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NOTES ON THE GEOLOGY AND GEOMORPHOLOGY OF THE CAREY ØER, NORTH-WEST GREENLAND

BY

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WITH 6 FIGURES IN THE TEXT

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Abstract

The Carey Øer, a group of small islands, is located in the southern part of Smith Sound, North-West Greenland. The largest of the islands, Nordvestø, was investigated. It consists, as do apparently all the islands in the group, of Precambrian metamorphic rocks dominated by grey, banded gneiss and pink gneiss. Doleritic dykes and sills occur. No sedimentary rocks occur *in situ*. A great number of glacial erratic boulders, identical with sedimentary rocks found *in situ* on the mainland and on Saunders Ø east of the islands, are present. As indicated by the erratics, the islands were covered by the Greenland ice sheet, but local glacial ice may have occurred both before and after they were covered by the Greenland ice sheet. The geomorphological features suggest that the characteristic flat summit surfaces of the islands are remnants of the same late Pliocene or early Pleistocene erosion surface, which occurs on the neighbouring mainland and on Saunders Ø. The erosion surface was heavily dissected by fluvial action with the formation of steep cliffs. This was followed by a marine submergence which flooded the river valleys and produced the islands. Raised beaches are found in several places on Nordvestø and on Mellemø and Isbjørneø as well. Periglacial features such as frost cracks, solifluction lobes, frost mounds, frost-shattered rock, talus, permafrost, and snowbank trimlines are common.

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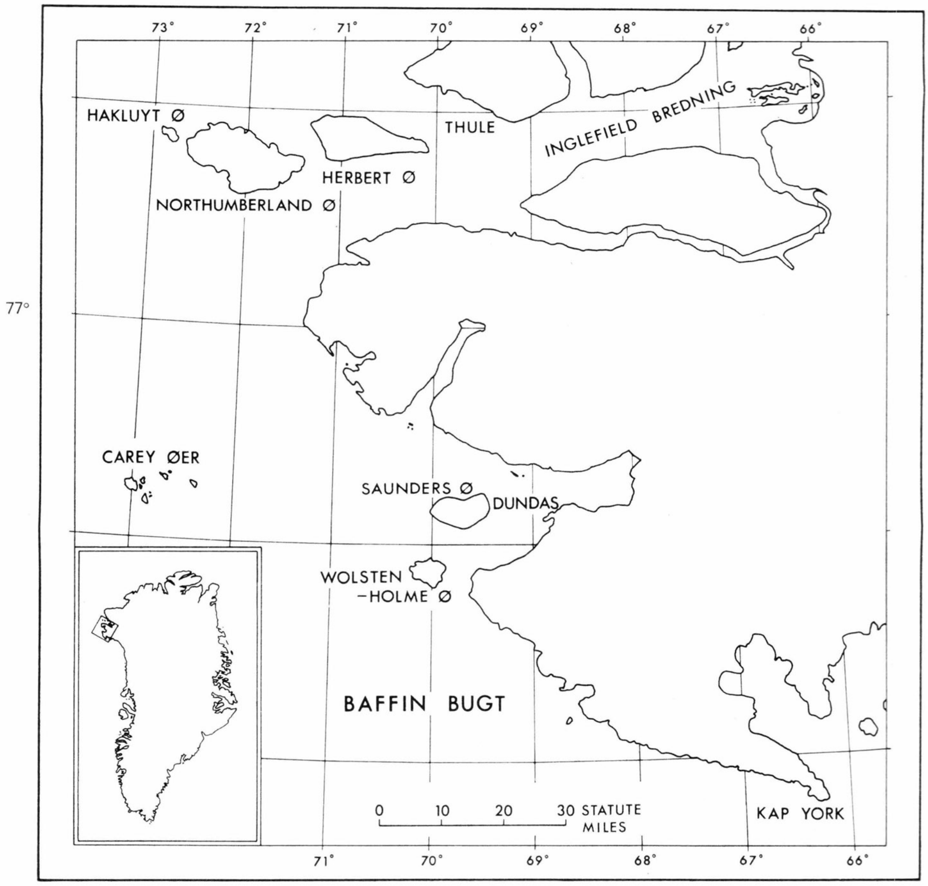

Fig. 1: Map showing the location of the Carey Øer, North-West Greenland. The location indicated on the map as Dundas is that previously occupied by the Thule settlement before this was moved north. Very often the area around Dundas erroneously is still referred to as the Thule area.

