopes of the inlet itself can be explained by a final stage of downwasting that first exposed the valley cols while covering the lower areas. The overflow channel cut into the col of Horr Valley, and the series of fragmentary raised lake shorelines and the raised delta could have been caused by a successively lowering ice block in the valley mouth while the tops were exposed. The overflow channel between Long Lake and Mugford Harbour Valley on Cod Island and the lake shoreline at the head of Long Lake itself can be explained by the presence of a diminishing ice block in the lower part of Long Lake Valley. Further evidence is given by the marked overflow channels which empty into

Eskimo Cove on Grimmington Island and which could well have been formed by overflow from an ice-ponded lake in the head of the adjacent cirque valley.

At lower levels, isolated patches of stagnant ice occasionally blocked outlet channels and ponded lakes on the inland area. The higher lake levels observed around Rifle Lake are probably due to such an ice block lying across the present narrow outlet valley.

It is possible to envisage that in a gradually ameliorating climate ablation would become greater each year until the final remnant of the waning ice sheet would melt away very quickly, producing huge volumes of melt-water. A stagnant remnant of ice covering Shark Gut Harbour, or alternatively a similar remnant to the south of the watershed covering Lost Channel and the lower end of Cut Through Valley, could be postulated at this stage. It might be expected to produce melt-water in sufficient quantity to flow over the watershed, wash the fines from the unconsolidated drift, and sort the remaining boulders into the distinctive water-lain pattern observed in the low cols where the flow was concentrated.

For the present, no definite chronological correlation between lake shorelines, overflow channels, and water-lain material can be attempted. It can, however, be suggested that the retreat of the main Wisconsin ice in the local Kaumajet Mountain area was mainly one of overall downwasting, rather than solely the retreat of an active ice front.

A careful search for morainic evidence in the thresholds and valleys of the inland area and of the north and west facing cirques to the west of the mountain group was made to assess the extent of any late Wisconsin resurgence of local movement once the main ice flow from the west had disappeared. A lack of evidence showing that post-Wisconsin cirque glaciation was confined to the small cirque valleys, leads one to the conclusion that the last main ice flow in this area originated in the west.

During the later phases of emergence of land from the Wisconsin ice masses, a positive change in base level occurred, due to marine transgression. Overlapping this, and occurring at least in part contemporaneously, the land started to regain its isostatic equilibrium, causing a negative change in base level that left a series of raised beaches in favourable locations. These raised beaches were examined in Rifle Bay, Cut Through Valley, Neisser Inlet, Horr Harbour, Seal Bight, Eskimo Cove, Mugford Tickle, Sutherland Inlet, Anchorstock Harbour, and Mugford Harbour.

In each case the height of the raised beaches was measured above high tide level. Allowing for a slight variation in high tide level over the course of forty days ($2\frac{1}{2}$ feet difference was noted at base camp on the isthmus in Lost Channel), and for reading error in aneroid measurements, a remarkable coincidence is found in beach levels. Distinct beaches were found at 15, 32, 44, 78, 92, 131, 165, 177 and 225 feet above sea level. In seven cases raised beaches occurred at over 300 feet, three of these being coincident at approximately 340 feet in Anchorstock Harbour and Eskimo Cove. Fragmentary evidence was found for beaches at approximately 415 feet. It can be noted that beaches at about the 400 foot level only occur on the south shore of Cod Island. It is thought that an explanation for the features above 400 feet is most probably found in the sequence of downwasting stages postulated for the higher terraces in Sutherland Inlet and detailed in the text. The conclusion is reached that isostatic recovery has produced a negative change in base level of some 340 feet. The pattern of isostatic recovery indicated by the spacing of the beaches seems to be an initial, slow, gradual uplift with occasional still stands, followed by relatively fast uplift between frequent still stands.

In some of the cirque valleys opening to the south side of Grimmington Island, there is a distinct break in slope between 350 and 400 feet above sea level. Above this point the valley is graded to a base level at approximately 350 feet above the present sea level. Below this level, the valley falls away quickly to the sea and a gorge is a common feature cut down through the marine terraces. Evidence that uplift is still continuing is given by the continued vigorous downcutting of this gorge at all levels below 350 feet.

The changes in base level can to some extent be related to the formation of the cirques. The large, well-developed cirque forms are cut down to or below the present sea level. Many have had their form determined before the marine transgression. The cirques and cirque valleys which are cut to a base level approximately 350 feet above the present sea level could have had their final form determined by cirque erosion at the end of the Wisconsin maximum. It is not thought that the cirque glaciation in the Little Ice Age significantly altered the size of cirques, but merely refreshed the sculptured forms and striations.


Umiakovik Lake
North River
West River
Umiakovik Trough
Saputit Lake
Ikinet Brook
Base Camp
OKAK BAY

Fig. 49

SECTION 3 - OKAK BAY AREA

CHAPTER 9

PHYSIOGRAPHY AND PREVIOUS WORK

The area is best described with reference to the broad physiographic divisions of "bay zone," "valley zone," and "interior upland zone" recognized by Wheeler (1935) in the Nain-Okak section of Labrador. Okak Bay itself is the representative of the bay zone. Its head is approximately 20 miles west of the coastline, and the mouth of the bay between Uibvak point and Ublik point is 15 miles wide. The bay mouth is filled with islands, the largest being Okak Island (8 miles by 8 miles, maximum elevation 1,810 feet). As Wheeler noted, the bays to the south of Okak Bay run in a directly east to west direction. North of Okak Bay they run south east or north east. Okak Bay itself has an irregular course; it lies predominantly east to west, though the direction taken by the head of the bay is undoubtedly influenced by a major fault zone which trends north west to south east.

Unlike the bays to the south and north, Okak has relatively gently sloping sides. The walls show markedly glaciated forms and in places are interrupted by more nearly north to south through valleys with typical U-shaped cross sections, resulting from glaciation. Many of these cross valleys have been so deeply eroded that before the recent emergence of the coast they were sea channels cutting off portions of the present mainland. One such channel is Umiakovik trough, which runs from Umiakovik Lake through Tasiuyak Lake and reaches the coast at Tasiuyak Bay. Wheeler (1935), who first noted these forms, describes a similar channel which lies to the west of the Kiglapait Mountains, running from the head of Webb Bay to Tessiujak Bay.

The head of Okak Bay has a broad tide flat which is covered by one foot of water at its deepest point at high tide. The tide flat is composed of delta sands, probably derived from the extensive sands in the valleys upstream. Base camp was established on a small point of land on the south of the bay between the river outpouring from Saputit Lake and Ikinet Brook.

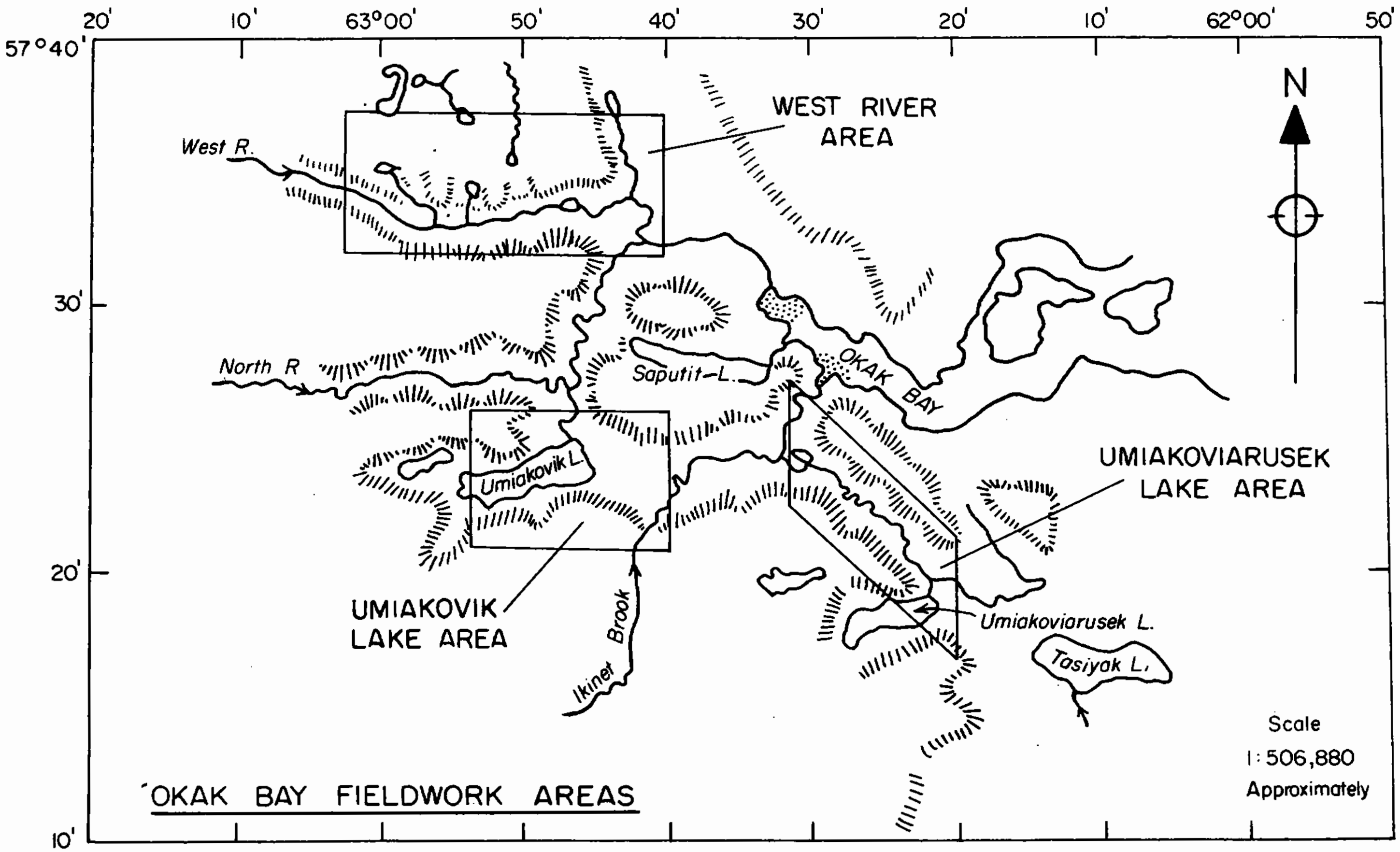
The main river entering Okak Bay is North River, which flows from the inland watershed for some 20 miles through deep, wide valleys cut into the highland before it opens out into the broad, flat basin at the head of Okak Bay. The valleys show every sign of glacial erosion rather than stream action. They are disproportionately wide in comparison to the brooks that they contain, and the branch valleys often enter the deep east to west valleys at a high level. The valley floors and basin at the head of Okak Bay are covered with dense forest vegetation. Out on the flat valley floors the rivers meander through the forest. Occasional boulder rapids characterize these sections of the rivers. Lakes, due to inequalities of glacial deposition or erosion, are frequent. This area, rich in glacial deposition forms, is representative of the valley zone.

The interior upland zone can best be described as the irregular surface of a plateau some 2,000 to 3,000 feet in elevation, deeply dissected by the valleys already mentioned. The surface irregularities rarely exceed 500 feet, shallow lakes abound, and the drainage pattern is erratic. Glacial deposition features are abundant on this surface. Wheeler, who has surveyed the area to the west and south of Okak Bay, notes that the main divide between the coastal and George River drainage areas is encountered at about longitude 63°45' W. Due to the irregularity of the topography the divide is very complicated in detail.

While Okak Bay is a major feature on the Labrador coast and its hinterland is rich in glacial deposition features, little geomorphological investigation had been completed in the area. The only geological investigation has been done by Wheeler (1935) who included the Okak Bay area in his discussion of the Nain-Okak section of Labrador. Wheeler surveyed the fieldwork area to the west and south of Okak Bay and produced a reconnaissance map at the scale of 1:500,000. The present topographic map of the area relies heavily on this work. Wheeler made observations on glacial phenomena within the area, including remarks on striae, direction of ice movement, cirques, and morainic features. He concluded that the centre of accumulation at glacial maximum was about 57° N. and 70° W. Wheeler further discussed the relationship between geology and topography and made notes on vegetation and climatic conditions. Later travel through the area enabled him to construct a geological map (unpublished) which formed an invaluable basis to the writer's own geological observations in the area.

Wheeler's work covered a much greater area than that of the present fieldwork, and was primarily reconnaissance geology. No attempt was made at a detailed interpretation of pleistocene chronology. Nevertheless, the examination clearly showed the relative abundance of glacial deposition forms in the area and the writer is deeply indebted to the personal suggestion from Wheeler that fieldwork in the Okak Bay area would complement similar investigation in the Kaumajet Mountains. A grateful acknowledgement is also made for subsequent communications and advice regarding the area.

The fieldwork was concentrated in the valley and interior upland zone. North River and Ikinet Brook were used to gain access to the valley and upland zone from Okak Bay. Three inland fieldwork areas were examined in detail. The first area, known as Umiakovik Lake area, is situated between 62°39' W. and 62°55' W. and 57°22' N. and 57°27' N., and includes Umiakovik Lake and the Umiakovik Trough south of North River and west of Ikinet Brook. The second area, known as the West River area, is between 62°40' W. and 63°04' W. and 57°33' N. and 57°37' N. and includes the valley and upland zone to the north of West River, which is the major northern tributary of North River. The third area,



WEST RIVER AREA
West R.
North R
Saputit L.
OKAK BAY
Umiakovik L.
UMIAKOVIARUSEK LAKE AREA
UMIAKOVIK LAKE AREA
Ikinet Brook
Umiakoviarusek L.
Tasiyak L.
N
Scale
1:506,880
Approximately
OKAK BAY FIELDWORK AREAS
57°40'
30'
20'
10'
20'
10'
63°00'
50'
40'
30'
20'
10'
62°00'
50'

Figure 50

known as the Umiakoviarusek Lake area, is contained within the co-ordinates of 62°20' W. and 62°34' W. and 57°18' N. and 57°27' N. and includes the centre portion of the Umiakovik Trough and the eastern end of Ikinet Brook. The three areas were chosen after careful examination of air photographs in the pre-fieldwork season. The photographs showed that each of the areas described had distinct series of glacial deposition features which merited ground examination and from which an understanding of late stage glacial activity could possibly be deduced.

In each of the areas, glacial deposition forms were examined on both lowland and highland, and observations were continued in the valleys connecting the areas. In this way it was possible to complete a comprehensive examination of the Okak Bay area as a whole, including detailed study in critical areas.

As mentioned in the earlier notes on surveying, absolute measurement of height in areas remote from sea level presents practical difficulties. It was found, however, that the average of readings taken on entry and exit from the Umiakovik Lake area gave a very close approximation to the height of 150 feet above sea level given for Umiakovik Lake by Wheeler. A similar close approximation was found to occur with a height of 164 feet above sea level for Umiakoviarusek Lake. It is considered that while the aneroid method used is not strictly permissible, the heights given for the lakes in question are very close to the absolute values. Thus, relative heights in these areas were rounded out to the datum of the lakes, and heights above sea level incorporate the lake elevations given above. Similarly, the height of the canoe camp in the West River area was used as a datum for heights in that area. The height of the canoe camp was obtained by taking an average of measurements up from sea level, down to sea level, and across from Umiakovik Lake. The divergence in these readings was less than 20 feet and the resulting average of absolute height may be accurate to 50 feet.

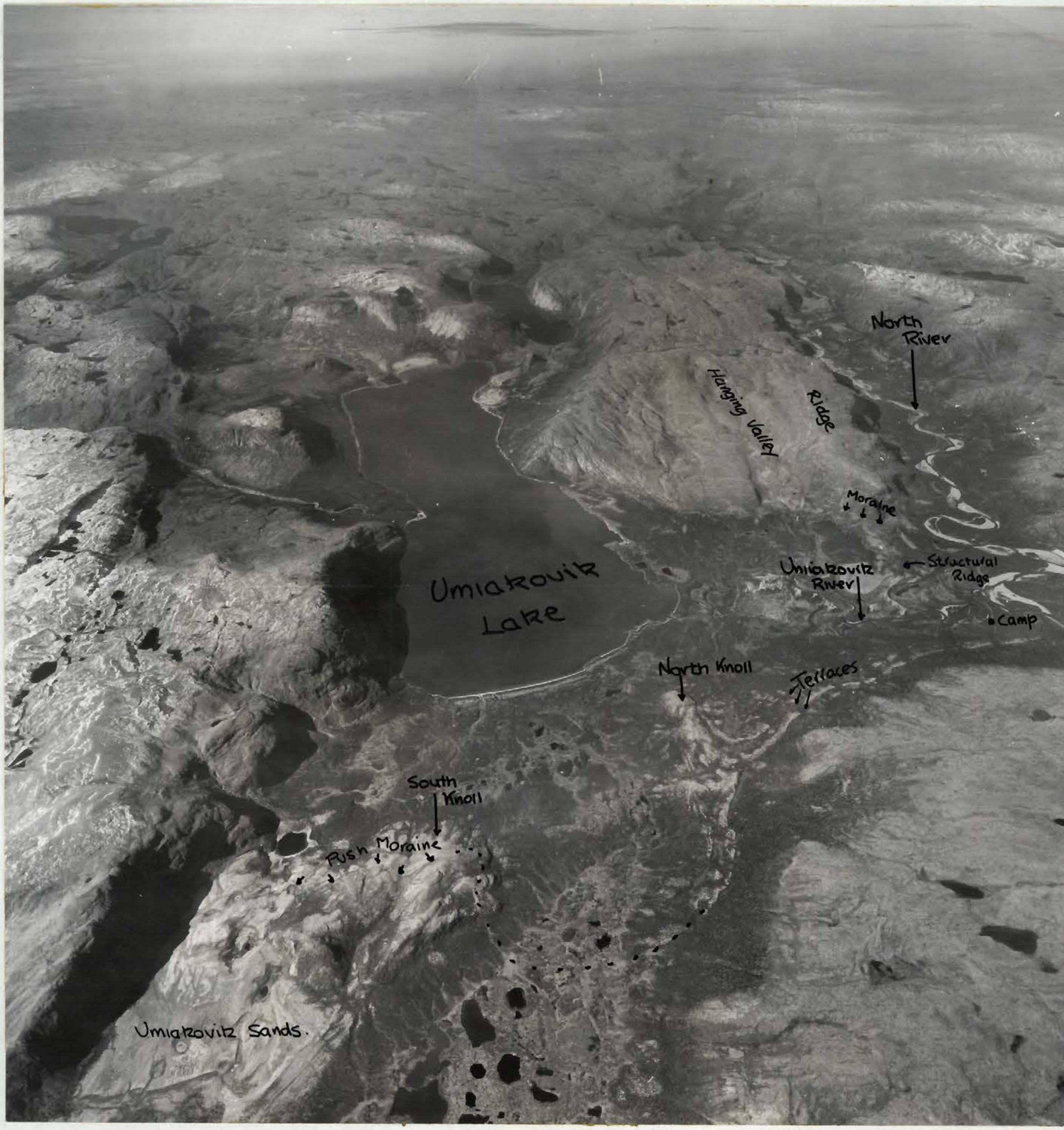

North River
Hanging Valley
Ridge
Moraine
Structural Ridge
Umiakovik River
Camp
Umiakovik Lake
North Knoll
Terraces
South Knoll
Push Moraine
Umiakovik Sands.

