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[1]Nettleton, L. L. 1940. Geophysical prospecting for oil. New York: McGraw-Hill, pp 51-62.

[2]Crary, A. P., R. D. Cotell, and J. Oliver, 1952. Geophysical studies in the Beaufort Sea, 1951. Trans. Am. Geophys. Union, 33:211-16.

[3]Crary, A. P., and N. Goldstein. 1959. Geophysical studies in the Arctic Ocean. A.F.C.R.C. Geophys. Res. Pap. No. 63, A.F.C.R.C. TR-59-232(1), Vol. 1, pp 7-30, 183-218.

[4]Hunkins, K. 1962. Waves on the Arctic Ocean, J. Geophys. Res., 67:2477-89.

[5]LeSchack, L. A. and R. A. Haubrich. 1964. Observations of waves on an ice-covered ocean, J. Geophys. Res., 69:3815-21.

[6]Church, P. E. 1962. Pers. comm.

[7]Thiel, E., A. P. Crary, R. A. Haubrich, and J. C. Behrendt. 1960. Gravimetric determination of ocean tide, Weddell and Ross Seas, Antarctica, J. Geophys. Res., 65:629-36.

RECENT CHANGES OF SEA-LEVEL ALONG THE NORTHEAST COAST OF BRODEUR PENINSULA, BAFFIN ISLAND, N.W.T., CANADA

Introduction

During the summer of 1962 a survey of Recent changes of sea-level along the northeast coast of Brodeur Peninsula was carried out between 73°38′ and 73°48′N. and 84°15′ and 85°17′W. (Fig. 1). A preliminary examination of aerial photographs indicated an uplift of the land, which is assumed to have been caused by isostatic recovery after the deglaciation of the peninsula.

Brodeur Peninsula is the most northwesterly land area of Baffin Island. Its northeastern side consists of a plateau of horizontally bedded limestone, which lies between 1,100 and 1,800 ft. above sea-level. The plateau is bounded by steep cliffs that in some instances plunge directly into the sea, but that elsewhere are separated from the shore by a rock bench. The region is dissected by two major rivers, the valleys of which form broad embayments in the plateau, and by numerous small streams. Two types of coastline, relevant to the present study, can be recognized. Where the coastline is cliffed, there is little evidence of the Recent uplift. The major river valleys, on the other hand, probably formed fiord inlets during the earlier stages of the uplift and raised strandlines and river terraces are consequently well developed there.

The aims of the study were to assess the amount of uplift as shown by the postglacial marine limit, to determine whether the uplift has been continuous, or whether it has been interrupted by still-stands, and to establish whether the peninsula has been warped during this period of uplift. It proved impossible during only one season to separate the Recent world-wide eustatic rise of sea-level from the more localized uplift of Brodeur Peninsula. Therefore, the altitude of the highest marine features will provide only a minimum figure for the amount of uplift.

Field methods

Two broad categories of evidence were used in this study. First, raised strandlines were identified and their altitudes accurately measured. Identification was based on the lithology and faunal content of unconsolidated marine deposits resting on the strandlines and

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on the position of the strandlines in relation to the coastline. Second, river terraces found in the major valleys were examined. Their altitudes were plotted against the river long profiles and an attempt was made to link them with the raised strandlines. Fluvial terraces were recognized by their occurrence in river valleys and from the lithology of deposits found on their surfaces. Further, since fluvial terraces mark former river beds, they increase in height upstream in contrast to marine terraces, which are horizontal in a longitudinal direction. This characteristic aids in distinguishing the two types.

All altitudes were referred to a datum bench mark, which was set at approximate mean sea-level, determined by observing the tidal range in Lancaster Sound and Admiralty Inlet over a number of days. The error of this datum is estimated to be not more than 2 ft. Height measurements were made from the bench mark with a Wild N. 10 level and a Paulin altimeter. In the following sections an asterisk appended to a name denotes that the name is not official, but used here for ease of reference.

