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A RECONNAISSANCE OF THE QUATERNARY GEOLOGY OF EASTERN NORTH GREENLAND

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The aim of the field work in 1979 was to provide a stratigraphic framework which, together with later air-photo interpretation, will make possible the drawing of a 1:500 000 Quaternary map of the area. We concentrated our work on localizing and dating the outer limit of maximum ice cover, and on determining when glaciation started, and at what time the present distribution of ice was achieved. However, much work was also done on the pattern of isostatic readjustment and, in easternmost Peary Land, investigations were made on a *c.* 100 m thick sedimentary sequence of pre-Holocene age at Kap København. Figure 43 shows the area and place names mentioned in the text below.

Earlier studies

The study of Quaternary geology in this region was initiated by Lauge Koch during the Second Thule Expedition 1916-18 and the Bicentenary Jubilee Expedition 1921 (Koch, 1928). Quaternary studies were also made during the Danish Peary Land Expedition 1947–50 (Troelsen, 1952; Laursen, 1954), during a series of American air reconnaissances in the 1950s (Davies, 1961; Krinsley, 1961), and later by geologists working with GGU (Dawes, 1970; Christie, 1975; Weidick, 1976a, 1977, 1978). Pollen diagrams from the interior part of Independence Fjord were published by Fredskild (1969, 1973).

Glaciation and deglaciation

From the observations he made during his sledge journey Koch (1928) concluded that the ice age glaciation in the region comprised two elements: (1) an extension of the Inland Ice, which then filled Independence Fjord and reached into southern Peary Land, and (2) a dynamic independent ice cap covering northern Peary Land and Johannes V. Jensen Land. Remnants of this northern ice cap now exist as small ice caps in the area, the largest being Hans Tavsens Iskappe.

The Inland Ice had its north-eastern margin near the mouth of Independence Fjord where Koch (1928), in the snow covered land on southern Herlufsholm Strand and at Kap København, thought to recognize systems of large terminal moraines running in a direction more or less perpendicular to that of the fjord. These moraines were also observed, later, by Davies (1961). This view of the extent of the ice cover was later supported by Troelsen (1952) who, from a study of erratic boulders, concluded that the Inland Ice had reached its northern limit along a line that runs parallel to, and 35 km to the north of, Independence Fjord, where it merged with the northern ice cap. Detailed studies of the relation between the Inland Ice and the northern ice cap at their junction in the interior Independence Fjord area have been carried out by Christie (1975) and Weidick (1976).

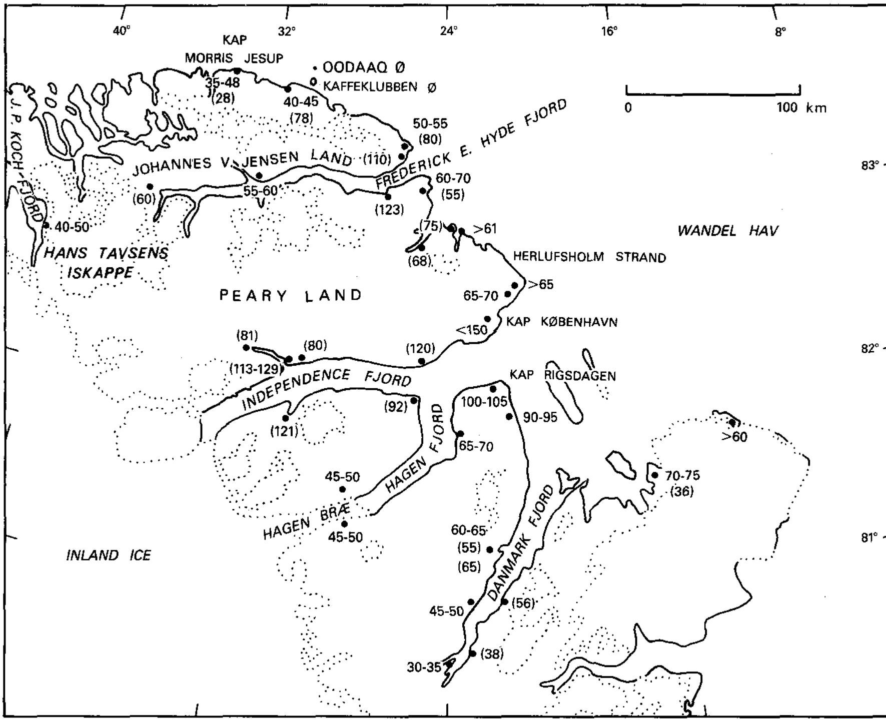

Fig. 43. Marine limits in North Greenland. Compiled from our own observations and those of Troelsen (1952), Davies (1961 – 'marine terraces'), Krinsley (1961) and Weidick (1977). The values quoted from earlier authors are shown in brackets.