Fig. 51

CHAPTER 10

UMIAKOVIK LAKE AREA

The Umiakovik Lake Area was entered by way of North River and a small tributary of North River named Umiakovik River which leads from Umiakovik Lake. Below the junction of North River and West River the main stream shows evidence of vigorous downcutting. Seven major rapids, plus several patches of extremely fast broken water, give evidence of this.

Above the West River junction the river becomes confined to a wide valley. The floor of this valley is flat; the river widens, becomes shallow and follows the valley as it curves toward the south. About 4 miles upstream from the West River junction, on the west side of the river, there are two definite cross-valley moraine features, both descending from similar lateral moraine features on the valley sides. Immediately south of this point, the river, still with a current of between 7 and 10 knots, is incised in meanders between banks of sand 50 feet high. Both North River and Umiakovik River follow this pattern to the limit of examination. Above the junction of North and Umiakovik Rivers the U-shaped valley of North River continues directly westwards. The valley of Umiakovik River continues southwards to the head of Umiakovik Lake where, following the contact between the adamellite group and the the basement complex gneisses, it gently curves into a wide east to west trough. A canoe camp was established immediately south of the North River - Umiakovik River junction on the eastern side of the valley.

On the eastern wall of the valley is a series of well marked terraces. The features start in the vicinity of the base camp, the highest and most pronounced being about 400 feet above sea level (233 feet above canoe camp). The series rises to the south at approximately 100 feet per mile, the highest reaching

Fig. 52 View of moraine-kame features on eastern wall of Umiakovik Valley between North River and North Knoll.

Fig. 53 One of series of morainic features on eastern wall of Umiakovik Valley between North River and North Knoll. Material is rough, coarse and sandy with numerous well-rounded boulders. A deep gully is cut into the hillside on the right of the picture and flows to the north, away from the camera position.

Fig. 54 Same feature as above, showing exposed sloping surface of feature to record nature of material. Taken facing south, approximately 2 miles to south, and 200 feet above Fig. 53.

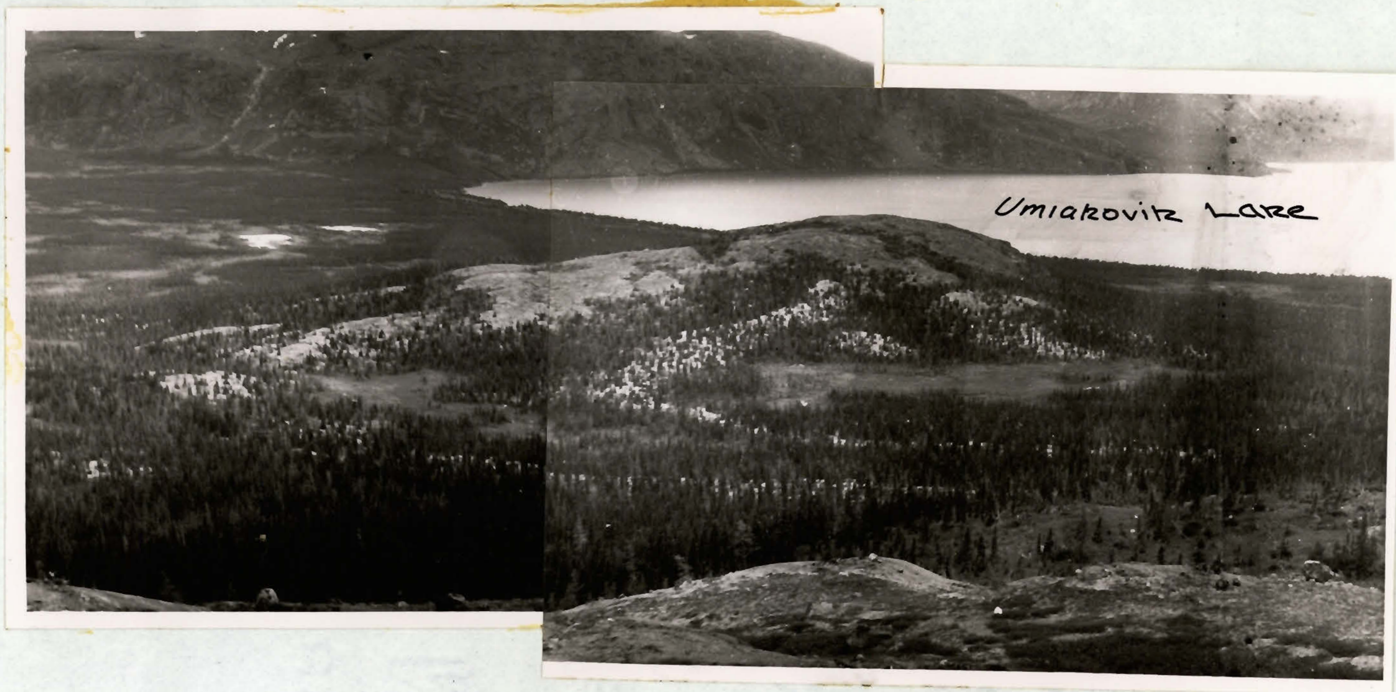


Fig. 55 Lateral moraine features curving from east side of Umiakovik Valley to north side of North Knoll.

733 feet above sea level, opposite the end of Umiakovik Lake. At this point, where Umiakovik Valley meets the east to west trough, a spur projects from the valley wall, rising to form a distinct knoll in the middle of the valley. The features reach their maximum elevation slightly to the north of this knoll. All but the highest one sweep down in a parallel arcuate form over the saddle, continuing this sharp curve to the west to merge into the north side of the knoll. From the vicinity of the spur the highest feature continues to follow the northern wall of Umiakovik Trough, gradually decreasing in height to the east and becoming less distinct. Below, and parallel to it, a fragmentary series of similar features can be distinguished.

The features are composed of rough, coarse, sandy material in which are numerous well-rounded boulders, varying in size from large boulders (10 feet by 15 feet) to others of an average diameter of 10 to 12 inches. The common rock type of the boulders is a pink, medium coarse grained granite, erratic to the banded granite gneiss bedrock. These boulders are absent from the sand in the terraces observed at river level. The features stand some 30 feet above the normal slope of the hill. Their top surface is occasionally flattened and invariably there is a small stream running in the channel on the uphill side. The very steep slope along the length of the forms eliminates marine, lacustrine or river terrace origin. From the nature of both the material and the slope, it is probable that they are complex features of lateral moraine origin in the ridged sections and possibly kame terrace origin in the flattened, terrace-like sections.

The highest point on the ridge above these features, separating Umiakovik River from the Saputit Lake drainage basin, is approximately 1,200 feet above sea level. The top of the ridge is 200 to 300 feet above the tree line, and the exposed rock surfaces are smooth, rounded and polished. Glacial debris and

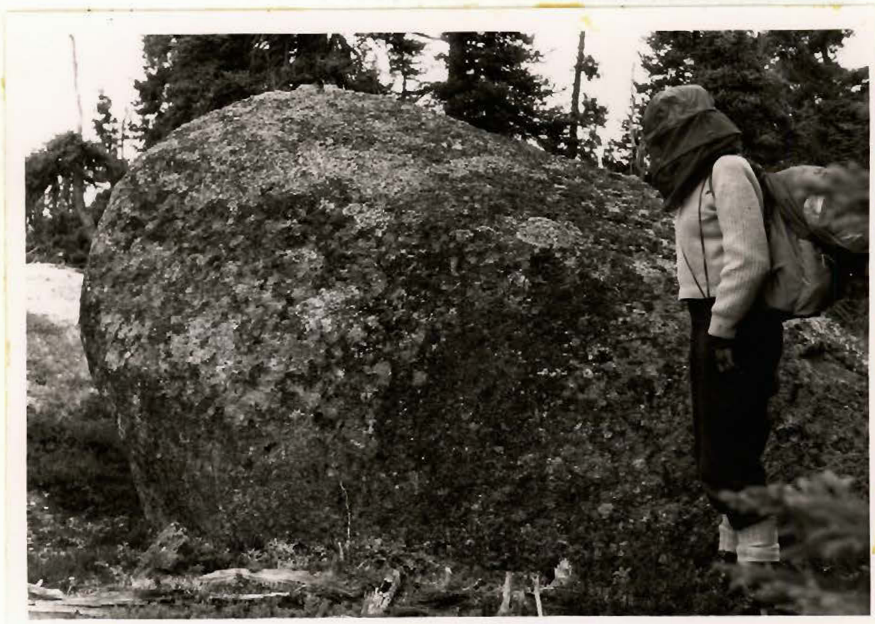
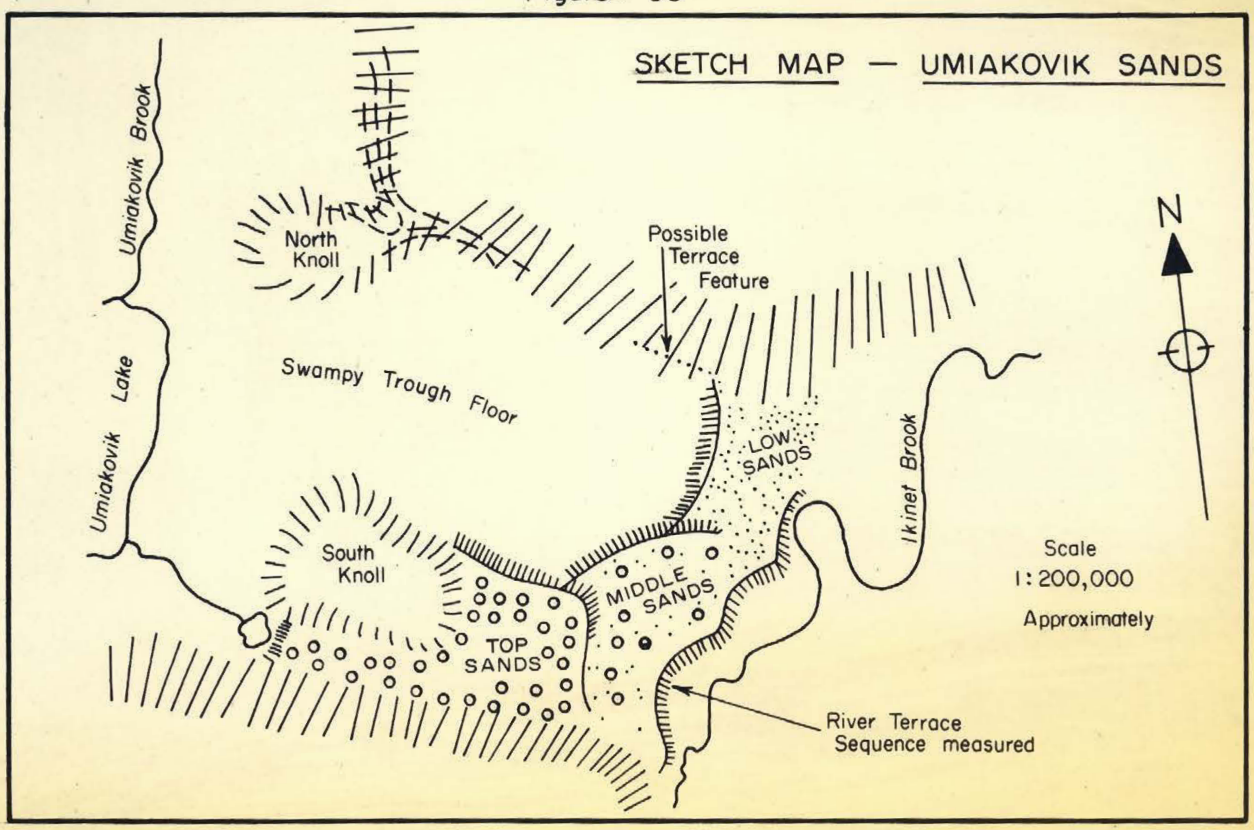


Fig. 56 Typical large erratic found on terrace features shown in Figs. 53 and 54.

Fig. 57 Ridge top between Umiakovik River and Saputit Lake drainage basin, showing north west to south east trend of glacial flutings and striations. Perched rocks also in evidence.

Fig. 58 Hummocky sands, with series of fragmentary shorelines at eastern end of Umiakovik Lake.

Figure 59



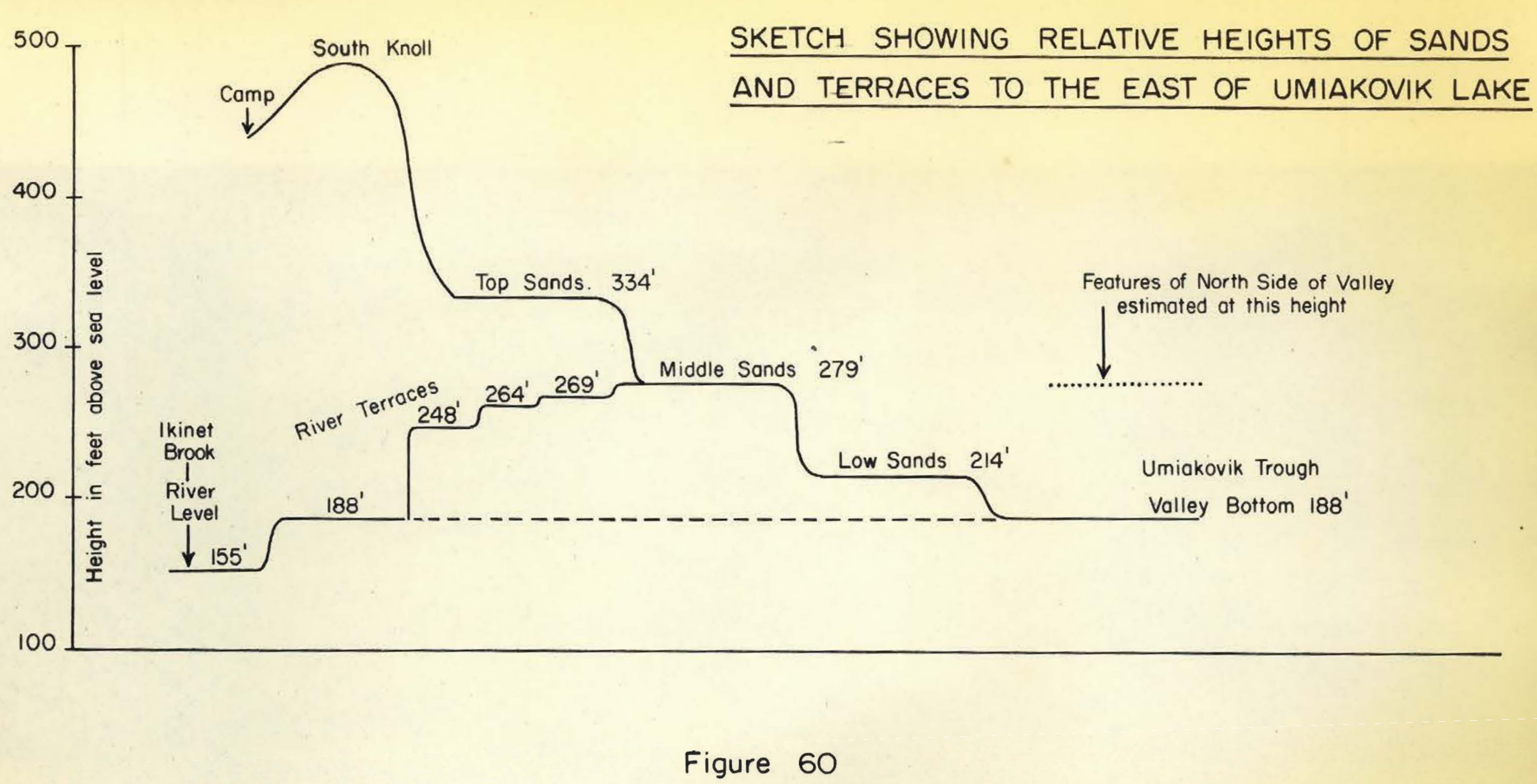


Figure 60

Fig. 61 Valley train in Umiakovik Valley, taken from South Knoll looking east north east.

Fig. 62 View of Top and Middle Sands from Low Sands.

perched boulders are common, among them erratics of plain granite sitting on the gneissic bedrock. Striations and distinct glacial fluting were observed on the highest surface. The striae and fluting trend in a south west to north east direction, approximately parallel to the axis of Umiakovik Lake. This evidence suggests that continental ice overrode the highest points of the area in the most recent advance of the Wisconsin ice, and that the depositional features at lower levels must be attributed to the action of the same ice sheet.

There is no heavy morainic material at the eastern end of Umiakovik Lake. There does, however, seem to be a series of hummocky sands, grading into a series of fragmentary terraces, the highest being 33 feet above present lake level.

South of the spur projecting from the north wall of the Umiakovik Trough and forming a knoll, named North Knoll, is a similar knoll close to the southern wall of the trough. This second knoll was named South Knoll. The lowest part of the trough floor between North Knoll and South Knoll is about 220 feet above sea level. This forms a low col to the west of which drainage is towards Umiakovik Lake. To the east of the col the trough floor is ill-drained and swampy, and has areas of hummocky moraine forming irregular hillocks frequently hidden by trees. Large boulders are common in these patches of moraine.