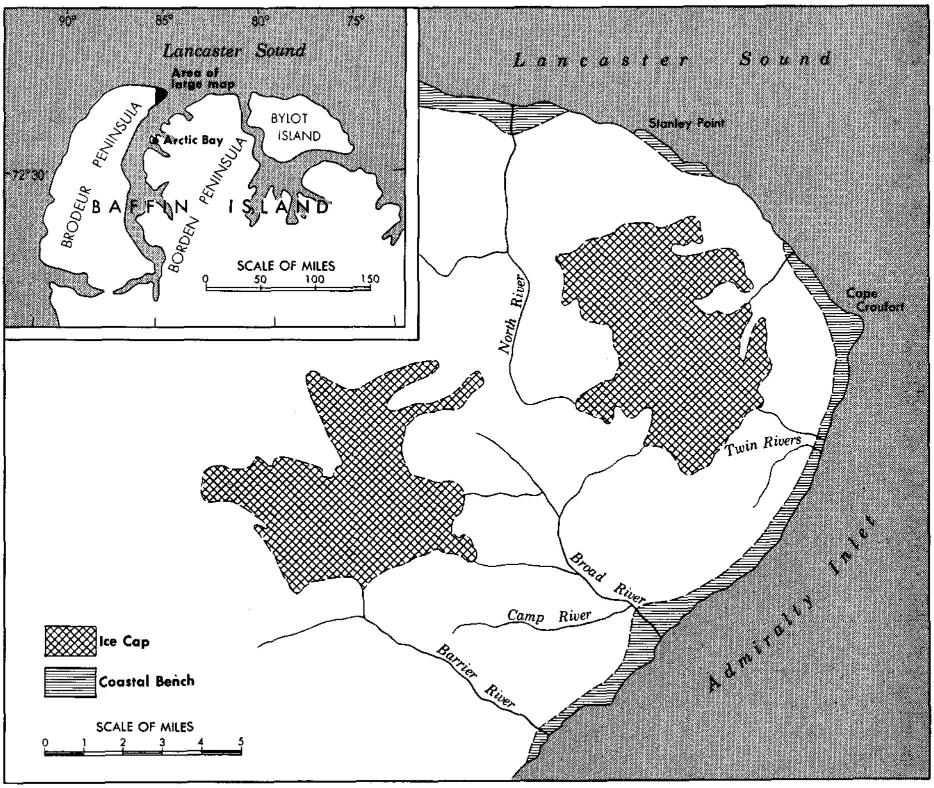

Fig. 1. Northeast Brodeur Peninsula

Field evidence

*North Valley**

In North Valley* (Fig. 1) strandlines are well developed up to 190 ft. above sea-level and fragments of *Hiatella arctica* are distributed throughout the marine deposits. Above 190 ft. the strandlines become more fragmentary but can be traced to an altitude of 297