Our observations support the concept of two distinct ice accumulations in the region at the time of maximum ice coverage; however, some of the terminal moraines recorded by Koch (1928) and Davies (1961) are not moraines, but thrusted floes of non-glacigene sediments (see below), and an outlet from the Inland Ice has indeed extended beyond the limits marked by Koch (1928) and covered northern Herlufsholm Strand where it formed an ice shelf that extended into the Wandel Hav. Erratics of southerly provenance, such as Proterozoic quartzites and dolerites, and crystalline rocks from the underlying basement, occur abundantly along the coast of eastern Peary Land. They are found up to the northernmost parts of the Herlufsholm Strand foreland, and as high as 400 m above sea level in the mountains immediately west of there. Lateral deposits from this ice occur along the eastern slopes of these mountains, and low hills of glaciofluvial sediments and till, indicating temporary ice front positions, are found on southern Herlufsholm Strand and to the west of Kap København. These reflect stages during the recession of the glacier in Independence Fjord.

The till cover, erratics, moraines and glaciofluvial deposits along the north coast of Johannes V. Jensen Land and eastern Peary Land show that here, also, an ice shelf existed, which was formed by the merging of outlet glaciers from the northern ice cap. These glaciers filled the major valleys along the north coast and the fjords of eastern Peary Land. The main outlet was the glacier in Frederick E. Hyde Fjord. This ice shelf reached a minimum thickness of 200–300 m over the coastal foreland.

During the disintegration of the ice shelves and the following general deglaciation, the ice flow became increasingly controlled by the major drainage basins and especially by the fjords. Lateral and terminal moraines, kame terraces and drainage channels along the fjord sides reflect this process. The glaciers eventually receded behind their present frontal positions, for we found marine sediments 20 km behind the front of Hagen Bræ. Davies (1961) suggested even more pronounced withdrawals. We have not been able to confirm the later readvance of fjord glaciers in the region that was described by Troelsen (1952) and Weidick (1972).

Isostatic rebound

Observations by earlier authors and by us relating to the altitude of marine limits in the region have been compiled in fig. 43. The 'marine terraces' reported by Davies (1961), though not claiming to represent marine limits, have been included because of the additional information they may give; however, some of the terraces visited by us were clearly of non-marine origin. Our own estimates are based on the occurrence of undisturbed non-marine sediments bordering on lower beach ridges and marine deltas, often associated with fossiliferous silt.

As pointed out by Weidick (1978), the interpretation of the data in terms of uplift patterns is complicated by the fact that the raised marine features reflect at least two distinct cycles of isostatic depression and rebound. The early, pre-Holocene cycle is represented by glacier disturbed marine sediments which reach altitudes of more than 100 m along Independence Fjord, notably in the area at Kap København; the 'marine terraces' observed by Davies (1961) at the mouth of Frederick E. Hyde Fjord could be referred to this category also. The Holocene rebound seems to have been less significant, but an interpretation of the data must await the results of absolute dating of shell material collected throughout the region.

The sedimentary sequence at Kap København

A sequence of unconsolidated sediments occurs, below till cover, in areas at the mouth of Independence Fjord on its northern shore. The most extensive exposures were observed in snow corries, at a site four kilometres south-west of Kap København, where the sediments attain a thickness of 90 m. A tentative facies analysis of the sediments at this site is given in fig. 44. The lithology and structures indicate deposition in a low energy environment with a rich supply of sediment. This supply was provided from the easily disintegrating sedimentary rocks of the Mesozoic and Palaeozoic Wandel Sea Basin, that constitute the bedrock in the adjacent upland areas.

The depositional environments included coastal lagoons, beaches and areas of sublittoral suspension sedimentation. These show that the entire sequence was deposited from slightly above, to somewhat below, sea level. The sublittoral sediments contain several molluscan assemblages, which reflect changes in the ecological conditions. The fresh water sediments contain abundant organic debris, notably moss remains and twigs, occurring in flasers and