To the east of South Knoll, a series of high sands stretches across the valley, limiting the ill-drained area and cutting it off from the drainage to the east. Distinct levels were observed in the sands. The lowest, at 214 feet above sea level, form a bar across the valley; the highest, 334 feet above sea level, extend in a ridge to South Knoll, approximately parallel to the south wall of the trough. Between the high sands and the low sands is a middle layer of sands at 279 feet above sea level. Each level of sands has a broad surface

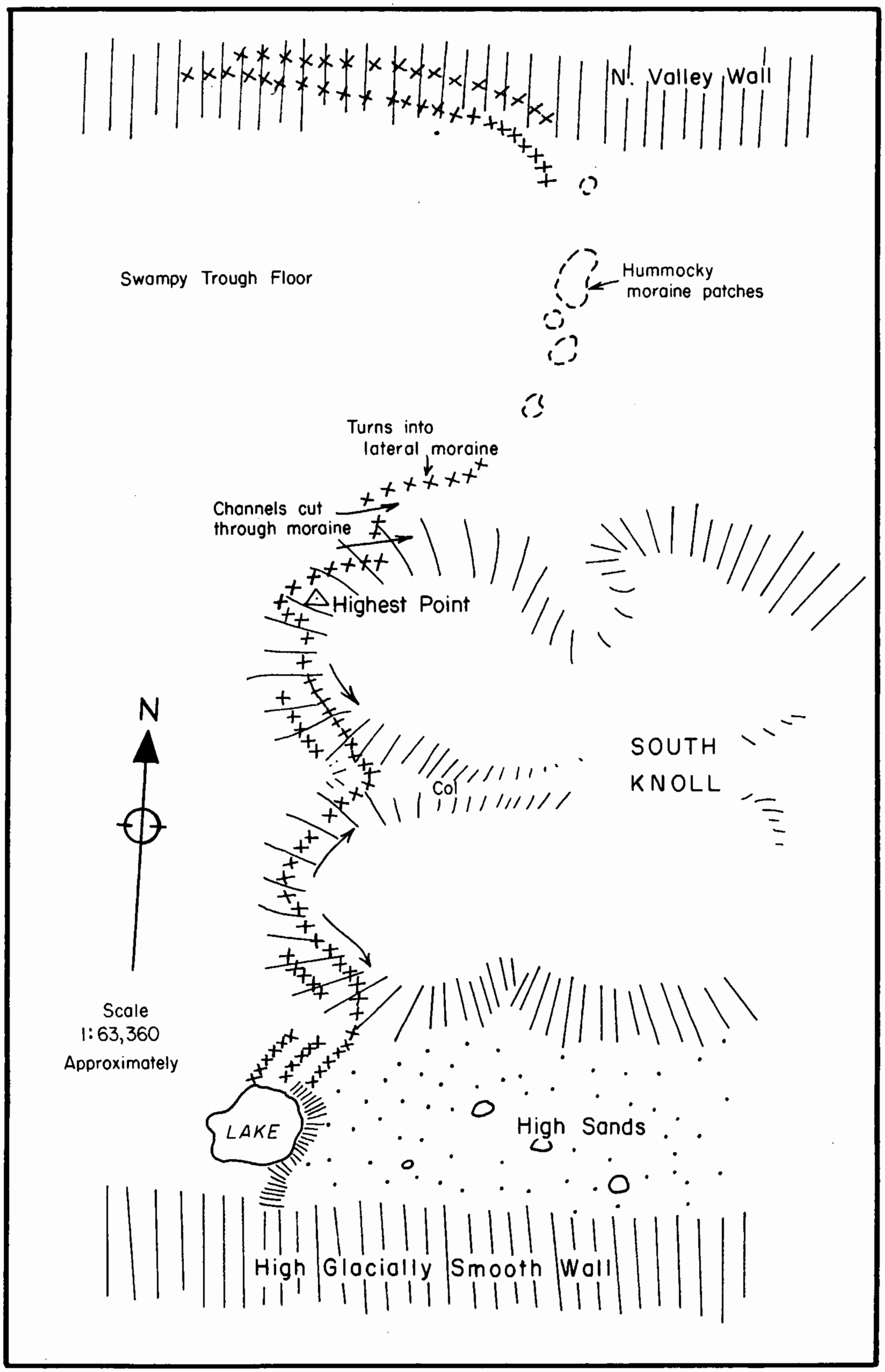


Figure 63 — SKETCH · SHOWING MORAINE ON SOUTH KNOLL

which is smooth and flat, apart from an almost imperceptible slope to the south east. The junction between the various levels of sand, and between the lowest level of sand and the valley bottom, is a steep scarp. The material of the sands is quite different from the terrace features on the valley sides, being composed of well-sorted sand and small gravel, with no large cobbles or boulders. Further to the east, Ikinet Brook emerges from a tributary valley in the south wall of the trough and cuts deeply through the sands as it drains to the east. The river level, measured close to the point of emergence from the tributary valley, is about 135 feet above sea level, which is some 33 feet below the lowest point measured in the valley bottom, measured to the west of the low sands. It is interesting to note that one major river terrace is exactly 33 feet above the present river level.

On the north wall of the trough the kame terrace features noted grade down to the level of the sands and terminate at them. From observation of the north wall of the trough from South Knoll, a high level terrace, above the tree line and approximately parallel to the low terraces, can be distinguished. This feature markedly increases its downward gradient to terminate at about 300 feet above sea level in the vicinity of the sands.

Examination of the southern wall of the trough revealed a distinct push moraine on the west side of South Knoll. The highest level of sands fills the gap between South Knoll and the trough wall. The surface of the sands is pitted with large indentations which appear to be kettle holes. Level with the western side of South Knoll the high sands terminate in a marked scarp which descends directly to the valley floor. From the top of the sands immediately above this scarp, following the hillside across the western end of South Knoll, is a moraine. The material in the moraine includes large, well-rounded and, occasionally, sub-angular material, mainly pink, coarse-grained granites. The highest

Fig. 64 Push moraine crossing col on west side of South Knoll.

Fig. 65 Push moraine on west side of southern lobe of South Knoll. Fragments of lower moraines are indicated.

- Fig. 66 Striations immediately east of moraine on South Knoll. Striations trend east-west at right angles to moraine.

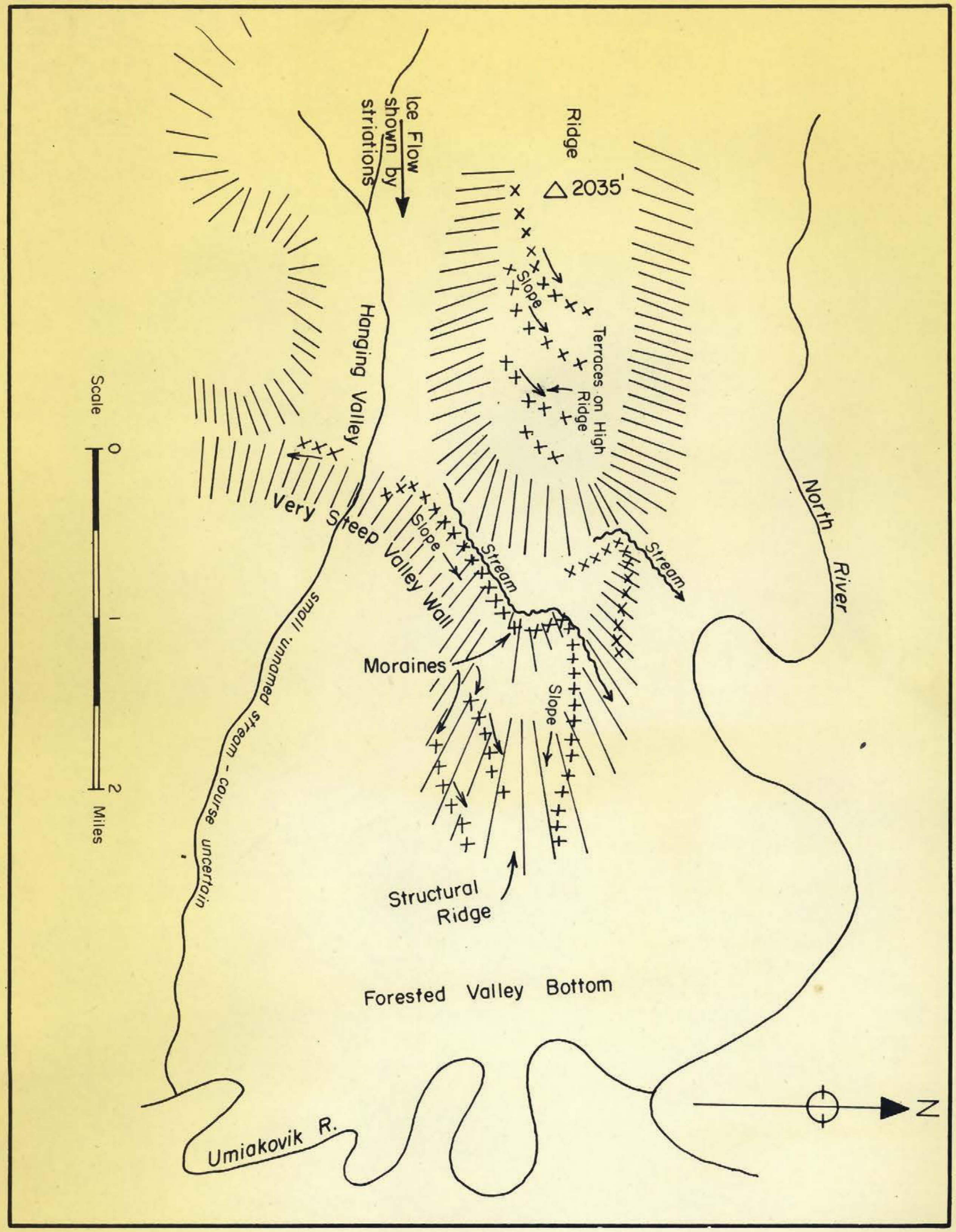


Figure 67 – SKETCH SHOWING POSITION OF TERRACES AND MORAINES TO WEST OF UMIAKOVIK RIVER

point of the knoll to the east of the moraine is not more than 50 feet above the moraine; the bedrock surfaces exposed are smooth and rounded. Fresh striations are not frequent, but were found east of the moraine, their trend being parallel to the main valley walls. The moraine has steep and varying slopes along its length. From the sands in the south it ascends 223 feet to the crest of the knoll and dips some 50 feet into the col in the middle of the knoll, then rises another 114 feet into the highest point on the northern side of the col. To the north of the knoll the moraine is cut through by a series of water-cut channels before it turns to the east, forming almost a lateral moraine along the north side of the knoll. This lateral moraine then dips down into the valley bottom, becoming less distinct at lower levels. On the far side of the valley, opposite to this moraine, two of the lower terrace forms also curve around and dip into the valley and there is a tentative connection between them in the shape of a series of moraine hummocks stretching in arcuate form across the valley floor. The whole feature suggests a terminal cross-valley moraine formed by an ice lobe advancing from the west.

An examination was made of the high land bordered by Umiakovik Lake, Umiakovik River and North River valley. The surface of this high land is dissected by a valley which runs in an east to west direction and "hangs" to the western side of Umiakovik valley. The highest point of the summit surface is to the north of this hanging valley at a point approximately 2,035 feet above sea level. The formation of boulder detritus is at a minimum; rounded, striated rocks characterize the summit level and a magnificently striated surface with very sharp and fresh striations was found below the summit level at 1,784 feet above sea level. The evidence supports the conclusion that ice completely covered the summit surface of this area and flowed over it from a westerly direction in comparatively recent times. Depositional features are abundant in

Fig. 68 Summit (2,035 feet above sea level) on ridge between Hanging Valley and North River Valley.

Fig. 69 Striations on ridge immediately below summit shown in Fig. 68.

Fig. 70 Terrace feature at approximately 1,300 feet above sea level to east of summit on south side of ridge between Hanging Valley and North River Valley. Taken facing west.

Fig. 71 Panoramic view of terrace forms (in foreground) to east of summit on south of ridge between Hanging Valley and North River Valley. Taken facing east at approximately 1,250 feet above sea level.

Fig. 72 Panoramic view of distinct moraine features on eastern end of highland block forming western wall of Umiakovik Valley.

the hanging valley. On the southern side of the ridge separating the hanging valley from North River a series of terraces, sloping gently to the east, curve around the ridge in a northerly direction. In the floor of the hanging valley several features which could be interpretated as eskers were noted, approximately parallel to the trend of the valley.

Very distinct moraine features were observed at the eastern end of this highland block, where it forms the western wall of the Umiakovik Valley. All the features are definitely deposits on bedrock and have no structural foundation. All contain the assortment of larger boulders which distinguish them from the sands. The first feature is a very marked moraine ridge (25 feet to 30 feet above hill slope) running down the hillside from the lip of the hanging valley. In the first 1,000 yards below the lip the feature descends 380 feet; below this point it turns sharply and follows the contour of the valley wall to the north before turning sharply 100° to the east to slope down directly across Umiakovik Valley. On reaching the valley floor it becomes less distinct and is lost in the trees.

A second feature close to and slightly north of the first, is of similar composition with regard to material and size, but it follows the contour of the hillside. This feature is terminated at its northern end by a small "tail" which, like the first feature, turns sharply and proceeds across Umiakovik Valley for a short distance. The freshness and similarity of material in these features suggests a contemporaneous deposition. Further features much less distinct, mainly gentle ridges in the boulder drift, occur in echelon below and south of the first moraine.

It is thought that an interpretation of these features must be looked for in an interplay of ice tongues in both Umiakovik Valley and North Valley at a late stage of the last glaciation.

It is possible to envisage the condition where a continental ice mass is downwasting and retreating simultaneously, when marginal ablation is in excess of central accumulation. Such conditions exist in the small Scandinavian ice sheets at the present time. When the regime of such an ice mass is delicately balanced, minor fluctuations or recessions in climatic conditions can cause a temporary advance of the ice margins.

With regard to the Okak Bay area, one could postulate that in similar conditions, a continental ice margin situated on, or immediately east of, the watershed would send digitated ice lobes into the valleys in a period of climatic recession, or would increase the thickness and size of ice lobes already in the valleys. It can be observed in the Scandinavian glaciers today that several variables determine the extent to which ice is increased in any one valley in response to any one climatic fluctuation, and it might be expected that a similar variation of ice lobe size in response to climatic fluctuation during the Wisconsin glaciation would occur in this area.

This hypothesis is strongly supported by the evidence observed in the Okak Bay area. The very fresh glacial striae on the summit surfaces suggest that all the glacial deposition forms are contemporaneous with late stage Wisconsin glacial activity. The freshness of the striae on South Knoll to both the east and west of the push moraine suggests that the filling of the main trough with ice, and the recession and readvance that formed the push moraine across the valley, were both recent and contemporaneous. The cross valley moraine in Umiakovik Trough, the kame terrace forms on the walls of the trough and Umiakovik Valley, and the lateral moraine on the western side of Umiakovik Valley clearly indicate the presence of an ice lobe contained by these valleys and Umiakovik Lake. The cross valley moraine features seen to the north of the West River Junction in North River Valley would indicate that an ice lobe contained in North River Valley extended at least to their position. Further, the lateral moraines in Umiakovik Valley produced by the ice lobe from Umiakovik Lake seemed to have their northern ends truncated and the material possibly incorporated in a lateral moraine of the North River Valley lobe. The series of kame terraces on the east side of Umiakovik Valley suggests that the continuing amelioration in climate saw extensive downwasting and the eventual disappearance of the ice lobes, though the small moraines curving from the kame terraces over the saddle of North Knoll strongly suggest that minor re-advances were made even during the final stages of the recession. Certainly, the evidence strongly supports the conclusion that late stage Wisconsin conditions saw minor re-advances in ice lobes contained in the valleys of the Okak Bay area.

The highest part of the trough floor in Umiakovik Trough is 220 feet above sea level. All other parts of valley bottoms in this area are below this level. With strong evidence of a sea level 350 feet above the present sea level in the Kaumajet Mountain area, one must consider the possibility that the marine incursion following the retreat of the Pleistocene ice sheets turned these valleys into inland arms of the sea. This suggestion is supported by the washed out and indistinct remnants of moraines and kame terrace forms below 300 feet that continue into well-preserved forms of a similar nature higher on the hillsides, and the working of valley sand material into beach levels at 334 feet, 279 feet, and 214 feet above sea level, which shows a remarkable correspondence with distinct raised beach features in the Kaumajet Mountain area.

Wheeler (1935) suggests that the cross valley sands were deposited as deltas by streams tributary to the trough during this period of higher sea levels. This is evidenced by the nature of the present sand material, which is characteristically deltaic, and also by the position of the higher masses of sand which occur at the point where a main tributary (Ikinet Brook) flowing from the highland opens into Umiakovik Trough. Sands observed in the lower regions of North River would correspond to similar deltas formed by North River flowing into progressively lower sea levels. It is also probable that Umiakovik Lake itself underwent a transition from salt water to fresh water at a higher level than at present, the subsequent lowering of lake level and formation of raised strand lines at the eastern end of the lake being due to downcutting of the lake lip by the outlet streams. Finally, evidence in this area seems to indicate that all traces of ice had disappeared before the onset of the marine incursion and did not subsequently reappear.

CHAPTER 11

WEST RIVER AREA

West River is the name given to the main tributary of North River. It flows from the interior upland zone in a west to east direction, cutting a deep valley in the high land before it emerges into the broad basin above Okak Bay and turns abruptly southwards to meet the main stream. The West River area was entered by canoe from North River via the southerly-flowing portion of West River. A canoe camp was established at the junction of West River and a small stream flowing from the north which joins West River at this elbow. The camp was 200 feet above sea level in the densely forested lowland basin.

The southerly-flowing portion of West River meanders with a strong current between high (20 foot) sandy banks, this portion of the river appearing to be adjusted to the base level of the North River Junction. Above the canoe camp the river was observed to be practically a chain of continuous rapids, some with a considerable fall (estimated 20 to 30 feet). A nick point is reached at a large lake named West Lake, which is about 4 miles west of the canoe camp. Inland from West Lake the river has a shallow gradient, and the drainage system covering the valley floor is chaotic, with numerous unconnected small lakes. Further inland at a point approximately 20 miles west of the canoe camp, a series of rapids marks the descent of the river from the lakes and drainage basin of the upland area to the confines of the valley.

Hummocky moraine occurs in quantity in the valley east of West Lake, and in smaller patches throughout the valley. Thick deposits of glacial outwash sands occur to the north of West Lake and were observed in irregular patches amongst the hummocky drift to the west of the lake.

In conclusion, the deposits in the valley floor are typically those of "dead ice topography", the rapid section of the river at the mouth of the

Fig. 73 Summit surface immediately north of West River, showing slight differences in appearance of drift. Taken facing north west.

Fig. 74. Summit surface to north of West River showing slight differences in appearance of drift. Taken approximately 1 mile to east of Fig. 73 above facing west at elevation of 1,500 feet. Lip of West River Valley is shown to left of picture.

valley can be explained as its vigorous readjustment after comparatively recent negative changes in base level, and the sands below the canoe camp can be correlated with the deltaic sands observed in the Umiakovik Lake area.