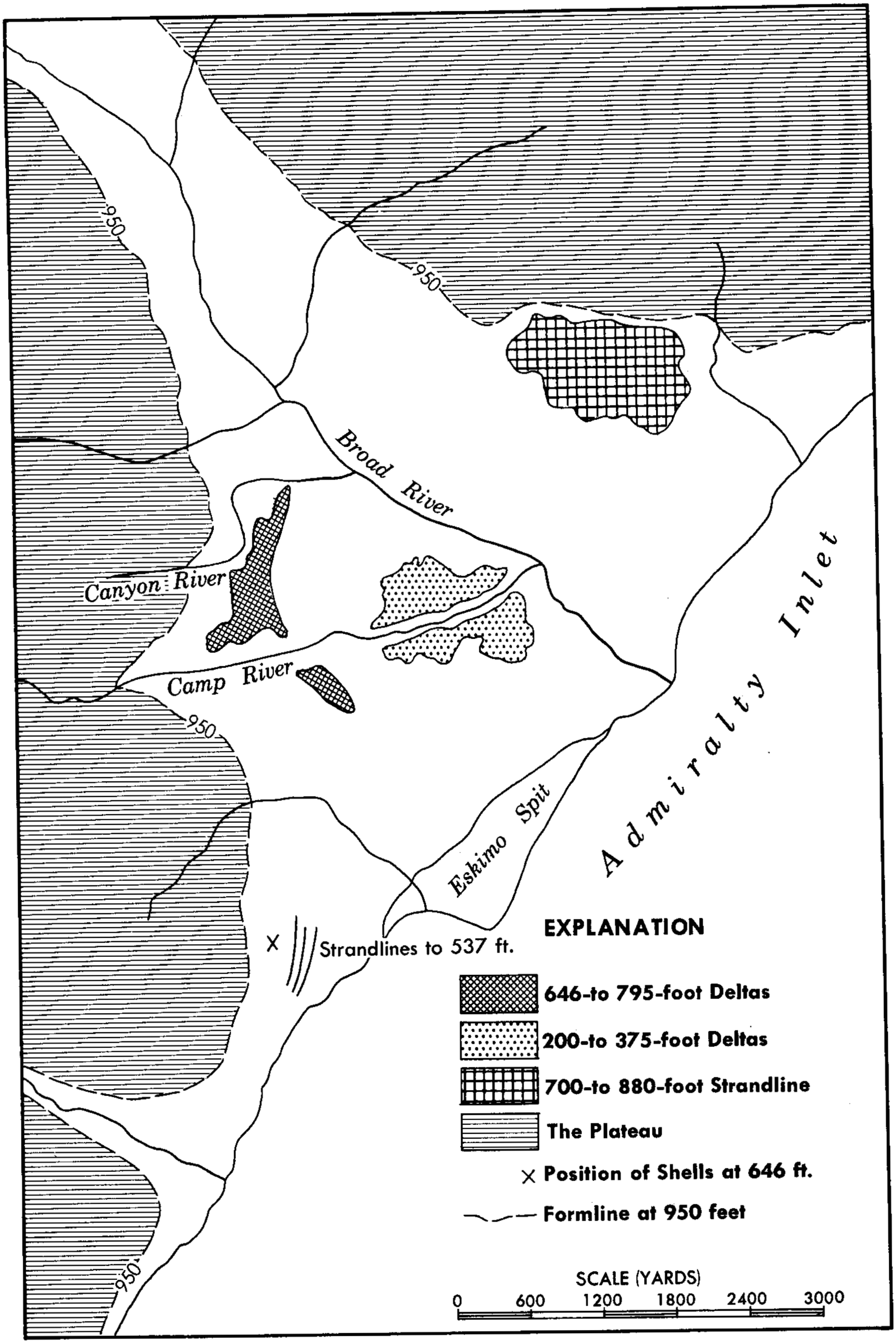

Fig. 2. Broad Valley*.

ft., with shell fragments occurring up to 278 ft. above sea-level. The strandlines terminate 880 yards inland against a wave-trimmed moraine at an altitude of 269 ft. River terraces are abundant in the valley and occur at 8, 14, 18, 30, 38, 45, 56, 69, 78, and 85 ft. above the bed of North River*. The 8-, 14- and 18-foot terraces are cut into bedrock, whereas the remainder are incised into a gravelly fill.

*Broad Valley**

In Broad Valley* (Fig. 2) strandlines and marine deltas are well developed to 375 ft. above sea-level, but fragmentary evidence of marine action is also present at greater altitudes. On the north side of the valley a distinctive deposit of round and subangular pebbles, set in a matrix of silt and sand, lies between 700 and 880 ft. Shell fragments are mixed with the silt and sand to an altitude of 815 ft. This evidence suggests that the deposit is marine, but it is possible that the shells are not in situ. Dyck and Fyles[1] report that the high-level shells at Eureka were redeposited by a glacier 20- to 28,000 years ago and are not related to the postglacial submergence. The position of the deposit in Broad Valley*, however, indicates that if it had been laid down by a glacier, this glacier would have moved from the interior of Brodeur Peninsula towards the coasts and a glacier moving in that direction would be unlikely to deposit shell fragments. The 700- to 880-foot deposit is therefore considered to be marine. Up-valley the deposit passes into silty ground moraine, and it is apparent that the limited inland extent of this marine deposit can be attributed to a glacier preventing any extensive marine incursion of Broad Valley* at that time.