INTRODUCTION

The Carey Øer are located between lats. 76°30′ N and 76°45′ N and longs. 72°00′ W and 73°15′ W, approximately 70 statute miles west of Dundas, Greenland (fig. 1). They consist of six islands one or more miles long, and twenty-six much smaller islands and skerries (fig. 2). Nordvestø, the largest, is approximately $2^1/_2$ miles long, 2 miles wide, and between 700–900 feet high. It is essentially an irregular plateau several hundred feet high, which terminates at or near the coast in steep cliffs. It is below the snow line although there are many perennial snow-patches. Three sizable meltwater streams occupy valleys which have been incised into the plateau. The bedrock consists of Precambrian metamorphic rocks into which doleritic sheets have been intruded. No sedimentary rocks, *in situ*, were seen on any of the islands.

COMMENTS ON THE BEDROCK GEOLOGY

Previous knowledge on the geological composition of the Carey Øer is relatively meagre. HAUGHTON (1859, p. 374) and NARES (1878, p. 45) reported from Björling Ø "granitoid rocks" and red gneiss respectively. KOCH (1920, pp. 7, 11) gives the same information concerning the rocks from this island and WORDIE (1938, p. 395) states that gneiss and dolerite sill occur on Nordvestø, Isbjørneø and Mellemø. MUNCK (1941, pp. 7–8) mentions the occurence of red gneiss, dolerite sills and diabase dykes from Nordvestø and Mellemø, and also gives a detailed petrographic description of diabase samples from these islands (*op. cit.*, pp. 28, 31).

Our investigations on Nordvestø indicate that the Precambrian basement complex occurring here consists of the following types of metamorphic rocks:

Grey Banded Gneiss: composed mainly of quartz, feldspar and biotite and fine- to medium-grained with a maximum grain size of 1–2 mm. A very small amount of magnetite and epidote ($< 1\,\%$) is present in the rock. The characteristic banding of the gneiss is due to alternating layers of grey gneissic bands and light pegmatitic bands.

Grey Foliated Gneiss: composed of quartz, feldspar and a relatively small amount of brown biotite mainly concentrated in thin layers. Cleavage of the rock is parallel to the foliation. It is fine- to medium-grained with a maximum grain size of about 2 mm.

Pink Gneiss: medium- to coarse-grained and composed of quartz, feldspar and brown biotite. The biotite content is relatively small and a marked concentration of quartz in more or less regular veins is a very characteristic feature.

Red Coloured Gneiss: composed of quartz, feldspar and green biotite. It is a medium grained rock and the feldspar appears turbid, partly seritized particularly along the margins. A well-developed foliation is characteristic.

Red Pegmatitic Gneiss: composed of quartz, feldspar and a small amount of biotite and green amphibole. The feldspar appears turbid. Veins of epidote occur regularly and are usually orientated parallel to the cleavage planes.

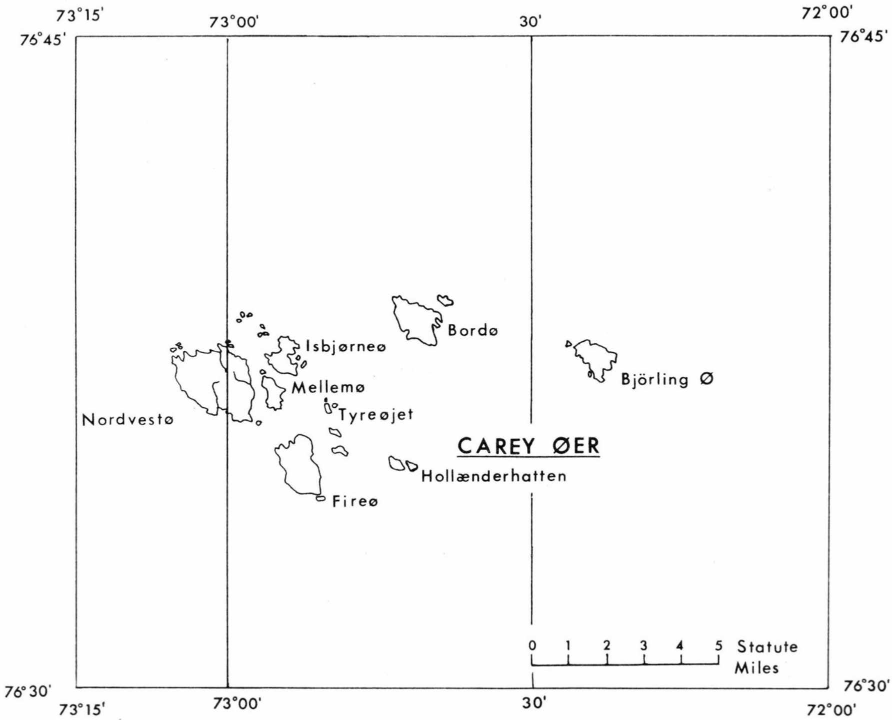

Fig. 2: The Carey Øer.