The valley walls are steep, rising approximately 1,500 feet to the upland surface. The walls are cut into by hanging valleys which have their lips approximately 1,000 feet above the valley floor and cut back to dissect the upland surface. The glacial deposits in the hanging valleys and on the upland surface were examined in some detail. Access from the canoe camp to the upland surface north of West River was made without difficulty up the eastern-facing wall of the highland.

The upland surface is irregular and characterized by a practically continuous cover of thin drift. The drift shows little or no evidence of frost-shattering, though lichen growth is well established and the finer drift fraction between the boulders has a thick moss cover. On the summit surface immediately north of West River, slight differences in the appearance of the drift seem to indicate an overlapping drift series: the drift nearer the river valley is fresher with a greater amount of fines, and low moraines stretch along its surface parallel to West River.

The surface of the highland block has a gently regional slope to the north: thus the hanging valleys of the north side of West River are cut against the regional slope, and the major valleys cross the watershed. To the south, small, vigorous streams flow over the lip into West River valley; to the north the streams flow into the drainage basin of Siugak Brook. Between the north and the south-flowing streams in the floor of the hanging valleys is usually a dry col.

The largest hanging valley cutting across the upland surface is approximately nine miles west of the canoe camp. A remarkable series of glacial deposition features is preserved in this valley. The features are typical of

Fig. 75 View of main lateral moraine damming High Lake in Large Hanging Valley to north of West River. Taken facing east.

Figure 76 - FIELD SKETCH SHOWING FEATURES IN LARGE HANGING VALLEY TO NORTH OF WEST RIVER

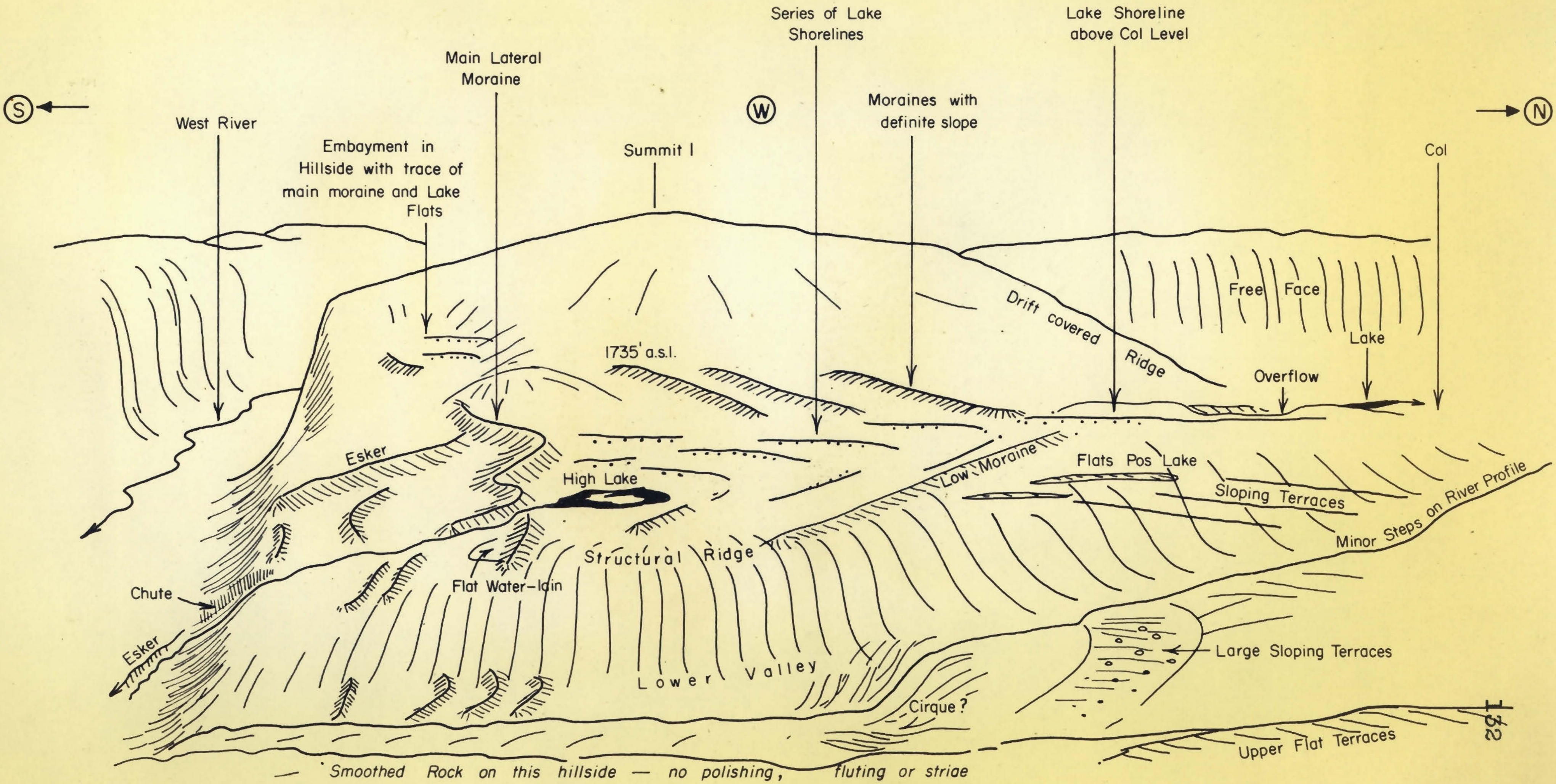


Fig. 77 Panoramic view looking east showing features on lip of large hanging valley to north of West River. Prominent is the large esker going down the slope in the foreground. Also visible are the lake shorelines above High Lake and the terrace features on the east wall of the hanging valley.

those observed in the smaller hanging valleys, and they were carefully examined. The hanging valley itself is aligned approximately north to south and hangs an estimated 800 to 1,000 feet above the floor of West River Valley. South of the col the valley is a composite feature, with a structural ridge parallel to its walls running down the centre, splitting it into two smaller valleys at different levels. These were named Upper Valley and Lower Valley. Both have the same col, about $1\frac{1}{2}$ miles north of their lips. The col is moraine-covered, very flat, and on its western side a lake, draining to the north, is trapped in a depression.

The lip of both Upper and Lower Valley is bevelled before the free face into West Valley commences, and it is topped by a major moraine which can be traced across the hanging valley and which continues on the highland surface to east and west. Below the main moraine on the bevelled lip are several features. First, there is a large esker at approximately right angles to the main moraine, dipping steeply towards West River Valley. Secondly, there is a deep chute, cut by a stream flowing from a cleft in the main moraine; this chute descends the north wall of West River Valley, and from its bottom an esker can be traced along the north side of the valley for approximately two miles; it then widens into a large raised delta which partially dams the eastern end of West Lake, forming the glacial outwash sands noted previously. The third feature on the lip of the hanging valley is a series of small moraines approximately parallel to the main moraine but down the lip from it. Other points of interest include the presence of a small flat water-lain area south of the main moraine on the east side of the hanging valley, and the division of the main moraine in Lower Valley into two or three small arcuate (up-valley) moraines which eventually join and continue east as a single feature.

Upper Valley contains High Lake, which is dammed by the main moraine and

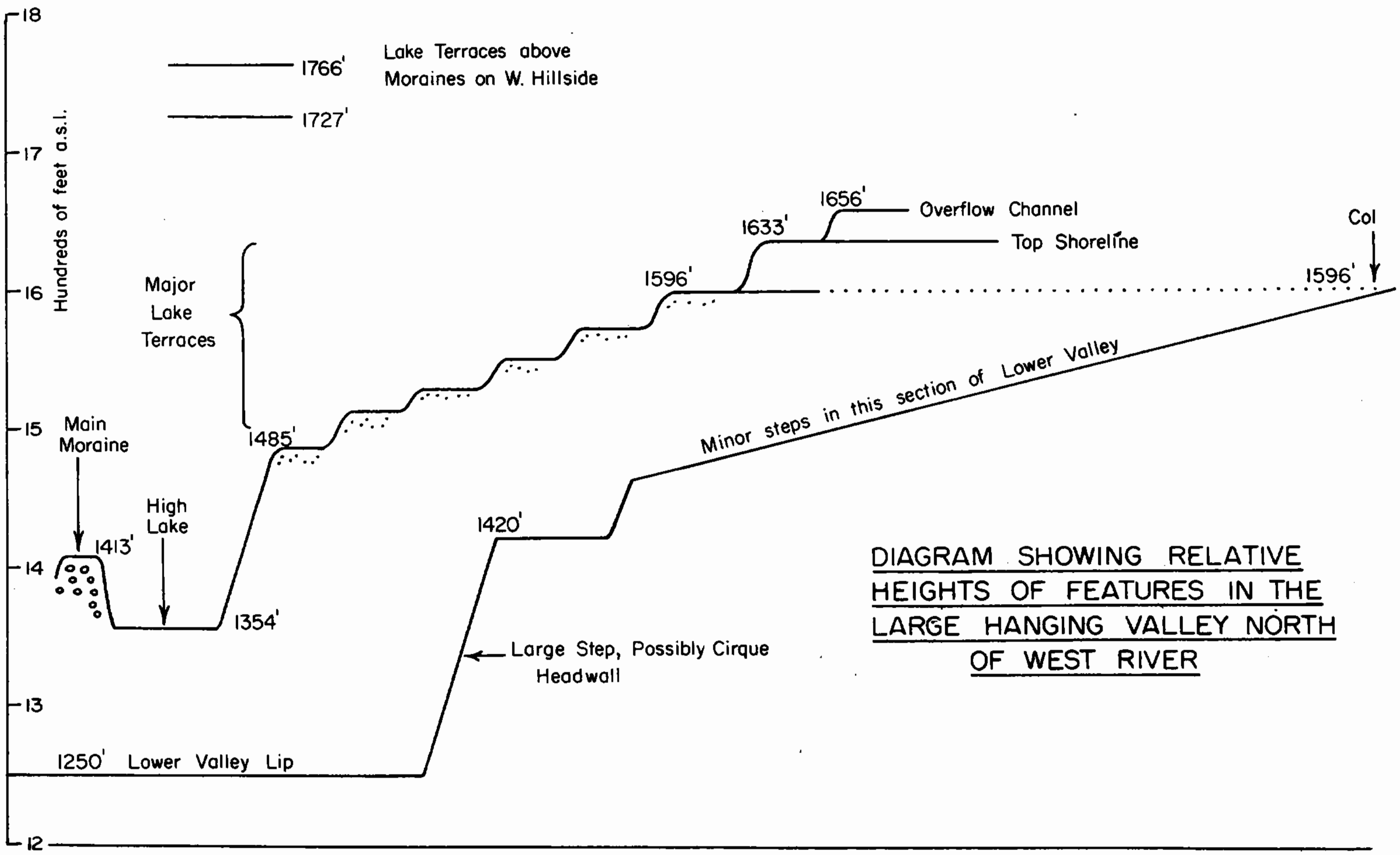

18
17
16
15
14
13
12
Hundreds of feet a.s.l.
1766'
1727'
Lake Terraces above Moraines on W. Hillside
Major Lake Terraces
1485'
1596'
1633'
1656'
Overflow Channel
Top Shoreline
Col
1596'
Main Moraine
1413'
High Lake
1354'
1420'
Minor steps in this section of Lower Valley
Large Step, Possibly Cirque Headwall
1250' Lower Valley Lip
DIAGRAM SHOWING RELATIVE HEIGHTS OF FEATURES IN THE LARGE HANGING VALLEY NORTH OF WEST RIVER

Figure 78

which overflows through the cleft and down the chute mentioned above. North of High Lake a series of former lake levels was established and the mean level of the better-formed terraces was measured with the aneroid. The most prominent terrace is the highest, at 1,633 feet above sea level and 279 feet above the present level of High Lake. This well-preserved shoreline is cut into a bank of drift and there is a wide overflow channel whose highest point is 23 feet above the shoreline, flowing to the north. The next highest terrace, at a height of 1,596 feet above sea level, is similarly preserved and is a feature continuous with the present col of the hanging valley. Five other terraces, at 216, 195, 172, 158 and 131 feet above the present High Lake level, were recognized. Terraces lower than the level of the col were traced only south of the col, which exhibits a gently sloping drift cover. The moraine blocking the High Lake is 54 feet high at the lake lip and is the largest deposition feature in Upper Valley. Overflow channels were found crossing this moraine at higher levels than the top of the present moraine opposite High Lake.

The Lower Valley, though having a common col with Upper Valley, is 104 feet lower at the lip. The valley floor ascends in steps: the first step seems to be a small cirque with a headwall of 170 feet. There follow a series of minor steps to the col. There is no apparent correlation between these steps and the shorelines of Upper Valley, but the valley steps do accord with lacustrine flats on the Lower Valley sides.

The main walls of the hanging valley show conspicuous features related to deposits in the valley floor. The west wall has definite moraines with a marked slope (gradient 1 in 12 by aneroid measurement) to the north. The highest point reached by these moraines was approximately 1,735 feet above sea level. All the moraine features are south of the hanging valley col: north of it the west wall has a free face.

At the southern end of the east wall, at 1,766 and 1,727 feet above sea level, are definite, flat, water-lain terraces. The terraces are not extensive, being formed in a small embayment in the wall. Below them are wide (60 feet) kame terraces sloping down into Lower Valley, with practically the same slope as the moraines on the west wall. The junction of the kame terraces is occasionally coincident with the flats in Lower Valley, though the lower portions of the kame terraces are not well preserved and this coincidence must not be stressed.

For the sake of clarity, a tentative chronological interpretation of the hanging valley features may be made at this point. The abundant fresh drift and striations prove that the ice completely covered this area in late Wisconsin times. However, a stage of downwasting can be envisaged where the ice was confined to the main trough of West River Valley and the hanging valleys. Possibly at this stage small amounts of melt-water dammed between the ice and an embayment in the hillside formed the small shoreline features at 1,766 and 1,727 feet above sea level on the east wall of the hanging valley. Further downwasting exposed the highest points on the valley floor, and melt-water filled the depression around the highest point, possibly covering it. A lowering of the ice to the north of this highest point, which would be probable if the ice were completely stagnant and not being fed by vigorous supplies from the west, would possibly create an overflow of water from the south to north. Subsequent separation of the ice lobes in the hanging valley would allow the trapping of melt-water, whose deposits form the present col. The absence of lake shorelines to the north of the col could be explained by drainage developing underneath the completely stagnant ice. Meanwhile the south lobe would remain active while ice was being supplied from the west.

Ablation would cause gradual retreat of both the lobe in the hanging valley and the main ice in the trough. Temporarily worsening climatic conditions would cause fluctuations in the retreat, these stages being indicated by the moraines on the west wall of the hanging valley and the kame terraces on the eastern wall. As the retreat continued, a series of lakes would be dammed south of the col and against the ever-lowering ice front. Probably this downwasting continued until the lobe of ice in the hanging valley completely disappeared and the level of ice in the West River Valley fell below the level of the hanging valley lip. A later resurgence of the ice in the West River Valley which was primarily confined to the main trough, probably reaching a maximum height of no greater than 1,400 feet, would have been responsible for the main lateral moraine which crosses the mouth of the hanging valley and dams the present High Lake. This late ice lobe at this height would account for the overlapping fresh drift observed on the lower parts of the summit surface to the east of the hanging valleys. Stagnation and downwasting characterized the final stages of this ice. The esker leading down into West River Valley south of the main moraine, and the small shoreline caused by water dammed between the ice and the lateral moraine, give evidence of this. The water dammed in High Lake cut through the lateral moraine, forming the chute on the valley side and the esker under stagnant ice still filling the valley bottom; the delta expansion of this esker 2 miles to the east of hanging valley, and the arcuate series of kames across the valley at this point, would indicate that the ice lobe had its terminus at the eastern end of West Lake.

A broad, high ridge terminates the hanging valley on the west side. The highest points on this ridge are two summits at 2,286 feet and 2,296 feet directly west of High Lake. These summits are two of the few drift-free points on the upland surface. The outcrops are sub-angular and only slightly

Fig. 79 Summit of Mount Tricorne showing incipient frost-shattering. Altitude 2,765 feet above sea level.

smoothed and rounded. Any such rounding occurs on their western side. On the exposed bedrock and the upland surface as a whole, frost-shattering is at a minimum.

The main lateral moraine observed in the hanging valley can be traced across the southern end of the ridge, and further to the west parallel to West River Valley. It dams a series of lakes against that part of the upland surface draining towards West River Valley. One such lake immediately west of the ridge is Pear Lake, which has a subsiduary lake named Ear Lake in the same drainage basin. Continuing westwards, the moraine is a dominant feature, 100 feet high at the point where it dams Snow Lake in a narrow fault valley which dissects the upland in a north to south direction. The evidence of shorelines cut into the drift above the lakes indicates that they have been higher and more extensive than at present. In each case the overflow has cut down through the unconsolidated moraine material and progressively lowered the lake level. The moraine has a regional slope from west to east on the sections observed, though considerable variations in local slope occur along its length; as, for example, across the lips of the hanging valleys.