Other evidence in Broad Valley* bears out the hypothesis that the 700- to 880-foot bench is marine. On the south side of the valley, strandlines rise to 537 ft. above sea-level and shell fragments are present at most levels. However, shell fragments were also observed up to 646 ft., in the loose talus material above the strandlines, and it is assumed that these shells are derived from terrace deposits that have subsequently been destroyed by mass wasting. Therefore, since the shells at 646 ft. form part of a continuous sequence from the present beach and are not an isolated occurrence it seems reasonable to place the marine limit above 646 ft. in this area rather than at the altitude of the 537-foot strandline.

Farther inland deltas of unconsolidated shingle occur on either side of Camp River* between 646 and 795 ft. above sea-level (Fig. 2). No shells were found either on the surface or in the deposits of these features and it is thus impossible to be definite about their origin. However, they are analogous in both position and form to marine deltas observed in the same valley between 200 and 375 ft. Moreover, the grain sizes of the deposits of the 646- to 795-foot deltas are very similar to those of undoubted marine strandlines in the vicinity.

There are thus three lines of evidence in Broad Valley* that suggest marine action at a height exceeding 650 ft. This evidence is not extensive, however, and it is only below 375 ft. in Broad Valley* and 297 ft. in North Valley* that raised marine features are abundant.

Eight fluvial terraces are represented in Broad Valley* between 4 and 70 ft. above the bed of the river. The vertical interval separating the terraces is therefore small and, although cut into bedrock, no terrace is more than 10 ft. wide.

Discussion

The marine limit

There has been little past work on the Recent emergence of Brodeur Peninsula. Blackadar[2] reports the lower limit of perched boulders at 430 ft. above sea-level for Yeoman Island, which certainly suggests the upper limit of submergence. Yeoman Island is approximately 150 miles south of the area considered in this paper. Bird (pers. com.) places the marine limit at 216 ft. on Mount Sherer, on the west coast of Brodeur Peninsula and at 230 ft. in Strathcona Sound, a few miles north of Arctic Bay. The marine limit on the northeast coast of Brodeur Peninsula, which corresponds to the upper limits of submergence reported by Blackadar and Bird, would seem to lie at 375 ft. in Broad Valley* and 297 ft. in North Valley*, since it is only below these heights that evidence of marine action is abundant. If this inference is correct, the fragmentary remains of marine features above 375 ft. in Broad Valley* would date from a period earlier than the Recent emergence.

Other workers in the Arctic have produced evidence of marine action at altitudes higher than the accepted marine limit. For example, high figures have been obtained by Wengerd[3] and Mercer[4] for the upper limit of submergence in Frobisher Bay, but they have been discounted by Ives in a recent review of the marine limit in eastern arctic Canada. Shells have been found at altitudes exceeding the marine limit near Eureka, but radiocarbon dates suggest that they are not in situ.[1] Narwhal bones were reported by Bernier[6] at 1250 ft. on Bylot Island, but Falconer[7], in the most recent determination of the upper limit of submergence close to Bylot Island, places the marine limit at an altitude of 287 ft. at Tay River. The evidence of marine action above 375 ft. in Broad Valley* would seem to fall into the same category. It is therefore possible that there are two distinct series of raised marine features in the Canadian Arctic, the lower relating to the Recent emergence and the higher either to an early stage in that period or to a separate and older emergence.