Red Schistose Gneissic Rock: composed of quartz, feldspar and magnetite. The feldspar appears turbid with partly seritized borders. The rock shows a clear banding due to the higher concentration of the dark minerals in broad bands which alternate with relatively narrow pink bands.

Light Pegmatite: composed of quartz and feldspar in cm size grains. Intergrowth between the two minerals occurs very commonly.

Dark Grey Schistose Gneiss: composed of quartz, green amphibole and green biotite. A clear banding is characteristic and is due to a concentration in bands of the dark and the light minerals. The content of quartz is greater than that of amphibole, which again exceeds the content of biotite. The foliation appears to be nearly perpendicular to the cleavage planes. The grain size is fine to medium but marked variations occur locally.

The *Grey Banded Gneiss* and the *Pink Gneiss* are the most prominent rock types in which the other rock types are found locally as more or less irregular veins, dyke-like layers, lenticular bodies and more or less extensive tabular masses. Thus there is a clear similarity with the basement complex as it is developed in the North Star Bugt Area (DAVIES *et al.*, 1963, pp. 16–27). In accordance with the previously mentioned information given by earlier writers it seems justified to postulate that all the islands in the group consist of the same types of rocks as those occurring on Nordvestø.

A K/Ar. age determination on biotite from a sample of the *Grey Banded Gneiss* gave an age of 1740 ± 30 m. y. (O. LARSEN personal comm., 1967). This suggests that the area was metamorphosed during the Nagssugtoqidian (Hudsonian) orogeny.

The metamorphic rocks form two local synclines on the southern part of Nordvestø. The axes of these synclines dip gently to the SSE. The axis of the westernmost syncline follows the general line of the river valley which terminates on the southern side of the island (figs. 2 & 4). The crest of the intermediate anticline has been eroded. However to judge from the steep dip to the east and the west found in the rocks along the ridge, which forms the highest elevation on the island, the crest of the anticline was located parallel to the ridge. Unfortunately, the structural pattern on the northernmost and the westernmost parts of the island was not investigated owing to the short duration of our stay and in particular to the poor weather conditions.

A prominent dolerite sill, in some places with a thickness of 30–45 feet, is intruded in the Precambrian basement complex and extends over most of the island. The smaller areas of dolerite bodies covering the summit surfaces of Isbjørneø and Mellemø are possibly remains of the same sill. A dolerite dyke, partially forming a steep coastal cliff, is found along the eastern beach of Nordvestø north of the river valley (figs. 2 & 4). The samples described by MUNCK (*op. cit.*, p. 31) originate from this dyke. Another basalt body forms a relatively low coastal cliff along the northern part of the west beach of Mellemø, but it was impossible to decide whether it formed part of a dyke or a sill.

ORIGIN OF THE SUMMIT SURFACES AND THE ISLANDS

Several of the Carey Øer are characterized by flat summits (fig. 6). The summit surface on Nordvestø is considerably dissected and in general less than 800 feet above sea level. Those on the other islands are lower and in some cases flatter. They are erosional surfaces, as they cut the Precambrian basement complex and the basalt sills and dykes. These surfaces terminate near or at the coast in steep cliffs, some of which are in places hundreds of feet high.

The summit of Saunders Ø (figs. 1, 3) is an erosion surface which truncates folded Precambrian sedimentary rocks belonging to the Thule Group (Davies *et al.*, 1963, pp. 14, 16). This surface is probably a remnant of the erosion surface found on the neighbouring mainland between 1000–1300 feet above sea level which is thought by Davies (*op. cit.*, pp. 11–12) to be late Pliocene or early Pleistocene in age. The Precambrian peneplain which has been exhumed in Inglefield Land (Cowie, 1961, pp. 40–41) is still buried at Saunders Ø by the Precambrian sedimentary rocks found there. Perhaps the summit surfaces of the Carey Øer are remnants of the late Pliocene—early Pleistocene erosion surface (fig. 3). If so, the erosion necessary to form them destroyed the Precambrian peneplain in this area and removed some of the rocks on which it was developed (fig. 3. See also Wordie, 1938, p. 395).