To the west of the fault valley the land rises to the highest prominence in the area, named Mount Tricorne (2,765 feet above sea level). The summit, though exhibiting rounded rocks, shows a considerable degree of frost-shattering. No polished surfaces, striations or fluting were observed. Erratics were found at the summit level. The summit and the last 450 feet leading up to it have some drift on them, but boulders in the drift are frost-shattered. A talus slope of large, frost-shattered blocks exists on the east side of the mountain and altogether presents a completely different aspect from the grey expanse of drift that blankets the lower slopes on all sides. The "trim-line" between the frost-shattered drift and the unweathered drift below it was estimated at 2,320

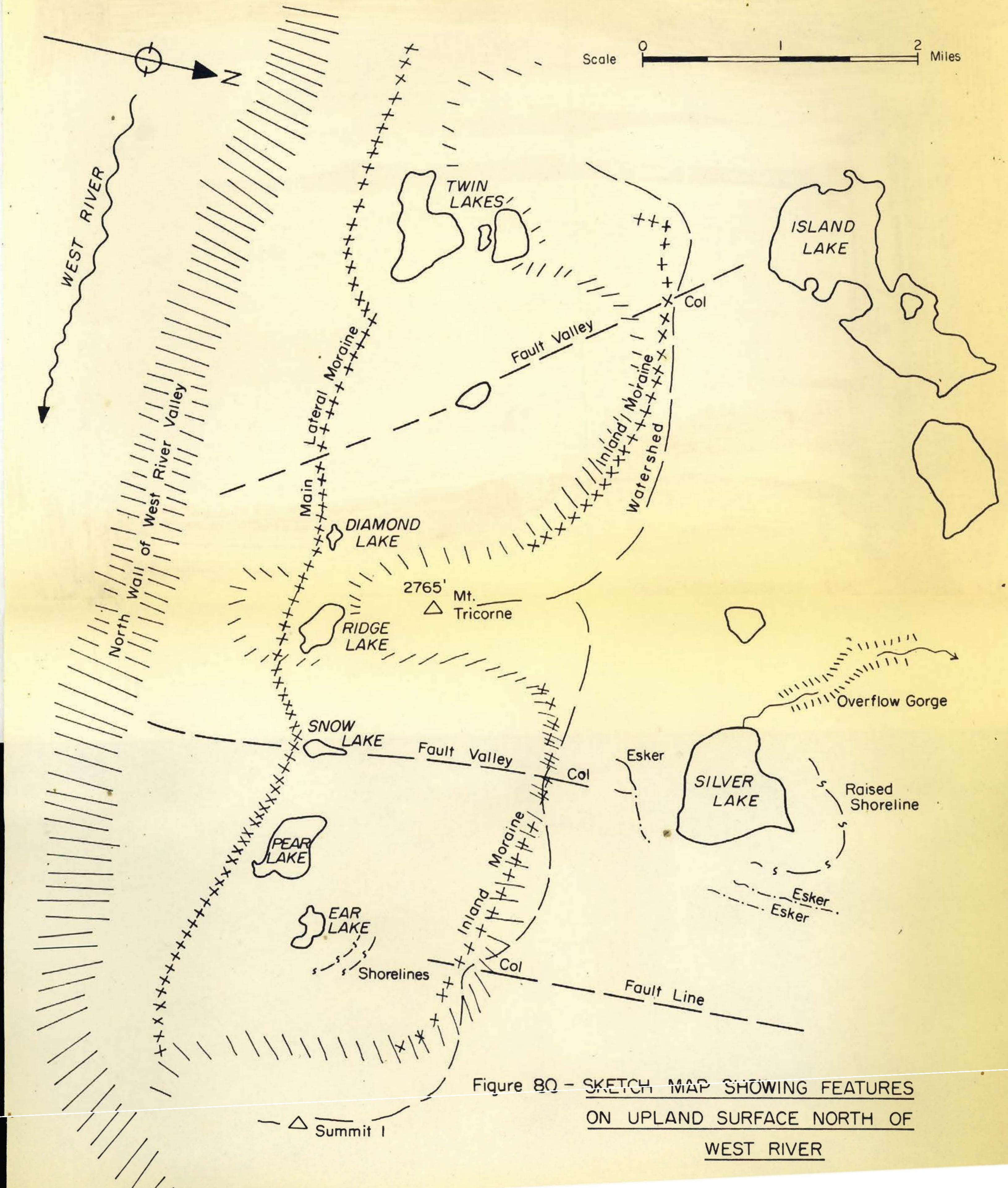


Figure 80 - SKETCH MAP SHOWING FEATURES ON UPLAND SURFACE NORTH OF WEST RIVER

feet above sea level. Unfortunately, the summit seems to be the highest point in the area (certainly as far as the Kaumajet Mountains to the north, and for as far as could be seen to the south). Thus, confirmation of this trim line in other areas could not be made.

Immediately south of Mount Tricorne the main lateral moraine dams another lake (Ridge Lake) against the mountain side. Continuing westwards, it crosses another fault valley and dams yet another lake (Diamond Lake); still further westwards it crosses the outlet of a large lake named Twin Lake. Beyond Twin Lake the moraine continues as a distinct feature for about 3 miles after which it gradually becomes less distinct and grades into the drift cover. The lateral moraine was not examined beyond this last point, though it may occur further to the west. In all, the lateral moraine was examined and shown to be an almost continuous feature for approximately 12 miles.

To the north east of Mount Tricorne a distinct moraine, termed the "Inland Moraine", crosses the col of the fault valley between Snow Lake and Silver Lake. This moraine can be traced from the ridge of Mount Tricorne across the fault valley and along the crest of the watershed to the east, until it curves southwards onto the ridge immediately west of the main hanging valley. A similar feature of the same dimensions and state of weathering was traced north westwards from Mount Tricorne to a point immediately south of Island Lake. At its western end the moraine again curves southwards into a ridge north of Twin Lakes. Definite overflow channels have been cut through the Inland Moraine, the first one at 2,093 feet directly north of Ear Lake, the second at 1,924 feet on the col of Fault Valley, and the third one at 1,872 feet to the south of Island Lake. To the south of the Inland Moraine definite lake shoreline features were found cut into the drift above those attributed to lakes dammed by the lateral moraine. These shoreline features were fragmentary, mainly

Fig. 81 Annotated photograph showing features on the north and south walls of West River Valley in the vicinity of West Lake.

occurring in embayments in the hillside.

These observations support and extend the interpretation of the features in the hanging valley. At the stage in the retreat of the ice, when a vigorous ice lobe in West River Valley was still pushing fluctuating tongues into the hanging valleys and forming recessional moraines and kame terraces on their walls, one could expect a similar overflowing from the trough onto the lower parts of the upland surface. Such overflowing lobes would possibly be restricted by the higher north to south ridges on the summit surface, and the Inland Moraine lying along the watershed can be envisaged as the terminal moraine to such ice lobes. Subsequent recession of the ice lobes and release of melt-water would dam lakes between the ice front and the higher watershed, as it did in the hanging valleys. Such lakes would probably overflow to the north through the lowest points on the watershed, thus cutting the former terminal moraine at the cols, and the water would drain under the already postulated stagnant ice lobes existing north of the watershed. This under-ice drainage is evidenced by the esker to the south of Silver Lake, also by the fact that at some time an ice block plugged the natural outlet of Silver Lake to the north east, causing it to cut a deep overflow channel to the north west through much higher land. That minor fluctuations occurred in the retreat of these lateral ice lobes is suggested by fragmentary recessional moraines on the eastern flank of Mount Tricorne, south of the Inland Moraine.

The size and the continuity of the main lateral moraine parallel to the side of West River Valley and the fact that it rarely enters the hanging valleys cut into the upland surface, strongly support the contention that the feature was formed by a vigorous ice lobe entirely confined to the West River Valley.

Observations from the north and careful examination of air photographs show similar features on the south side of West River Valley, particularly in a hanging valley opposite the major hanging valley on the north side of the main trough. A lateral moraine can be clearly distinguished damming a series of lakes against the hillside. At about the same height as the moraine but leading downwards from it, a series of marginal drainage channels can be distinguished on the eastern wall of this hanging valley. These marginal drainage channels lead into a series of chutes completely dissecting the surface of the valley wall to the south of West Lake. These latter forms strongly support the hypothesis that the final stage of the ice in this area saw a stagnant lobe in the bottom of West River Valley.

The occurrence of frost-shattered material on the summit of Mount Tricorne invites the speculation that the top 450 feet of Mount Tricorne formed a nunatak or, at most, was briefly covered during the last major phase of Wisconsin glacial activity. An ice surface 2,300 feet above sea level in the vicinity of Mount Tricorne would, even assuming the 1:100 surface slope of an ice sheet postulated by Dahl, completely cover the other smoothed and striated summits examined in the Okak Bay and Umiakovik Lake areas. However, the evidence is not supported elsewhere, and it would not be sound to postulate an inter-glacial or even an interstadial period on the isolated evidence available. The trim-line that was tentatively postulated is in places obscured by talus material. It can only be clearly distinguished on the eastern side of Mount Tricorne. Relatively unweathered drift mixes with the frost-shattered material close to the summit. And there is some merit to the argument that a relatively high drift-free point projecting above the average level of the surrounding terrain would be more prone to the destructive action of the elements than the gently undulating, drift-covered upland surface. One must conclude that the evidence is not sufficient to advance such a hypothesis soundly, and that the

Fig. 82 Panoramic view of set of terraces encircling the northern rim of the lowland basin at the head of Okak Bay. Heights of terraces examined at eastern end of arc are indicated.

maximum thickness of ice in the West River area must remain undetermined.

Mention must be made here of a remarkable set of terraces that encircle the northern rim of the lowland basin at the head of Okak Bay. Most unfortunately, time did not allow a thorough study of these features and only a brief examination could be made of the terraces at one end of the arc. However, so striking are the forms that the results of careful air photo analysis and the brief field examination merit consideration.

Well-preserved terraces below the level of 300 feet are common on the sides of Okak Bay. These broad sandy terraces continue into the basin at the head of Okak Bay forming a series of sandy flats through which the major rivers cut their channels. To the north of the basin, a very low col separates the drainage basin of Siugak Brook and that of North River. On the south side of this col between the upland to the west and the hills to the north of Okak Bay on the east is almost an unbroken flight of horizontal terrace forms.

Initial observation of the terraces led to the assumption that they were marine features similar to those preserved in the Kaumajet Mountain region and were due to the marine incursion already postulated to explain features in the Umiakovik Lake area. Thus it was expected that aneroid measurements would possibly show a relationship between the Okak Bay terraces and other marine features. This certainly occurred at lower levels (one broad sandy flat was found at 221 feet above sea level, another at 303 feet above sea level). However, when measurements were taken on the two examples of the terraces, clearly preserved on the eastern face of the upland block, they were found to be at heights of 432 and 489 feet above sea level. These were not the highest terraces: the highest flight observed in the centre of the arc must have been at least 60 feet above the highest terrace measured. Further, the material of the terraces measured was considerably different from that of the marine terraces already examined. There was a high percentage of well-rounded boulder material and a considerable amount of sub-angular cobble and pebble sizes intermixed with the smaller fraction, this differing from the well-sorted sands and gravels found at lower levels.

Above the terraces on the higher slopes of the col are several distinct glacial deposition forms very similar in nature to the lateral moraines examined in West River Valley; also, at right angles to the moraines, there are deposition features that appear to be eskers. The distribution of the moraines in plain view would tentatively suggest that they had been formed by ice pushing from Okak Bay towards Siugak Brook, though this point should not be over-emphasized. The stream flowing from the col into Okak Bay invariably cut deep gorges through the unconsolidated material. The writer considers that the explanation of the terrace forms over 400 feet must be looked for in terms of ice-dammed water, held in a similar manner to that postulated in Sutherland Inlet in the Kaumajet Mountains. The difference in material in these terraces would seem to support this suggestion. A straightforward solution would be to postulate a large mass of downwasting ice completely filling the Okak Bay basin, which trapped water against the Siugak col at progressively lower levels during the recession. However, the col is low, not being higher than 700 feet, and the postulation of a mass of ice, large enough to block the drainage completely in the whole of the head of Okak Bay, with an edge no higher than 700 feet, is difficult to imagine. Further, one might expect an ice lobe in Okak Bay to have melted away before a possibly active ice lobe from Siugak drainage basin had disappeared.

Unfortunately, the data available does not allow further chronological interpretation of the forms to be made; though while the solution of this problem must necessarily await detailed field investigation, the evidence suggests that an explanation of the higher terrace forms must incorporate glacial activity and not an exclusively marine origin.

CHAPTER 12

UMIAKOVIARUSEK LAKE AREA

The final area to be examined was that containing Umiakoviarusek Lake. Access was by the eastern end of Ikinet Brook and a tributary stream named Umiakoviarusek River.

Between the base camp at the head of Okak Bay and the mouth of Ikinet Brook, a series of well-preserved marine beaches was noted on a small headland. These were measured and found to be at 25, 44, 122, 138, 165, 230, and 235 feet above sea level. The highest point on the small peninsula was 275 feet above sea level. The valley walls further inland were not conducive to the preservation of depositional features; thus, higher beaches could not be expected in this particular location. However, of the beaches measured, particularly those at 44, 165, and 230 feet above sea level, a very satisfactory correlation is shown at most levels with the series of beaches found in the Kaumajet Mountain area and other parts of the Okak Bay area.

Ikinet Brook enters Okak Bay immediately south of a small island situated in the centre of the bay. Between the river mouth and the island a tidal flat has developed, and it is possible to walk from the south shore to the island at low tide. The material of the tidal flat is sandy and similar to that deposited in the head of Okak Bay. It is derived from the unconsolidated material so abundant inland.

The easterly portion of Ikinet Brook leaves the Umiakovik Trough and reaches the sea through a narrow, U-shaped valley, which lies at approximately right angles to the head of Okak Bay. The valley wall is breached on the western side by an ice diffluence col that leads into the valley from Saputit Lake. On the eastern valley wall, immediately north of its junction with Umiakovik Trough, a large cirque form is cut, its lip being approximately 250 feet above


Kiglapait Mts.
Okak Island
Tasiuyak L
Martin Is.
Storm Lake
Umiakoviarusek L.
Embayment
Okak Bay
Umiakoviarusek River
Cirque
Canoe camp
Ikinet Brook
Diffluence col

Fig. 83

sea level. Through this valley Ikinet Brook flows with a rapid current, incising its meanders deeply into the sands that cover the valley floor. The height of the sand banks here is between 10 and 25 feet above river level, although occasional banks of between 50 and 60 feet above river level are found close to the valley wall, indicating that much of the sand has already been cut away and removed by the meandering river. The umiakovik Trough follows a general west to east direction. At this point, however, it turns slightly southwards into a north west to south east direction, becoming aligned with the major north west to south east fault system, which also influences the adjacent forms of Okak Bay and Tasiuyak Bay. Umiakoviarusek River flows from Umiakoviarusek Lake down this portion of the trough and joins Ikinet Brook where it turns into the outlet valley. Rapids are numerous on the lower sections of both Ikinet Brook and Umiakoviarusek River. A canoe camp was established in Umiakovik Trough, on the north side of the river above these rapids some 3 miles east of the junction of Umiakoviarusek River and Ikinet Brook. From the canoe camp, the upland surface north of Umiakoviarusek River and Umiakovik Trough itself were examined.

From the canoe camp to Umiakoviarusek Lake the south wall of Umiakovik Trough has a steep, cliff-like form. Almost certainly this wall of the valley is a fault-scarp. Immediately west of Umiakoviarusek Lake the adamellite group outcrops against the anorthosite group. The contact runs along the fault-scarp.

The north side of Umiakovik Trough has an entirely different aspect. The valley wall slopes at 45° up from the floor of the trough, to a height of approximately 1,000 feet. The tree line is approximately 900 feet above the valley bottom. Above the break in slope the surface grades gently upwards to the summit level of the highland.

Although the lower, drift-covered slopes of the north wall are conducive to the formation and preservation of glacial deposition and marine features, careful examination of the entire length of the lower wall between Umiakoviarusek Lake and the canoe camp revealed no such evidence. A similar examination of the surface above the break in slope was more rewarding. The minor configuration of the surface is strongly controlled by the dominant north west to south east structural trend. This has resulted in the etching of a series of ridges of varying size and cross-section, aligned approximately parallel to Umiakovik Trough. Occasionally embayments, possibly due to cirque action, are cut into the trough wall and truncate these ridges. Frequently small lakes are trapped between the ridges, and in some cases their outlet streams are controlled by the structure until they find a low point on a ridge and overflow into either Umiakovik Trough or northwards to Okak Bay.

Fragments of a lateral moraine can be traced along the trough wall immediately above the break in slope. The moraine is not a dominant feature, but is, nevertheless, a distinct accumulation of morainic material. In some places it forms a capping on a structural ridge, in others it is wholly composed of depositional material. Considerable variations in slope occur along its length, this being particularly noticeable in the vicinity of Umiakoviarusek Lake, where in approximately 200 yards the moraine descends 200 feet from east to west. Its regional slope is from west to east, the lowest point being 576 feet above the valley floor at its eastern end. The moraine crosses the path of several of the outlet streams flowing into Umiakovik Trough from lakes on the upland surface. These streams have cut through the unconsolidated morainic material to bedrock, but in no case have they cut into the bedrock itself for any appreciable distance.

The largest embayment in the trough wall is approximately 4 miles east of the canoe camp. The lateral moraine crosses its mouth, and a second moraine curves into the embayment behind the first. Above the moraines is a series of horizontal shorelines from a former lake dammed in the embayment.

2 miles to the east is Storm Lake. This lake is also in an embayment or incipient cirque form, the lip of the feature being formed by a structural ridge which is capped with fragmentary patches of the lateral moraine. Above the lake are shoreline features similar to those found in the embayment to the west. At higher lake levels the water overflowed to the east of the present outlet, through a very distinct overflow channel which crosses the ridge at 1,257 feet above sea level and approximately 1,100 feet above the valley bottom at a level coincident with a well-marked shoreline.

It is clear that neither the configuration of the bedrock nor the lateral moraine could have dammed lakes in these embayments at the level indicated by the shorelines. The presence of lateral moraines strongly supports the contention that the lakes were dammed by an ice lobe contained in Umiakovik Trough.

The upland surface above the lakes is capped by an adamellite outcrop, the broadest and highest part of the ridge being between the canoe camp and Okak Bay. Brief examination of the upland surface showed a much thinner and more spasmodic cover of drift than observed on other upland surfaces in the Okak Bay area. The exposed bedrock showed many smoothed and rounded forms, though no fresh striations were found. Despite the lack of fresh striations, the absence of frost-shattering and the relatively unweathered condition of the existing drift indicate that the surface was covered by ice in the last glacial maximum and strongly suggest that the recent complete covering of the upland surface and the damming of the lakes by a downwasting ice mass trapped in the valley were successive stages in the final phase of glacial activity.