Since Brodeur Peninsula was depressed by the weight of the last ice sheet, it is probable that the sea entered the main valleys as the ice retreated inland. The world-wide eustatic rise of sea-level following the decline of the Wisconsin glaciation would add to this effect. If some valleys, however, became deglaciated early, the sea would transgress these areas but would not enter those valleys still covered with ice. However, the isostatic uplift of the region would soon lead to emergence and the marine limit will occur at higher altitudes in those valleys deglaciated early, than in the other valleys of the region. Therefore, if the high-level marine features in Broad Valley* date from an early phase of the recent emergence, it is likely that Broad Valley* was deglaciated earlier than other parts of the region. There is evidence to support this hypothesis, for the upper limit of abundant marine action lies at 297 ft. in North Valley*, but at 375 ft. in Broad Valley*. It has already been indicated that the strandlines in North Valley* terminate against a wave-trimmed moraine and it is probable that the ice body, which formed this feature prevented a marine incursion of North Valley* until sea-level had fallen to 297 ft. above its present altitude. Broad Valley* apparently became icefree earlier as there is no evidence of glaciation below 375 ft. from the coast to Canyon River*. If deglaciation occurred extremely early in Broad Valley* and if uplift had been taking place while the other valleys were still covered by ice, a similar explanation could account for the high-level marine features.

The second hypothesis that the high-level marine features in Broad Valley* are related to an older emergence is merely a suggestion since the shells at 815 ft. have not been dated. However, if the shells in the talus material at 646 ft. in Broad Valley* are derived from strandlines that have been destroyed by mass wasting, it is likely that there has been a long period of erosion since their deposition. Moreover, the degree of weathering on these shells and on those at 815 ft. is much greater than on the shells found below 375 ft. and also suggests that the former may date from an earlier period. Further field work is necessary before the problem can be resolved.

This discussion bears on the glaciation of the northeastern part of Brodeur Peninsula. If the high-level marine features date from an emergence older than the Recent uplift, the region has probably never been extensively glaciated since that time, for it is unlikely that the 700- to 880-foot marine deposits in Broad Valley* could have survived a widespread glacial advance. If, on the other hand, these deposits date from an early period in the Recent emergence, the small ice cap 3 miles north of

Broad Valley* has probably been relatively stable since then, provided it dates from the last glaciation. This conclusion can probably be extended to the other small ice caps in the region.

The nature of the uplift

In assessing the nature of the Recent uplift of the region, greater emphasis must be placed on bluffs, terraces, and strandlines cut into bed rock than on similar features formed of unconsolidated material. However, rock benches cut by marine agencies during the postglacial period can necessarily cover only a small area owing to the time factor involved. The extensive rock platforms, sloping away from the plateau edge and occurring between 10 and 150 ft. above sea-level in Broad Valley*, at Stanley Point beach, in the Cape Crauford-Twin Rivers area and in North Valley* (Fig. 1) are therefore not of postglacial marine origin and it is more reasonable to assume a glacial, interglacial, or preglacial age for them. It thus follows that although rock platforms are found around the coast below the marine limit, they do not provide criteria on which still-stands in the relative uplift can be based.

Raised strandlines are extensively developed on each platform but since they are depositional features separated by bluffs a few feet high, it is unlikely that any major still-stands have occurred during the uplift. Moreover, it is impossible to trace a single strandline throughout the region. A similar conclusion is suggested by the river terraces in North* and Broad* valleys. There is never more than a 9-foot vertical interval separating any two terraces and although the terraces in Broad Valley* are cut into bed rock they do not exceed 10 ft. in width.

Eskimo Spit* (Fig. 2) indicates that uplift is still in progress or has ceased only recently. Its height decreases to the south from an altitude of 22 ft. to 4 ft. above sea-level, when it grades into the contemporary beach. Most of the spit is therefore fossilized. The recurved ends suggest that it has grown in a southwesterly direction and since each recurved end developed at sea-level, it is apparent that uplift was taking place while the spit was developing. As the spit is at present growing towards the south, it is likely that uplift is still continuing or has stopped very recently.

Since all the raised strandlines are depositional features and since the only extensive rock benches along the coast are glacial, interglacial, or preglacial in age, it was not possible to determine whether any warping has occurred during the uplift of the northeastern part of Brodeur Peninsula.