After the development of the late Pliocene and/or early Pleistocene erosion surface, the area was uplifted and the surface was dissected by fluvial erosion. The Carey Øer and Saunders Ø suffered less erosion than the surrounding areas. With the continuation of the erosion, they became considerably higher than the areas around them. Following submergence, they became islands. The height of the Carey Øer and the absence of other groups of islands is puzzling. Perhaps the area in the vicinity of the Carey Øer was higher than the general level of the late Pliocene—early Pleistocene erosion surface and remained so after uplift because more resistant rocks were found here and/or the area was not close to the major streams. Or perhaps the area around the Carey Øer

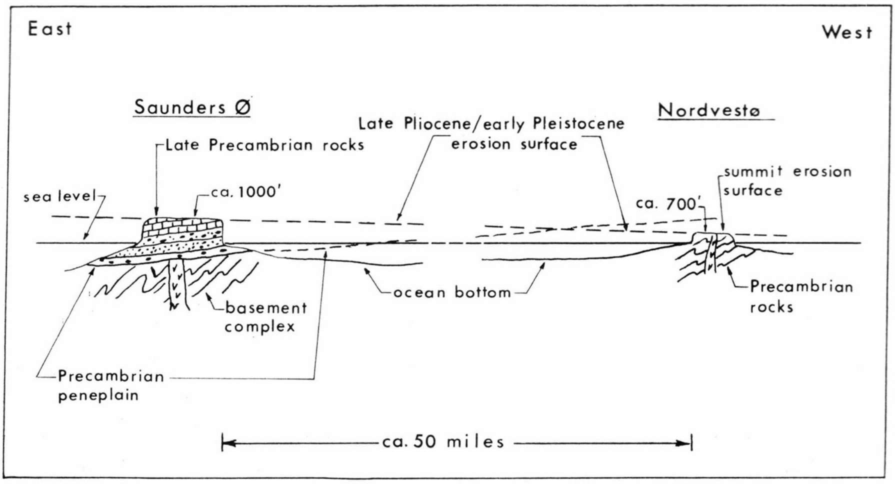

Fig. 3: Diagrammatic sketch showing the origin of the erosion surface found at the summit of several of the islands in the Carey Øer group.

was deformed, either before or after the development of the erosion surface, in such a way that it became and remained higher than elsewhere.

The coastal cliffs of the Carey Øer are not due primarily to glacial erosion, as they are as steep and high on one side as on another. The presence of cliffs hundreds of feet high at Dundas Fjeld, Saunders Ø, and elsewhere, which are too high to have resulted from glaciation, and the absence, as far as is known, of wave-cut platforms in front of the Carey Øer cliffs, prove that these coastal cliffs are not due to glacial or marine erosion but must be due mainly to pre-glacial fluvial erosion.