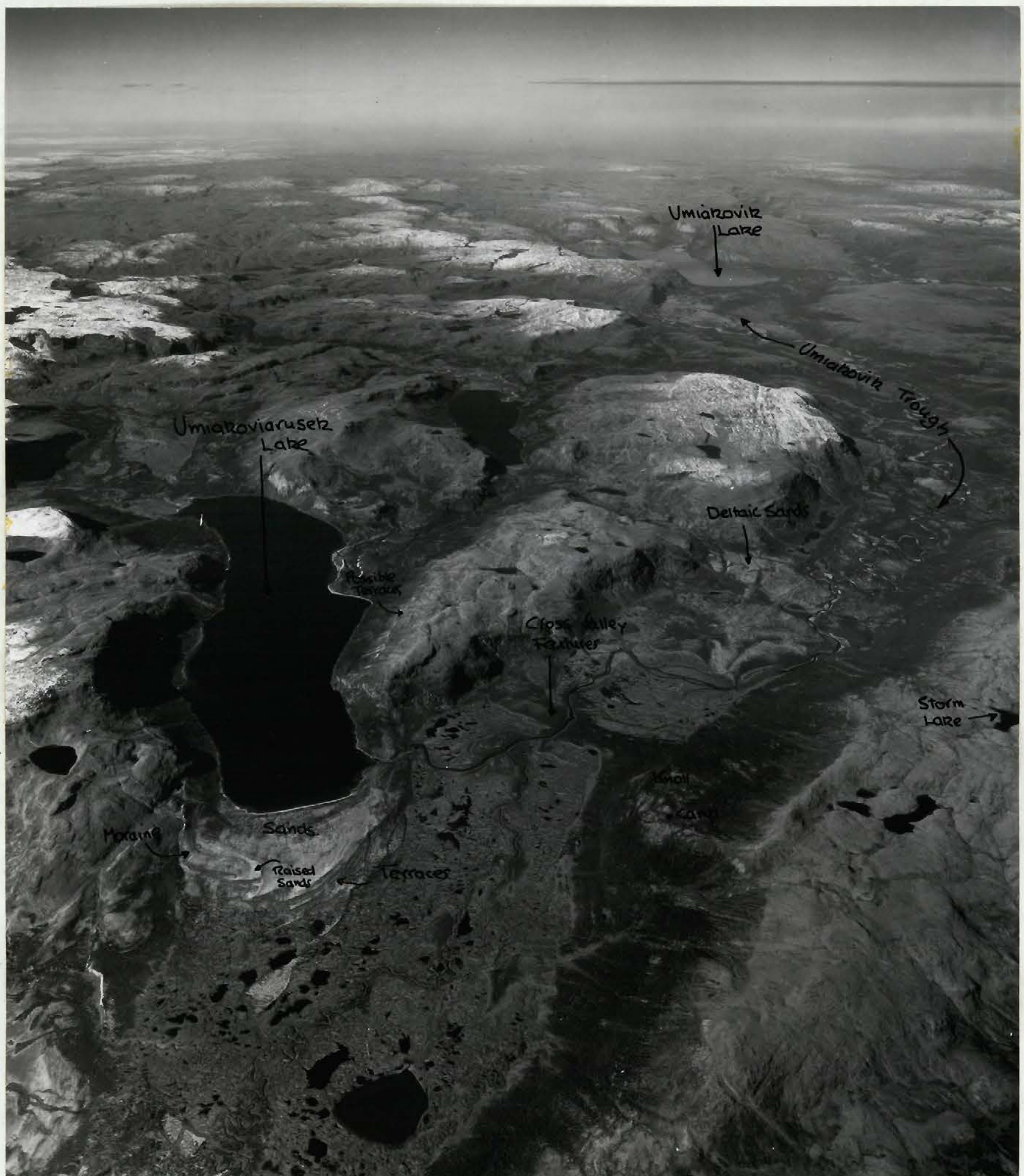

Umiakovik Lake
Umiakovik Trough
Umiakoviarusek Lake
Deltaic Sands
Possible Terraces
Cross Valley Features
Storm Lake
Knoll
Camp
Sands
Moraine
Raised Sands
Terraces

Fig. 84

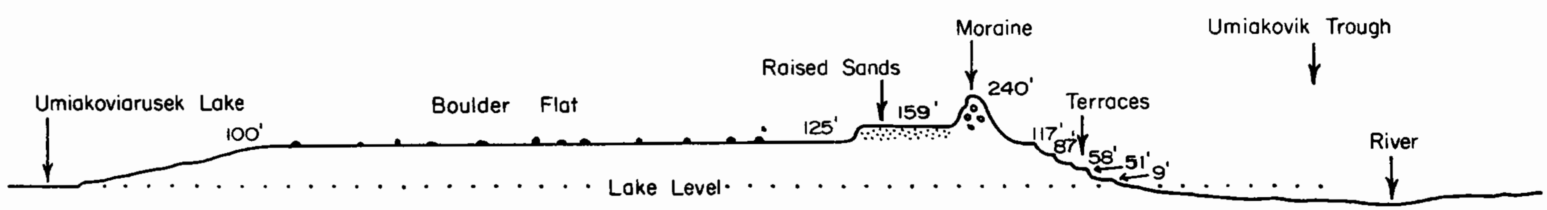
A camp was established on a knoll projecting from the north side of Umiakovik Trough, immediately north of the eastern end of Umiakoviarusek Lake. From this camp examination of Umiakovik Trough was carried out. The main source of Umiakoviarusek River is Umiakoviarusek Lake, though there is a small tributary which joins the main stream close to Umiakoviarusek Lake and has its head waters in the highland to the north. The main river meanders, braids and wanders from side to side of the trough on its way to the sea. Frequently the changes in course are directly due to irregular deposition of material on the trough floor. The south wall of the trough is cut into by a hanging valley approximately midway between Umiakoviarusek Lake and the canoe camp and from its mouth spreads a large raised delta. The river skirts this delta to the north, although it still has to cut its way through the fringe of the sands, and in doing so is restricted to a gorge with sides of unconsolidated material 50 to 60 feet high. East of the raised delta the river flows through a braided section, and still further east it is again limited to a narrow channel where it cuts through a series of arcuate features that extend across the trough from wall to wall. The northern half of these arcuate features was closely examined. Though the features are depositional and have a plan similar to cross-valley terminal moraines, they grade gently up from the valley floor, and are formed of sand and gravel, rather than the larger debris and boulders usually associated with morainic deposits. Only two boulders were observed in the cross-section exposed where the main stream cuts a 20 foot cleft through one of the features, though more were noted at its junction with the valley wall. This latter material, however, is almost certainly talus material that has fallen from above and is not characteristic of the whole feature. A consideration of the form and material suggests that they are kame terraces, formed at the snout of an ice lobe, which have later been reworked by marine agencies.

Approximately 6 miles to the south east of the knoll is a large lake named Tasiuyak Lake. Between Tasiuyak Lake and Umiakoviarusek Lake is a series of high sands similar to those observed in the Umiakovik Lake area. Observed from the west these sands appear to fill the valley completely, blocking the drainage from west to east. This is evidenced by the course of the tributary stream of Umiakoviarusek River, which flows from the highland in a north west to south east direction until it reaches the sands, where it follows their edge for a short distance before turning back into Umiakovik Trough and flowing to the sea via Umiakoviarusek River. These sands also have a distinct reverse slope on the inland edge, which rises abruptly 50 to 100 feet above the valley level.

Between the sands and the kame terrace features already mentioned, the floor of Umiakovik Trough is swampy, with innumerable small lakes and a chaotic drainage pattern. Small, irregular hummocks of moraine form the only dry patches on the trough floor. It could be described as being typically "dead ice topography".

Probably the most interesting and significant group of features in this area was found immediately east of Umiakoviarusek Lake itself. At this point there is a series of high (110-125 feet above lake level) sand and gravel deposits separating the lake from the main north west to south east trend of Umiakovik Trough. The sands have an arcuate eastern edge, readily discernible on air photographs. Cut into this eastern edge is a series of terrace-like steps from the highest level to valley floor level. Their heights were found to be 173, 215, 222, 251 and 281 feet above sea level. On the eastern edge of the deposit the top level of the sands is flat, but to the west it is gently

SKETCH SECTION SW-NE ACROSS UMIAKOVIARUSEK SANDS



Heights above Umiakoviarusek Lake Level

Distance across section approximately one mile

Figure 85

bevelled, the slope leading towards Umiakoviarusek Lake. Close to the lake this slope increases markedly, and grades into a raised lake shoreline a few feet above lake level. The top of the sands is unlike similar deposits observed in the Okak Bay area, in that it is covered with boulders. The boulders are rounded or sub-angular, and of many and varied rock types. All the rock types observed in the area are represented, along with types of granite and quartzite that are not found locally. The boulders are nearly all partly buried in the fine sand and gravel surface of the sands. On the top of the main bulk of sand and gravel, and raised 32 feet above the boulder flat, is an area of raised sands stretching out from the south side of the valley in a finger-like projection. On top of these raised sands is a distinct moraine, composed of fresh boulder material, which lies arcuate across the edge of the sands and stands approximately 100 feet above them at its highest point. This moraine is a continuation of some lateral moraines on the south side of the valley considerably above the level of the sands, and approximately 500 feet above lake level. The terminal moraine starts from this lateral moraine level as a 100 foot-high feature, continues down the valley wall towards the sand deposits maintaining its size and leads across on top of the sands still with the same vertical dimension. It continues further eastwards along the south wall of the trough, and a similar terminal moraine leaving the lateral moraine was observed approximately $1\frac{1}{2}$ miles east of the sands. This second terminal moraine does not, however, descend into the valley as far as the first, at no time coming below 300 feet above lake level. It is interesting to note that, while abundant boulder material occurs in the terminal moraine on the sands and further boulder material occurs on the main body of the sands themselves, no such boulders were found on the small strip of raised sands which surrounds the terminal moraine.

Unfortunately, it was impossible to reach the north wall of Umiakoviarusek Lake. However, observations from the top of the sands at the south east end of Umiakoviarusek Lake, and careful examination of air photographs, reveal that at least one, and possibly two, lateral moraine features are deposited on the valley side, parallel to the lake axis. The similarity of these features, and those so well displayed in the Umiakovik Lake area, is remarkable, both on the ground and on air photographs. Abney level sights taken from the end of the lake indicate a considerable slope in these lateral moraine features from south west to north east.

The presence of what appears to be a terminal moraine superimposed on marine sands immediately creates a problem which has direct bearing on the chronology of late Wisconsin events in the area. A number of working hypotheses may be advanced to explain these features.

Hypothesis 1: The moraine represents a terminal moraine on the valley floor caused by an ice lobe that was contained in Umiakoviarusek Valley. The sands are deltaic sands formed later by a stream flowing down Umiakoviarusek Valley into a higher sea level; they surround the terminal moraine, leaving only the top exposed.

The fact that there is no evidence of ice action in any part of the Okak Bay area after the marine incursion strongly supports this hypothesis. The character of the sands and to a great extent the material of which they are composed are similar to the deltaic material observed throughout the area. However, if this moraine feature was firmly based on the valley floor, it would have a height of 260 feet above valley floor level. This is a considerable height, and such a moraine could be considered a major feature. No other depositional feature of this size was found in any part of the Okak Bay area.

While this in itself would not rule out the explanation, it might be expected that such a major feature would be a complete terminal moraine, arcuate across the end of Umiakoviarusek Valley. No trace of such a feature can be observed on the western side of the valley at the present time. The height of 260 feet is calculated on the assumption that the valley floor would slope gently from Umiakoviarusek Lake to the present level of the tributary river running in the centre of the trough, if the sands were not in position. An argument might be advanced that a rock barrier exists underneath the present site of the sands and that the moraine is not such a major feature, merely that it is based on a rock bar. There is, however, no evidence of a higher rock base observable at the valley side. The valley sands appear to be deposited against a normally sloping valley side and not around the sides of a spur.

Hypothesis 2: The moraine was formed by an ice lobe overriding deltaic sands after isostatic uplift had exposed the delta form.

The moraine definitely seems to be on top of the sands. The lateral moraine is approximately 100 feet high, the terminal moraine at the point where it leaves the lateral moraine and continues down the bedrock of the valley wall is approximately 100 feet high and the feature on top of the sands is 100 feet high. It could be argued that a movement of one ice lobe would push up approximately the same amount of material in most positions around its snout. Further, the abundance of boulder material on top of the delta sands could represent ablation moraine deposited from the ice lobe which caused the push moraine.

However, the area of raised sands seems to coincide exactly with the base of the terminal moraine; if these sands were deposited before the advent of the moraine, it would be a remarkable coincidence if neither similar sands nor moraine were found elsewhere. They seem rather to be post-moraine and have been deposited around its base. Further, when postulating such very recent glacial activity, it must be remembered that no evidence for ice action after the marine incursion has been found in any part of the Okak Bay area, and the material in the moraine is not appreciably fresher than similar material found in features attributable to ice activity before the marine incursion examined elsewhere in the field work area.

Hypothesis 3: The following chronology is advanced: (a) Downwasting and retreat of the late Wisconsin ice mass until the main valleys are ice-free. (b) Marine incursion with a maximum height of 290 feet above sea level with coincident deposition of delta sands. (c) Possible slight isostatic recovery: this may have occurred at this stage though it is not entirely necessary in the hypothesis. (d) Re-advance and formation of the moraine, this being evidenced by the moraine and the spread of boulders over the former delta sands. This would also account for the overdeepening of the valley behind the sands and the present position and depth of Umiakoviarusek Lake. (e) A continuation of the rise of sea level and deposition of the raised sands. This stage would see the reworking of parts of the moraine, the deposition of sands free of boulders and the partial covering of the boulders on top of the former delta sands with fresh sand and gravel material. (f) Continued isostatic uplift, giving a negative change in base level and the formation of beaches cut into the former delta.

While this last hypothesis accounts for the features as they are observed, it would require testing before it could be considered valid. Proof would rest with cross-sections dug through the moraine and sands. Certainly the postulation of ice advance between period of marine incursion has to be stratigraphically proved before the hypothesis could be acceptable.

Hypothesis 4: The original sands are not deltaic as has been assumed, but represent kame material deposited at the front of a late Wisconsin ice lobe that filled Umiakoviarusek Valley. The push moraine was caused by a late stage re-advance of the same ice lobe which overrode the kame material, probably incorporating some of the kame material in the moraine form. These events were followed by the marine incursion which covered the sands to the base of the moraine, reworking the surface, depositing fine material around the moraine in the form of the raised sands and spreading it over the surface of the kame material, half burying the reworked boulders. Isostatic uplift followed, lowering the sea level and cutting the series of beaches into the eastern side of the unconsolidated deposits. This hypothesis requires proof that the original material was of kame origin. This in turn would require statigraphic evidence from the sands, and a careful geo-chemical and possibly palaeontological analysis of the stratigraphy.

A consideration of the available evidence, particularly the interpretation of the various types of material observed in the different features, does seem to favour the two latter hypotheses, and while final proof must await careful and detailed investigation, the simplicity of the final hypothesis seems to favour its acceptance.

Certainly the Umiakoviarusek Lake area has seen the ice lobe activity recognized elsewhere in the Okak Bay area. As seen elsewhere, downwasting and recession of an active ice front have both played a part in the final disappearance of the ice. Finally, the succession of marine beaches cut into the deposits of unconsolidated material in the area gives strong evidence that isostatic uplift raised the area after a marine incursion. The series of sand deposits on the valley floor can be explained by the formation of deltas at the mouth of an earlier Umiakoviarusek River flowing into progressively lower sea levels. The numerous rapids and steep gradient in the lower sections of Umiakovik River and Ikinet Brook suggest that recent isostatic recovery has taken place and is probably still continuing.

CHAPTER 13

CONCLUSIONS

Extent of Wisconsin Glaciation

Elements of the upland surface were examined in all parts of the Okak Bay area. These areas stretched from longitude 62°20' W. to 63°05' W. and were at elevations between 1,500 feet and 2,800 feet. The abundant evidence on all the surfaces examined of striae, fluting, unweathered drift, smoothed and rounded outcrops of bedrock indicates that the area has been completely inundated by ice.

The highest point in the area (Mount Tricorne, 2,765 feet above sea level), while showing a certain degree of frost-shattering and an absence of freshly striated or polished bedrock, does exhibit smooth and rounded bedrock forms, a definite if fragmentary drift cover and several unmistakable rounded, perched rocks and erratics, all giving firm evidence of the passage of ice over the summit.

The freshness of the drift material deposited on the summit surfaces, the presence of clearly cut striae, which are not enduring geomorphic features, and the sharply preserved forms of many of the depositional features prompt the conclusion that the latest glacial inundation occurred in post-Sangamon times.

Unlike the Kaumajet Mountains, the Okak Bay area does not present a morphological barrier to the passage of ice. It would not require an exceedingly vigorous flow of ice to cover its relatively low surface. Nevertheless, ice has flowed over the highest point of the area in comparatively recent times, and a minimum thickness of 700 to 800 feet above the general upland level would be necessary to achieve such flow.

In terms of absolute height, one must think of the minimum Wisconsin maximum at 3,000 feet above sea level, while realizing the possibility of substantially thicker ice masses during the Wisconsin in the Okak Bay area.

Direction of Ice Movement in the Okak Bay Area.

The main movement of ice through and over the Okak Bay area was from a westerly direction. This is clearly evidenced by the direction of striae and associated chatter marks, roches moutonnées and innumerable, lesser, rounded bedrock forms on the upper surfaces. The evidence of erratics in most parts of the area is not at all distinct. Indicator erratics are few, as outcrops of most of the major rock types occur throughout the area. However, on the upland surface to the north east of Umiakoviarusek River, the numerous erratics of the anorthosite group occur on the outcrops of adamellite, while careful search revealed no trace of adamellite erratics on either the anorthosite or gneissic series immediately west of the contact. This is particularly significant, as no outcrops of anorthosite were noted to the east of this particular occurrence of adamellite.

The pattern of drumlins and drumlinoids observed by Douglas and Drummond (1955) during air photo interpretation of this area supports the hypothesis of an ice mass flowing in a west to east direction. An examination of the Nain-Nutak topographic map (scale 1:506880) shows that the watershed between Okak Bay and the George River drainage system (approximately 45 miles west of Okak Bay) varies in height between 2,000 and 3,000 feet and forms no significant barrier to ice flow from further inland.

Undoubtedly the lower levels of the westward-flowing ice were influenced by the topography, particularly by the major west to east pre-glacial valleys. The overdeepening of these troughs and the creation of hanging valleys indicate that ice flow must have been concentrated in them during the glacial period. Certainly ice lobes were channelled in the troughs during the slow, fluctuating withdrawal of the final ice in the area. Less influence on ice flow direction were exerted by the irregularities in the upland surface. On all the higher points of the surface, the indications of flow show it to have been from a west or south west direction. The consistency of these indications suggests that the ice maximum did not just cover the surface, but was of sufficient depth to override completely the irregularities in the upland surface. This probably indicates that the maximum height of the ice was above the minimum Wisconsin maximum of 3,000 feet above sea level, for which there is evidence in the area.

While the evidence from this area strongly supports the contention that ice originated in the west, the Okak Bay area itself cannot offer evidence of the centre of ice flow. This writer does not consider Wheeler's (1935) postulation of a centre of accumulation at latitude 57° N., longitude 70° W., based on his own observations in the Okak Bay area and those of Odell (1933) on the coast further north, to be a sound approach to the problem. Rather, it must await careful geomorphological study of the central and intermediate areas.