Conclusions

The Recent uplift of the northeast coast of Brodeur Peninsula is attributed to isostatic recovery following the deglaciation of the area. Two distinct series of raised marine features are present. The lower, up to 375 ft. above sea-level, date from the Recent emergence. The higher, up to 880 ft., were formed as a result of an older emergence or because of an early retreat of the ice from Broad Valley* during the Recent deglaciation. No major period of stability occurred during the uplift of the area, although minor still-stands are indicated. Evidence was found in the landscape that suggests that uplift is still continuing or has ceased only recently. It is also suggested that the small plateau ice caps have been relatively stable in the recent past.

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[1]Dyck, W., and J. G. Fyles. 1963. Geological Survey of Canada radiocarbon dates I and II. Geol. Surv. Can. Pap. 63-21, pp. 9-10.

[2]Blackadar, R. G. 1956. Geological reconnaissance of Admiralty Inlet, Baffin Island, Arctic Archipelago, N.W.T. Geol. Surv. Can. Pap. 55-6, p. 22.

[3]Wengerd, S. A. 1951. Elevated strandlines of Frobisher Bay, Baffin Island, Canadian Arctic. Geog. Rev. 42:651.

[4]Mercer, J. H. 1956. Geomorphology and glacial history of southernmost Baffin Island. Bull. Geol. Soc. Am. 67:553-70.

[5]Ives, J. D. 1963. Marine limit in eastern arctic Canada. Geog. Bull. 19, pp. 117-21.

[6]Bernier, J. E. 1910. Report on the Dominion Government Expedition to the Northwest Waters and Arctic Archipelago of the D.G.S. "Arctic" in 1910, p. 77.

[7]Falconer, G. 1962. Unpublished field report, Geog. Branch. Cited in ref. 5.

Note on cover picture

The large iceberg of which a part is shown in the cover picture had drifted into Slidre Fiord shortly before the U.S.C.G. Icebreaker *Westwind* arrived in August 1953 on its resupply mission. The personnel of the weather station Eureka felt that this large iceberg, if grounded nearby would assure them their water supply for the coming winter. On their suggestion Capt. Currie made a gallant, if futile, attempt to move the iceberg, as shown in the frontispiece, which also gives an indication of the size of the iceberg, of which about one-half is out of the photograph. The only effect of the captain's endeavours was to knock off some pieces of ice.

The iceberg, which had probably come from one of the glaciers that calve into Greely Fiord, kept on drifting back and forth, until it apparently grounded and later froze in some 3 miles (5 km.) up the fiord from the station.

Shortly after the turn of the year strains, perhaps set up by tides, caused it to split into three pieces, two large ones of about equal size, which tilted towards one another, and a small one, which rolled over. The cover picture shows a formerly submerged part of the small piece and in the right background the top of one of the large pieces, which is about 60 ft. (18 m.) above the level of the fiord ice.

The ice face in the foreground shows well-developed, closely spaced fluting. This was probably the result of differential thawing, caused by variations in the crystal structure of the serial layers that make up the mass of the iceberg.

When the smallest piece rolled over it broke up the surrounding fiord ice and lifted a number of pieces of it out of the water. Somehow they came to rest in horizontal attitudes on shelves of the iceberg that had been under water. They made it easy to measure the thickness the fiord ice had attained at the time of the upheaval. This was about 4 ft. (1.2 m.) and is rather close to the average for that time of year in spite of the rather thick cover of snow of about 30 in. (76 cm.) that blanketed it. This provided a certain amount of insulation and could have retarded the growth of the ice.

The snow cover consists of three distinct layers. A bottom layer of not very clean snow, about 9 in. (23 cm.) thick, is followed by a centre layer, almost 12 in. (30 cm.) thick, consisting of snow mixed with a large amount of silt that had been blown off the adjacent land and gave it a brownish colour that appears almost black in the photograph, and a top layer of rather clean snow, around 9 in. (23 cm.) thick.