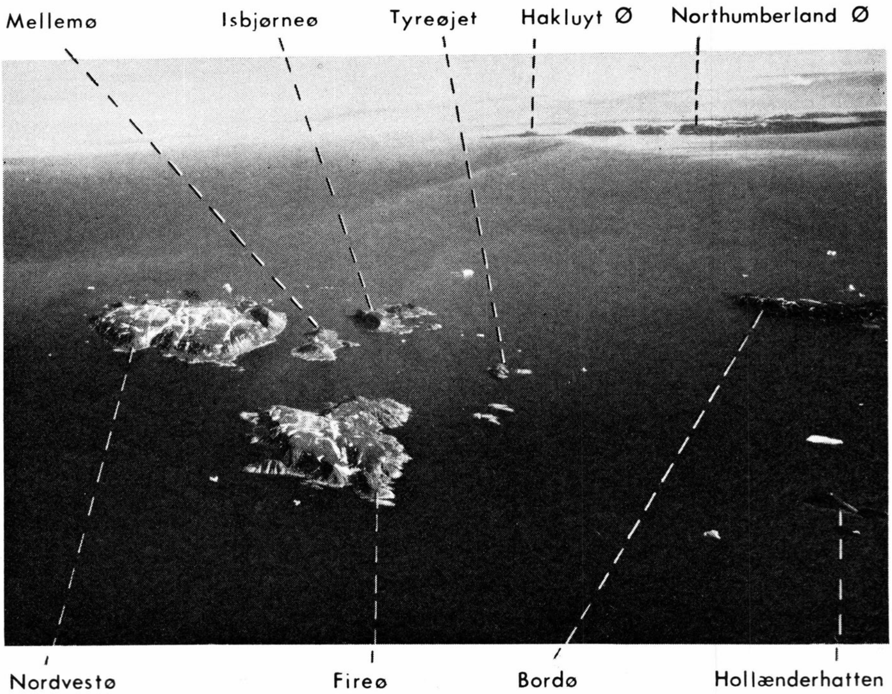

Fig. 4: Aerial photograph showing most of the islands in the Carey Øer group. Copyright: Geodetic Institute, Copenhagen.

STRAND FLATS

A narrow strand flat is found on Nordvestø and on at least one other island. The strand flat on the northern side of Nordvestø immediately east of where the river reaches the ocean (fig. 2, 4) is well developed. It is approximately 1000 feet wide and about 100 feet high at its inner edge, where it meets a steep cliff. The strand flat at the south end of Mellemø is between 200–300 feet wide and 50–75 feet high at its inner edge (fig. 6). Little time was available for their study. Their distribution is not known, nor how or when they were formed. The considerable amount of bedrock erosion necessary for their formation, and the fact that the relation of sea level to land has been continually changing ever since the islands were deglaciated (Nichols, 1953), make it unlikely, however, that the strand flats are post-glacial in age. They deserve study.

GLACIATION

As mentioned above, only metamorphic and igneous rocks are known to occur *in situ* on Nordvestø. Fragments of limestone, sandstone, quartzite, and conglomerate, however are very common. The largest are approximately 4 feet in diameter but most of them are much smaller. Doleritic fragments are found on outcrops of metamorphic rocks, and fragments of these rocks are found on outcrops of dolerite; but neither kind, even close to contacts, is abundant. These fragments are glacial erratics. They were not dropped by icebergs or sea ice, as they extend above the marine limit. They are not significantly more weathered than erratics in the Dundas area. No glacial striations or polished rock were observed. No small roches moutonnées were seen, and only one or two doubtful examples of large roches moutonnées were noted. Near the summit of the island are several small outcrops which were truncated, planed, and smoothed by glacial action. The erratics and the truncated surfaces prove that the island was overrun by glacial ice whose source was not local (Paterson, 1951, pp. 31–43). That it was ice from Greenland and not from Ellesmere Island which glaciated the Carey Øer is indicated by the following: (1) Rocks identical to the sedimentary erratics on Nordvestø are found *in situ* in the Dundas area, on Saunders Ø, and presumably on the ocean floor between the mainland and the islands. (2) The ice sheet in southern Greenland once extended in places as much as 100 miles beyond its present terminus, as shown by the numerous glacial lakes which extend in the Søndre Strømfjord area from the terminus of the glacier out to the coast. (3) The Carey Øer are closer to Greenland than to Ellesmere Island. (4) The Greenland ice sheet is larger and thicker than any of the ice sheets now found on Ellesmere Island.

No fossiliferous till was seen, although it should be present because the Greenland ice sheet moved over many miles of marine deposits before reaching the Carey Øer. The thinness of the glacial drift and the absence of roches moutonnées suggest that the area was not intensely glaciated. This was perhaps due to: (1) short duration of glaciation; (2) thinness of ice; (3) the protective action of local ice formed before the Greenland ice sheet covered the islands.

The Greenland ice sheet must have been considerably more than 1000 feet thick in the vicinity of Nordvestø during its full-bodied stage. The summit of the island is approximately 900 feet above sea level, and Baffin Bay, only 6 miles south of the island, is 1800 feet deep (*U. S. Navy Dept. Hydrog. Office*, 1953). With such a thickness, the ice sheet at the full-bodied stage must have extended many miles beyond the islands.

No evidence was found of local glaciation either before Nordvestø was covered by the Greenland ice sheet or after its retreat from the island. However, whenever the island was not covered by the Greenland ice sheet and when the snow line was 300 feet or more below the summit of the island, local glacial ice would have been present. This condition probably occurred during the advancing stage of the Greenland ice sheet, and the presence of perennial snow fields on the island at the present time suggests that it may have occurred even during the retreating stage of the Greenland ice sheet.