Recognition of Separate Phases of Major Glacial Activity

All evidence in the Okak Bay area points to a complete inundation in comparatively recent (post-Sangamon) times. No stratagraphic evidence was found that allowed the writer to show that interglacial conditions existed before the deposition of the present drift. Thus, remarks concerning separate phases of glacial activity must be confined to the possible recognition of an interstadial in the area.

Two groups of evidence may be considered in this respect. The first is the weathering evidence that occurs on Mount Tricorne, the second the ice lobe activity confined to the main troughs.

The evidence of weathering on Mount Tricorne was discussed in the text and the conclusion was reached that the last glacial action overrode the summit and that frost-shattering is attributable to lengthy exposure of the summit, due to slow downwasting, and a possible condition of equilibrium with flow temporarily equalling ablation, but that the evidence does not warrant the postulation of a complete recession followed by an advance up to a slightly lower level than the summit. It is really unfortunate that points of the same height or higher do not occur in the same area to allow confirmation of this conclusion.

In the West River area it was postulated that the advance of the final ice lobe to fill West Valley was an event that occurred after ice had previously receded from the valley. As the depositional features observable on the valley floor are necessarily those of the final ice filling, evidence to separate the lobe in time from previous deposition must come from its highest contact with former material. The critical point is the difference of the dominant lateral moraine along the north side of West Valley from the higher features, and of the "newer" drift that overlaps the edges of the valley on the upland surface from the "older" drift in the area.

The lateral moraine is certainly a clearly defined feature. It is larger, sharper and better preserved than other higher moraine forms. The "newer" drift is characterized by a greater percentage of fines in its composition and by numerous low morainic ridges. It certainly has a different surface appearance from that of the drift immediately to the north. There is, however, no apparent difference in the disintegration or weathering between either the morainic features or the two types of drift. Frost-shattering is practically absent from all the deposits. Approximately the same cover of lichen and moss grows on both varieties. Breakdown of the surface material and formation of distinguishable A and B horizons are negligible in either material. Periglacial forms occur equally rarely in both areas. In short, while it is undisputed that a fresh resurgence of ice produced the features, it is thought that the time interval between their deposition cannot be termed an interstadial, and that while ice possibly withdrew from the main valleys, the withdrawal represented the local fluctuation in the ice front over several miles rather than a major recession in response to prolonged climatic amelioration. The fluctuations concerned represent stages in the final withdrawal of ice from the area.

Cirque Glaciation

Unlike the Kaumajet Mountain area, widespread dissection of the upland surface by cirque glaciation has not taken place. Nevertheless, more or less developed embayments, probably resulting from cirque erosion, were noted in the Okak Bay vicinity.

Cirque erosion has certainly caused the small hollow in the southern end of Lower Valley in the main hanging valley of the West River area. A large cirque form has been cut into the eastern wall of Ikinet Brook outlet valley. The series of embayments noted high on the eastern wall of Umiakovik Trough is most probably due to cirque erosion, as is the pronounced hollow in the valley wall above the eastern end of Umiakoviarusek Lake.

This, however, does not represent major cirque activity. The lips of these cirque forms vary in height between 250 feet and 1,000 feet above sea level, and the various examples face to the south, west and north respectively. Neither evidence of late stage cirque activity was found, nor were moraines that could possibly have resulted from cirque glaciers.

The apparently few examples of cirque glacier activity in the Okak Bay area should not be over-emphasized. The magnificent cirques on the northern side of the Kaumajet Mountains owe much of their initial development and deep sculpturing to their exposed mountainous position, as do the cirque forms in the Kiglapait Mountains some 50 miles to the south east. The relatively low upland surfaces in the Okak Bay area would definitely not present such favourable accumulation areas to initial cirque glaciation, with the result that there are correspondingly fewer well-developed and distinct cirque forms.

Late Wisconsin Conditions

The evidence in the Okak Bay area supports the concept that the climatic amelioration that affected the last major ice sheet to inundate the summits completely had three distinguishable phases. The first was an exceedingly slow change in conditions, which saw a continued, vigorous outflow of ice from the centre of accumulation, though the overall size of the ice sheet started slowly to diminish both vertically and horizontally. The second consisted of an increased rate of warming, and a possible increase of cyclonic activity, which caused a delicate balance between outflow and ablation in the marginal areas, resulting in the fluctuating retreat of an active ice front. The third involved an ever increasing warming, causing complete stagnation of the ice, mass downwasting in situ and eventual disappearance of the ice sheet.

In the Okak Bay area the following phenomena can be related to the various phases.

Phase 1. The summit of Mount Tricorne is gradually exposed, while the ice margin remains to the east of the area.

Phase 2. The average position of the active ice margin moves across the area from east to west in response to the increased ablation. Digitation and fluctuation of the ice margin produces ice lobes in eastern Umiakovik Trough and in the lower part of North River Valley. Melt-water is ponded against valley walls and causes the raised lake shorelines. Further retreat and fluctuation of the ice front, with the main ice mass mainly located on the upland zone, are responsible for the ice lobes in Umiakovik Lake and Umiakovik

Valley, West River Valley and hanging valleys and in Umiakoviarusek Valley, and for the minor fluctuations within these lobes themselves, such as those causing the lateral moraines in Umiakovik Valley and on North Knoll, and those recorded by the lateral moraines on the side of the hanging valley. The end of Phase 2 sees a final re-advance which is particularly well shown by the late ice lobe confined in West River Valley and the retreat of the snout of this lobe to a point approximately over the present position of West Lake.

Phase 3. This is one of stagnation. Ice lobes melt in situ, as does the much reduced ice sheet. Abundant melt-water is released, producing the complex of marginal drainage channels, chutes, eskers and kames demonstrated in West River Valley. Final melting of the ice releases the en-glacial moraine, causing the conspicuous dead-ice topography that characterizes the valley floors.

Following the final emergence of land from the Wisconsin ice masses, a positive change in base level due to a marine transgression occurred. The water action reworked and subdued many of the lower glacial deposition features and deposited sand on the surface of others. Rivers pouring into the higher sea levels produced the accumulations of deltaic material so well shown in the Umiakovik Trough.

Eventually the land started to regain its isostatic equilibrium with a progressively negative change in base level, causing a reworking and re-deposition of the fresh laid deltaic material, the cutting of marine shore-lines in favourable locations and the formation of deltas by rivers transporting the unconsolidated material to a progressively lowering sea level. Distinct marine features were found at 214, 279, 244 feet in the Umiakovik Lake area, 25, 44, 122, 138, 165, 230, and 235 feet on the south side of Okak Bay and 175, 215, 222, 251, 281, and 313 feet above sea level in Umiakoviarusek Lake area. These may be compared with the 15, 32, 44, 78, 92, 131, 165, 177, 225, 340 foot sequence observed in the Kaumajet Mountain area. This isostatic recovery seems to be continuing in the present day, as is evidenced by the rapids and gorges found on the lower sections of all the major rivers which enter Okak Bay. The recovery can best be explained as the vigorous readjustment to a comparatively recent negative change in base level.

SECTION 4 - GENERAL CONCLUSIONS

CHAPTER 14

Area Conclusions

Considering the Kaumajet Mountain and Okak Bay areas together, one may conclude that during the maximum of the Wisconsin glaciation, the highest summits of the area were completely submerged beneath the continental ice mass. The final movement of this continental ice in the area was from the west, the actual direction of flow across the fieldwork area being from west-south west to east north east. The basal ice flow of this main movement was, however, strongly influenced by the topography of the area, particularly in those places of high relief.

The above conclusion implies an ice mass with a minimum thickness of 5,000 feet on the coast at a longitude of $62^{o}00'$ W. and this estimate can be regarded as the minimum thickness of maximum glaciation.

With regard to the depositional evidence in the area, the conclusion is reached that it is related to the late Wisconsin glacial maximum period. The depositional evidence, though particularly abundant in the Okak Bay area, does not allow the sound postulation of an interglacial or major interstadial between glacial maximum in the Wisconsin and later stages of Wisconsin ice activity. In the passage from maximum Wisconsin inundation to final dissolution of the ice in the area, three phases can be recognized. The first of these was a prolonged period when marginal ablation occurred, but was in equilibrium or slightly in excess of central outflow. This resulted in the gradual lowering of the ice surface in the area and presumably the initial retreat of the outer fringes of the ice margin.

The second phase saw a relatively rapid withdrawal of an active ice margin across the area from east to west, the margin occasionally digitating and fluctuating in response to climatic variation. While no evidence was found to establish a major interstadial in the fieldwork area, it is possible that major ice lobes, originating in the fieldwork area during this phase, extended to the already deglaciated region to the east, allowing interstadials to be recognized in that area.

The final phase of ice dissolution saw the starvation of the central zone of accumulation, with subsequent stagnation of existing ice masses, and a very rapid downwasting in situ resulting in the total disappearance of the ice.

With regard to the final centres of major ice activity, the area did not form the nucleus of significant late-stage Wisconsin ice activity. Local glaciation was limited to the cirques and cirque valleys, their lobes only occasionally reaching as far as the main troughs. The main cirque glaciation occurred during the waxing and waning phases of the continental ice sheet, though minor cirque glaciation has occurred in comparatively recent historical time, refreshing the sculptured forms and striations.

The final removal of ice was followed almost immediately by a marine incursion. This definitely affected those parts of the landscape beneath the waters, and reworked many of the glacial landforms in the present valley bottoms. Subsequent isostatic uplift has raised the area a minimum of 350 feet above the present sea level. This isostatic recovery is incomplete and is proceeding vigorously at the present time.

The Regional Significance of the Area Conclusions

1. Regarding the overall glaciation of Labrador-Ungava, the evidence clearly refutes the early work of Bell (1882-84), Daly (1902), and Coleman (1921) who suggested that the higher parts of the eastern edge of north east America had not been covered by continental ice. Further, it tends to support the later work of Ives (1957-58), Wheeler (1958), and Douglas and Drummond (1953), who, in opposition to Flint (1943, 47, 52 and 57), contend that the final stage of

continental glaciation saw the downwasting of a stagnant ice mass whose centre was in central Labrador-Ungava, rather than the retreat of an active ice front to a series of icecaps on the coastal mountains.

2. With relation to the dissolution phase of the last continental ice mass, it is not thought that the whole removal of ice from its maximum to its final disappearance can be completely explained by the hypothesis of starvation, stagnation, and downwasting. It is suggested that the ice mass was already considerably reduced from its maximum extent before stagnation and rapid downwasting occurred, and that this earlier stage of reduction saw the retreat of an active ice margin, which in places digitated into topographically controlled, fluctuating ice lobes whose extent can be clearly traced in the depositional evidence. It is further advanced that this early phase of retreat saw both the exposure of the higher coastal mountains as nunataks, and also the maximum development of an exposed, ice-free continental shelf to the east of the present coastline.

3. Two hypotheses may be considered concerning the relationship of the events recognized in the fieldwork area to the Torngat and Koroksoak post-Sangamon glaciations suggested by Ives (1958)b for north eastern Labrador. The first hypothesis suggests that the maximum inundation of the area is related to the Torngat glaciation. The interglacial phase postulated for the northern area would thus be represented in the fieldwork area by recession that gradually uncovered the summits. The subsequent Koroksoak period would see a reactivation of the ice mass which possibly grew and gently overlapped the lower summits, though perhaps leaving the higher summits exposed. The final recession of ice would then be coincident with the downwasting postulated for the Koroksoak, with the possible exception that the area here discussed saw a phase in its overall retreat with a fluctuating ice margin.

This hypothesis has some points to commend it. If it is assumed that Ives' "Torngat" and "Koroksoak" glaciations occur within the relatively recent "classical Wisconsin" period, then the state of the surface material on the Kaumajet could be interpreted as follows. First, one could follow Tansley (1949), Dahl (1955), and Ives (1958)a, who suggest that mature mountain-top detritus takes a long time to form and the mature detritus on the Kaumajet indicates that the summits have been exposed at least since early classical Wisconsin (Torngat) time. Secondly, the unweathered state of the granite gneiss erratics makes it unlikely that they were deposited before early Wisconsin times, and thus must have been deposited since the Sangamon interglacial.

However, Ives (1958)b advances strong evidence for an interglacial between his suggested Torngat and Koroksoak glaciations, an interglacial that saw "the disappearance of continental ice from most if not the whole of Labrador-Ungava". In the face of such evidence this writer feels it unrealistic to postulate that the field area, situated as it was on the margin of a continental ice sheet, would be inundated with ice during such an interglacial.

The abundant evidence of inundation of the area by continental ice and, apart from the mountain-top detritus, the absence of depositional or topographic evidence that could be related to an interglacial stage after such inundation, tend to support a second hypothesis proposing that the glacial phases recognized in the area are essentially those of the final stage of major inundation in Labrador-Ungava corresponding perhaps to Ives' Koroksoak period. It could be suggested that at the maximum of this glaciation the ice in the area completely overrode the summits, removing detrital material, and had a sufficiently vigorous flow to transport the numerous erratics vertically upwards through many hundreds of feet. There then possibly followed a period of equilibrium, or of slight overall lowering of the ice surface, which might be correlated with the "kame terrace-lateral moraine stage" advanced by Ives. The final dissolution would see ever increasing melting, resulting initially perhaps in the withdrawal of an active ice front and finally in the starvation and stagnation of the whole ice-mass.

With this hypothesis, the problem of mountain-top detritus as an indicator of nunataks in the north east Labrador area immediately presents itself. Considerable care, however, must be used when applying this concept to non-gneissic areas away from the type locality.

There is evidence accumulating from a detailed study of the drift sheets of central north America to indicate that the post-Sangamon glacial period may be considerably longer than previously thought. The work of Dreimanis (1959) suggests that the Sangamon interglacial terminated approximately 80,000 years before present, whereas earlier thought placed the beginning of the Classical Wisconsin glacial at only 25,000 years before present. Great caution must be used in seeking parallels between central north American stratigraphy and that of Labrador. Nevertheless, if the Sangamon ended at this very early date, the possibility can be envisaged that the glacial periods of Torngat and Koroksoak advanced by Ives (1958)b, both occurred after the end of the Sangamon interglacial. It also follows that the Koroksoak alone could have been substantially longer than the total suggested duration of a classical Wisconsin. Its length could certainly have been greater than that conceived to fit into the pattern of the classical Wisconsin, where the Koroksoak glaciation, and possibly the Torngat also, were thought to occur within the last 25,000 years.

In short, the possibility of a lengthy Koroksoak glaciation must be seriously considered.

The relative breakdown of gneissic erratics and the volcanic complex of the Kaumajet Mountains can also be considered. The volcanic complex was in places highly fragmented into mountain-top detritus. On no occasion was any sign of frost action observed on any of the numerous gneissic erratics. This cannot be stressed too strongly: if it is assumed that the erratics were positioned not later than the time when the summit surfaces were swept by ice, and from the abundance of erratics it is perhaps possible to suggest that the same agency both deposited the erratics and swept the mountain tops of pre-glacial debris, then volcanic bedrock and gneissic boulders would have been exposed to the same weathering conditions since the withdrawal of the ice. The subsequent breakdown of the two might indicate that the volcanic bedrock was more susceptible to such action than the gneissic boulders. Even if one postulates that the bedrock was more vulnerable because of its configuration, it would be difficult to ascribe the complete contrast in weathering to this alone. In fact the evidence could suggest that the volcanic rocks, in particular the volcanic breccias that occur on many parts of the Kaumajet Mountain summit surface, are lithologically more susceptible to frost-shattering than is granite gneiss.

While suggesting that the Koroksoak period might possible be of some considerable duration one must not forget the presence of well-preserved striae observed on the summit surface of the Kaumajet Mountains. Striae are not usually enduring geomorphic features. While it is thought possible that such striae could have been preserved since the Koroksoak glaciation, it is not as probable that they would have endured through an interglacial from the former Torngat glaciation. A considerable amount of the mountain-top detritus occurs in situ below the position of the striae, indicating perhaps that if the striae were of Koroksoak age, the breakdown of the volcanic series to mountain-top detritus would have to have occurred since that time.

The writer feels that at this time the limited evidence can best be explained by following Odell (1933) and Tanner (1944) in the conclusion that there has been time since the dissolution of the Koroksoak glaciation in the Kaumajet Mountain area for the volcanic series to break down under frost action and form a considerable quantity of mountain-top detritus, and that the presence of mountain-top detritus on the Kaumajet Mountains does not necessarily indicate nunatak conditions during the Koroksoak period, nor does it completely invalidate the tentative relation of the final Kaumajet glaciation to that same period.

Just how much lithological differences affect this breakdown cannot be determined. In illustration one can cite the adjacent Kiglapait Mountains which rise to 3,150 feet some sixty miles to the south of the Kaumajet group. These are basically composed of anorthosite and appear to carry no detrital mantle at all. (Morse, personal communication). Certainly they are as exposed to the weathering as are the Kaumajet group. Possibly their lithology inhibits frost-shattering. In conclusion it is thought that the concept of mountain-top detritus as an indicator of nunatak areas can be applied soundly only in areas where at some point topographic evidence gives suitable indication of the effect of lithology on bedrock disintegration.

4. The theoretical concept of Dahl (1946 and 1947), based on the measurement of the marginal slopes of present and past ice sheets, suggesting that the maximum slope of an ice sheet bordering a deep ocean would be 1:100 must be examined in the light of the evidence indicating that a continental ice sheet

covered the summits of the Kaumajet Mountains to a height of 5,000 feet (1,660 metres approximately).

Consideration should first be given to the height of the ice over the Kaumajet Mountains. The evidence of erratics detailed in the text clearly demonstrates a vigorous flow over the Kaumajet group. To achieve this flow, the ice mass relies on two factors: first, a sufficient thickness of ice over a mountain mass to make the topographic barrier insignificant, and secondly, a surface gradient over the obstruction sufficient to achieve the flow of basal ice up the reverse slope presented by the barrier. The postulated height of ice surface of 1,660 metres allows a thickness of 440 metres (approximately 1/5th of the total thickness) over the highest part of the summit level (Brave Mountain 1,220 metres). This certainly does not relegate the mountain barrier to an insignificant basal irregularity.

If Dahl's hypothesis is to be accepted, one cannot expect a greater gradient over the mountain mass than 1:100. This is not a steep gradient. If is difficult to envisage an ice mass with such a surface gradient inducing a basal flow sufficient to place erratics on the mountain summits without a considerable thickness of ice covering these summits.