It is not known for certain when Nordvestø was first deglaciated. Krinsley (Davies *et al.*, 1963, pp. 56–57) collected shells from marine till on Saunders Ø (fig. 1). They were dated by the radiocarbon method and found to be more than 32.000 years old. The area where the shells were collected is about 55 miles nearer the coast and the Greenland ice cap than is Nordvestø. This island was therefore deglaciated before Saunders Ø and more than 32.000 years ago.

The presence of glacial striations and roches moutonnées around Dallas Bugt, Inglefield Land, of glacially-planed surfaces on the southwest side of Marshall Bugt, Inglefield Land, and of glacial striations around Rensselaer Bugt, Inglefield Land, all associated with drift only slightly weathered, proves that during the full-bodied stage of the Wisconsin glaciation the Greenland ice sheet filled part of Nares Sound. The fact that the Greenland ice sheet extended out to and beyond the Carey Øer at about the same time suggests that Nares Sound during the full-bodied stage of the Wisconsin was probably completely filled with the Greenland and Ellesmere Island ice sheets.

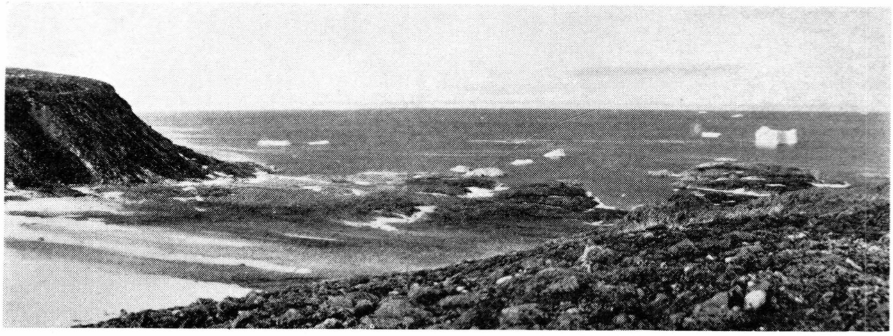

Fig. 5: View over the river valley on the northern part of Nordvestø showing the raised beaches found in the bottom of the valley. Phot. B. FRISTRUP, 28/7 1965.

RAISED BEACHES

The presence of raised beaches on Nordvestø, Mellemø and Isbjørneø was first reported by WORDIE (1938, pp. 394–395, 413). During the authors' visit raised beaches were observed at several localities on Nordvestø. They extend up to 190 feet above sea level (average of 3 altimeter readings) in the lower part of the valley that terminates on the north side of the island (fig. 5). The highest beach in this area was not seen because when the area was visited on July 29, 1965 a snow patch extended inland from the uppermost observed beach and concealed still higher beaches. Extensive well-developed raised beaches are found on the east side of the island, particularly in the area near the mouth of the river which reaches the ocean on this side. Beach gravels 200 feet above sea level (average of 6 altimeter readings) are found here, and gravels which are either marine or glaciofluvial are found approximately 30 feet higher. Unidentified marine shells were found up to 20 feet above sea level in these beach deposits. The highest beach seen is located in the valley which terminates on the southern side of the island. Here well-rounded boulders extend up to 265 feet above sea level (average of 3 altimeter readings), above which are found subangular blocks. The excellence of the rounding, the abrupt change from round-stones to subangular blocks, the absence of a terminal moraine, and the uniform valley gradient prove that the round-stones are marine rather than glaciofluvial.

The raised beaches found on Mellemø extend up to approximately 170 feet above sea level (fig. 6), while those on Isbjørneø are reported by WORDIE to extend up to 140 feet or more (WORDIE *op. cit.*).

The highest marine deposits on Saunders Ø, which were studied by KRINSLEY (DAVIES *et al.*, 1963, p. 56), are 125 feet above sea level.