On this basis it is suggested that the figure of 1,660 metres for the height of the ice flowing over the Kaumajet Mountains must not be regarded as a maximum but as the minimum necessary for an ice mass to achieve such flow.

Accepting this figure, and assuming Dahl's gradient of 1:100 to be correct, the outer margin of the ice mass can be estimated at a minimum distance of 150 to 170 kilometers to the east of the present coastline. The essential problem is whether such an extension of the ice sheet was possible during the Wisconsin period.

Examination of Canadian Hydrographic chart (first edition), Nain to Saglek

Bay, which is a reproduction of the U.S.N.H.O. chart 5845 published in 1955, clearly indicates that a broad continental shelf fringes that part of the northern Labrador coast. Eastward of the Kaumajet Mountains the shelf extends for 100 to 120 kilometers before dropping off steeply into deep water. The present depth at the lip of the continental shelf is approximately 140 to 150 fathoms.

The concept of ice spreading over the continental shelf receives support from the geological evidence. Till has been found on George's Bank between Cape Cod and Nova Scotia (Shephard 1934). Cooke (1930) noted a big submerged moraine stretching from the Strait of Belle Isle to the junction of the Anticosti and Newfoundland channels. Tanner (1944) suggests that a row of banks which extend along the greater part of the Labrador coast probably represent a terminal moraine of the Wisconsin ice, and banks that could be interpreted as moraines occur on the lip of the continental shelf at 58°20' W., 56°30' N., 59°20' W. and 57°20' N., in the vicinity of the fieldwork area.

Clearly the Pleistocene sea level has direct relationship to the question of shelf ice. The exact position of the glacial shoreline is nowhere known, although the interaction of many complex factors, including a glacio-eustatic fall of ocean level, isostasy, epeirogenetic uplift and tectonic movements resulted in a negative change in base level during the glacial maximum. The amounts of this change have been estimated:- Ramsey (1931) calculated a fall in sea level of 275 metres, which the isostatic rise of the sea floor reduced to 183 metres. Farrington (1945) gives figures of the same order. Antevs (1928) gives an approximation of 93 metres for the Wisconsin period, though Daly (1934) would reduce this to 75 metres. In the absence of absolute data, an average of 100 metres would seem to be a reasonable approximation for the relative fall in sea level. Such a fall would create a coastal strip of about 15 to 20 kilometers in width in the vicinity of the fieldwork area, and would lower the sea depth at the lip of the continental shelf to approximately 200 metres (600 feet).

While it is recognized that the factors affecting the extent of shelf ice are complex, it is contended that the conditions outlined above would allow the accumulation of shelf ice off the Labrador coast. The ice would probably be grounded as far as the 200 metre (600 feet) depth at the edge of the continental shelf. A parallel can be found in the grounded portion of the Ross Barrier, where, if the ice were removed, the ground would be covered with 265 metres (800 feet) of water. However, the shelf ice on the continental shelf is not sufficient to contain the ice mass with a surface slope of 1:100. Either the fraction has to be revised, or a floating ice shelf extending from the grounded continental shelf ice has to be envisaged. The latter is not at all improbable. A floating ice shelf extends 15 kilometers from the grounded portion of the Ross Barrier. The Shackleton Ice Shelf floats for approximately 160 kilometers. A floating shelf of 40 to 50 kilometers wide would complete the requirements for Dahl's hypothesis. The postulation of an ice cliff would reduce the required width of the floating ice still further. Therefore Dahl's figure is tenable, despite the apparent anomaly of a high ice mass at the coast.

It was, however, stressed that the 1,660 metre thickness of ice at the Kaumajet Mountains was probably a minimum figure. A relatively small increase in vertical thickness over the mountains would necessitate a considerable extension of the floating ice, and further extension of the floating ice would increase the effect of the elements that lead to its destruction. Thus, although the present state of knowledge of continental ice flow makes the postulation of an increase in ice thickness over the Kaumajet Mountains entirely speculative, Dahl's figure should be treated with caution. Meanwhile, to suggest the possibility of shelf ice along this part of the Labrador coast allows the reconciliation of the evidence of ice-covered coastal mountains, and the proposal of a relatively gentle marginal slope for continental ice sheets.

5. The understanding of the sequence and extent of the Pleistocene glacial inundations, particularly the recognition of the ice-free areas, has been enriched by many contributions from the fields of botany and zoology. The formulation by Scandinavian authors (Blytt 1881) of the classical "nunatak hypothesis" and its later introduction to north America by Fernald (1925) has influenced several geologists and geomorphologists in their discussion of the extent of the Pleistocene Ice Sheets. Briefly, the hypothesis suggests that the discordance of present-day flora in remote areas with that of surrounding areas can be explained by certain plants having lived through the last glacial stage on nunataks that projected through the thinner ice margins. This view has been modified and amended by later authors. Abbe (1938), and Dahl (1955) suggest that possibly low-lying ice-free coastal areas, as well as mountain top nunataks, could form refuges for such plants, which would have migrated to their present areas during the period of post-glacial climatic amelioration. Rousseau (1953) advances the concept that "even if the limited areas to which these plants are confined were actually nunataks, the plants could just as easily have migrated there after the glacier's recession."

The evidence indicating that the Kaumajet Mountain area was completely inundated during the last glacial phase clearly has a bearing on these hypotheses. At the glacial maximum, the area would not provide suitable conditions for plant refuges. At the same time, shelf ice could be expected on the continental shelf to the east of the area, which would not allow plants an ice-free coastal strip for immediate migration.

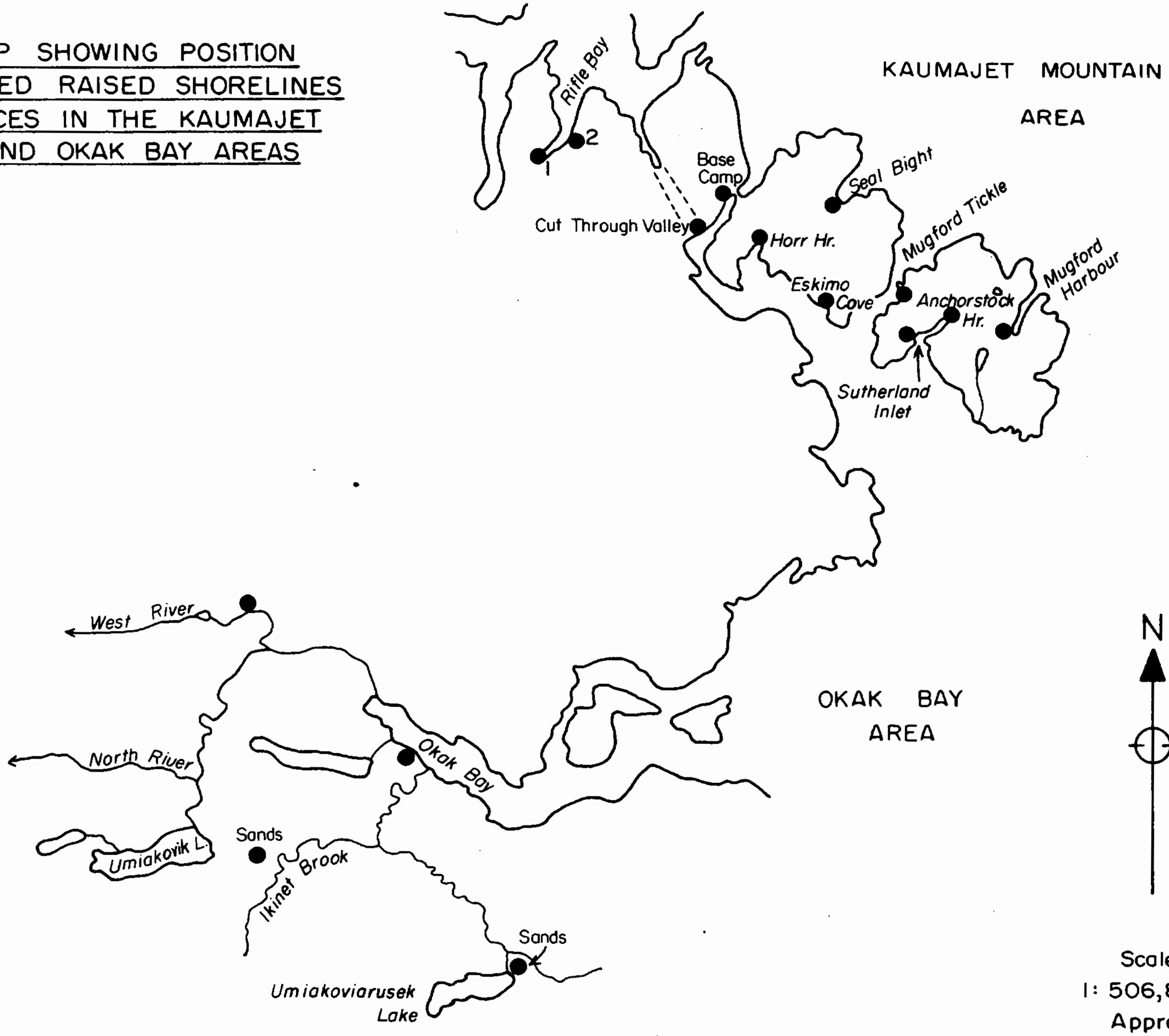
However, if tentative correlation may be made between the final Kaumajet glaciation and the Koroksoak period, then exposed coastal summits, and possibly an ice-free coastal strip, existed on the eastern side of the less severely glaciated Torngat Mountains to the north of the Kaumajet group. This coastal strip, widening to the north, could well have provided a refuge for the species found in the Kaumajet area, migrations occurring in the post-glacial climatic amelioration.

A collection of flowering plants was made from the Kaumajet Mountains. These 54 species (listed in Appendix B) probably constitute the majority of plants that flower during the summer in the area. The collection was named and examined by Löve of the Institut Botanique, Montreal, and also examined by Powell, McGill University. The plants are practically all high arctic species: "the most remarkable thing is perhaps that the collection is so uniformly high arctic, with only two species that may be of more southern origin" (Löve, personal communication). In the opinion of these botanists, on the basis of the species alone, it is quite possible, even probable, that the species migrated from a coastal survival shelf in the short time available after the last glaciation. It is suggested that the high arctic nature of the species allows the postulation of a refuge to the north of the Kaumajet Mountains, and that such a refuge would be provided by the nunatak conditions and ice-free continental shelf postulated to the east and north of the Torngat Mountains during the Koroksoak period. This concept is further supported by phytogeographic evidence (Hulten 1937, Löve and Löve 1957) for the survival of such arctic flora north of the ice sheets, and of migration southwards from Arctic Archipelago refuges in post-glacial time.

It would, however, be quite unsound to argue that the botanical evidence proved that the Kaumajet Mountains were inundated during the last glacial period. At this time such a suggestion must rest on geomorphological evidence. Meanwhile, it can perhaps be noted that the species do not indicate nunatak conditions, and are the type of plants that would be expected in the area if migration from a northern refuge had occurred after the last glaciation.

Finally, the essentially reconnaissance nature of this fieldwork must again be stressed. The conclusions presented are those indicated by the evidence observed. However, in several cases, particularly those regarding the question of mountain-top detritus and the associated nunatak problem, resolution cannot rest with this work alone. Rather it must come from a continuing series of systematic studies closely linked with an increasing body of regional observation. It is, however, hoped that this work may add to the evidence available to that study.

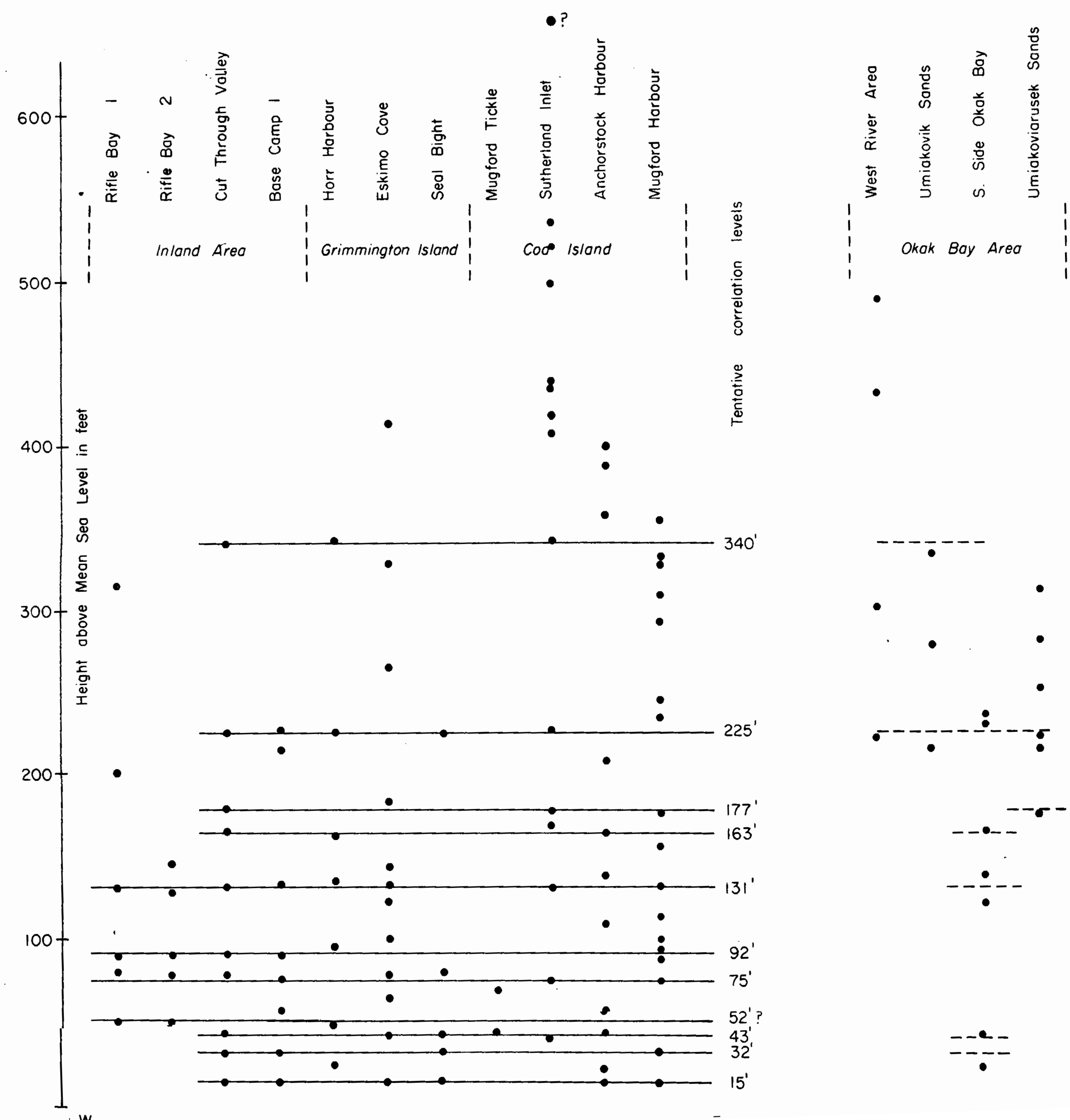
SKETCH MAP SHOWING POSITION OF MEASURED RAISED SHORELINES AND TERRACES IN THE KAUMAJET MOUNTAIN AND OKAK BAY AREAS



Scale
1: 506,880
Approx.

Appendix A. Part II

Diagram showing relative heights of shoreline and raised terrace features measured in the Kaumajet Mountain and Okak Bay Areas



APPENDIX B

Plant Collection from Kaumajet Mountains, and Cod Island, Labrador.

Collector: Mrs. R. F. Tomlinson, Montreal.

Identifications by: D. Löve, Institut Botanique, U de M., Montreal.

1. Tofieldia pusilla (Michx.) Pers.
2. Bistorta (= Polygonum) vivipara (L.) S. F. Gray
3. Sagina caespitosa (J. Vahl.) Lange
4. Minuartia (= Arenaria) groenlandica (Retz)
5. Stellaria crassipes Hult. (S. longipes Goldie s.lat.)
6. Cerastium alpinum L.
7. Silene acaulis L.
8. Viscaria alpina L.
9. Anemone parviflora Michx.
10. Ranunculus pedatifidus Sm. v. leiocarpus (Trautv.) Fern.
11. Papaver radicatum Rottb.
12. Draba cinerea Adams
13. Arabis arenicola (Richards) Gelert
14. Rhodiola (= Sedum) Rosea L.
15. Parnassia Kotzebuei Cham.
16. Saxifraga Hirculus L.
17. Saxifraga hyperborea R. Br. (= S. rivularis L. var.)
18. Saxifraga stellaris L.
19. Dryas integrifolia Vahl.
20. Potentilla Crantzii Beck
21. Rubus acaulis Michx.
22. Sibbaldia procumbens L.
23. Oxytropis Maydelliana Trautv.

24. Oxytropis terrae-novae (= O. campestris (L.) DC var.)

25. Astragalus alpinus L.

26. Viola labradorica Schrank.

27. Chamaenerium (= Epilobium) latifolium (l.) Sweet

28. Pyrola grandiflora Radius

29. Ledum decumbens (Ait.) Loss

30. Cassiope tetragona (L.) D. Don

31. Harrimanella (= Cassiope) hypnoides (L.) Coville

32. Vaccinium Vitis-idaea L. ssp. minus (Lodd) Hult.

33. Diapensia lapponica L.

34. Gentianella Amarella (L.) Borner

35. Hippion (Gentiana) nivale (L.) F. W. Schmidt

36. Mertensia maritima (L.) S. F. Gray

37. Veronica Wormskjoldii R. S.

38. Castilleja septentrionale Lindl.

39. Euphrasia arctica Lange

40. Bartsia alpina L.

41. Pedicularis labradorica Wirs.

42. Pedicularis groenlandica Retz.

43. Pedicularis flammea L.

44. Pinguicula vulgaris L.

45. Armeria maritima L. ssp. labradorica

46. Campanula rotundifolia L. s.lat.

47. Solidago multiradiata Ait.

48. Solidago sp.

49. Erigeron humilis Graham (= E. unalaschkensis (DC) Vierhapper)

50. Gnaphalium norvegicum L.

51. Arnica alpina (L.) Olin ssp. angustifolia (Vahl.) Maguire

52. Senecio sp. (? pauciflora)

53. Taraxacum (? pumilum)

54. Hieracium sp.

s. lat. = sensu lato; in wide sense; s. str. = sensu stricto; in narrow sense; in paranthesis: synonyms; sp. = species, i.e. sp. unknown.

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