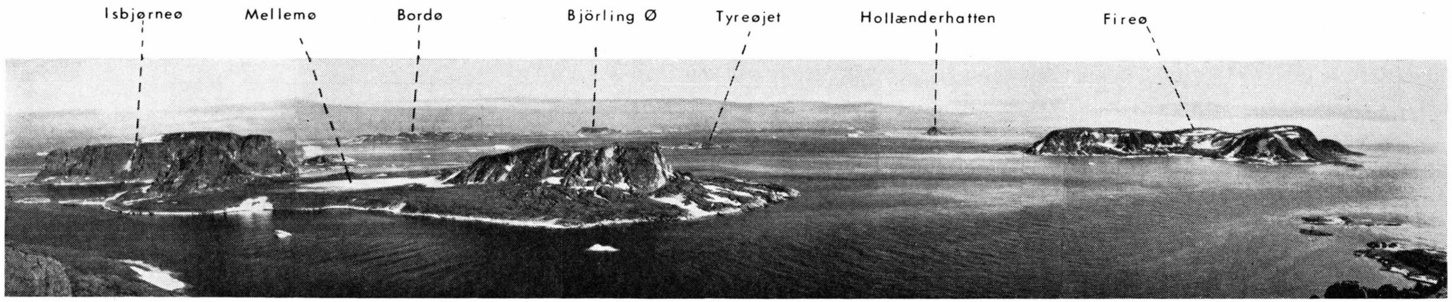

Fig. 6: View from Nordvestø of the Carey Øer group. On Mellemø raised beaches are clearly seen on the flat land surface between the two peaks. Phot. B. Fristrup, 28/7 1965.

The highest beach measured by the writers on Saunders Ø is at the northeast end of the island. It is approximately 150 feet above sea level. The marine limit is, however, undoubtedly higher, as an extensive solifluction sheet is found immediately above this beach. Raised beaches 130 feet above sea level (Nichols, 1953, p. 269) and raised marine terraces at least 150 feet above sea level (Davies *et al.*, 1963, p. 59) have been reported from the mainland.

PERIGLACIAL FEATURES

The permafrost is only a foot or so beneath the surface in places. Its presence enables water to collect, during the summer season, around boulders on sloping ground near cliffs. Without permafrost the water could not collect, but would drain away. Frost mounds are ubiquitous. They are commonly 10 feet across and about 1 foot high, and are composed of finer material than is found immediately around them. Scores of solifluction lobes were seen, some of them 30–40 feet across with terminal clifflets up to 3 feet in height. The volume of solifluction deposits on the island is small, however, due to the thinness of the till. Frost furrows are found on the bare elevated beaches and were also seen on ground covered with a thick mat of vegetation. In places, talus has accumulated beneath cliffs. Frost shattering is very common; it affects both bedrock and glacial transported fragments, the igneous rocks as well as the metamorphic.

Very thick (4 feet or more) peat deposits of the palsa type were found at several places near the edge of the summit. A dense accumulation of black lichens covers the rocks in most places, whereas the rocks immediately adjacent to the larger snow-banks are lichen-free. These snow-bank trimlines can be easily distinguished because the lichen-free rocks are light in color and the lichen-covered ones much darker. An excellent example is found in the valley which terminates on the east side of the island. When the area was visited on July 28, a snow-bank was present on the north side of the valley a few hundred yards from its terminus. The rocks on the north wall of the valley were lichen-free for approximately 30 feet above the snow-bank. Similar occurrences have been noted on the mainland (DAVIES *et al.*, 1963, p. 65). It is not known whether these trimlines are due to a recent amelioration of climate or to the seasonal variation in snow-cover. The problem merits consideration.

CONCLUSIONS

1. Only Precambrian metamorphic and igneous rocks are found on the islands.

2. The islands resulted from the submergence of an uplifted dissected late Pliocene – early Pleistocene erosion surface.

3. Nordvestø and presumably all the other islands were glaciated.

4. The Nares Sound between Ellesmere Island and Greenland was probably completely filled with glacial ice during the Wisconsin.

5. The marine limit on Nordvestø is approximately 265 feet above sea level.

6. Frost cracks, solifluction lobes, frost mounds, frost-shattered rock, talus, permafrost, and snow-bank trimlines are common.

Acknowledgements

Through the courtesy of the *Danish Government* and the facilities of the *U. S. Army*, *Air Force*, and *Navy*, the writers did three days of field work on Nordvestø between July 28 and August 3, 1965. These notes are based on this field work. Dr. CHARLES E. STEARNS read the manuscript and made many suggestions for its improvement. Mr. OLE JØRGENSEN, the Mineralogical and Geological Institute, Copenhagen, has kindly examined the collection of rock samples and determined their mineralogy. Mrs. RAGNA LARSEN of the Mineralogical and Geological Institute, Copenhagen, prepared one of the figures for the text.

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