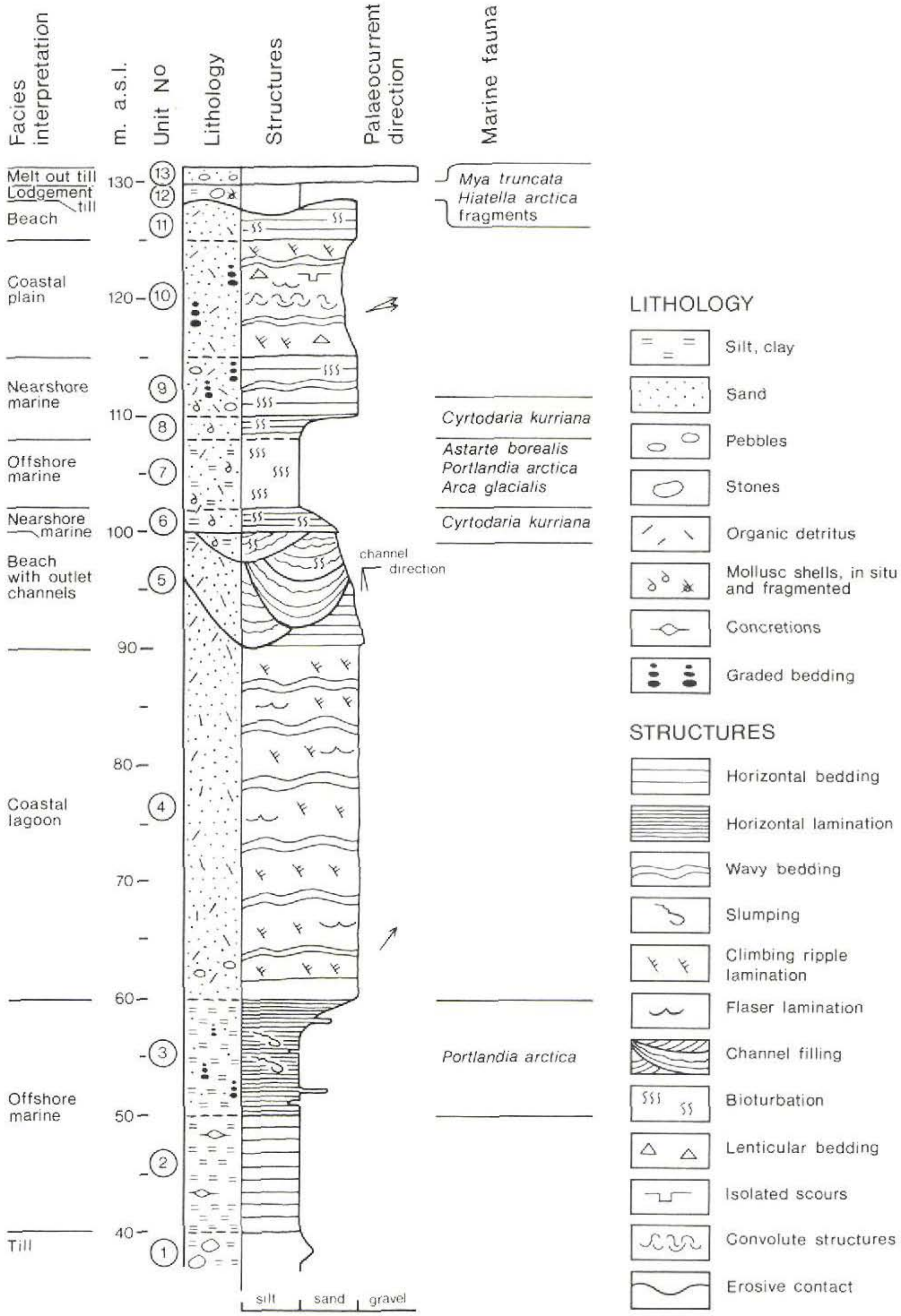

Fig. 44. Section through the sedimentary sequence 4 km south-west of Kap København.

Fig. 45. Ridge formed by a floe of sediments from the sequence at Kap København. At the foot the resistant unit 7 (see fig. 44) protrudes and shows the tilted layering, dipping towards the right, while the upper sandy units have been eroded and covered by till. The ridge is 30 m high. View towards south-west, 5 km west of Kap København.

wavy bedding in beds of 10–20 cm thickness. A preliminary study of the macrofossil content of these layers by B. Fredskild has shown remnants of several species which are now absent from North Greenland: abundant fruits and twigs of *Betula nana*, and a statoblast of the thermophilous fresh water bryozoan *Cristatella mucedo* (B. Fredskild, personal communication), all of which indicate a climate that was significantly warmer than the present. In unit no. 5 (fig. 44) logs of driftwood were found, and a preliminary survey by P. Wagner has shown that these are remnants of conifers of Siberian origin. Presumably it was a piece of driftwood from these sediments that was collected by W. Davies in the same area, and dated to more than 32 000 years BP (sample I-371, Trautman & Willis, 1966).

The sedimentary sequence has been observed in an area covering 10×20 km, and shows many traces of glacier overriding. Most exposures show folds, thrusts and reverse faults. The most impressive type of deformation is imbricated thrust floes which have given rise to a characteristic landscape of parallel, 40–50 m high ridges. These were interpreted as terminal moraines by Koch (1928), Troelsen (1952) and Davies (1961). Exposures show that these ridges are composed of tilted sediments of the same sequence with only a thin cover of till (fig. 45). Anslysis of the structures shows that the deforming force was provided by a glacier in Independence Fjord.

In areas north-east of Kap København marine deposits containing abundant shells of *Macoma balthica* may correlate with the sequence at Kap København. *Macoma balthica* is a boreal species which is now rare in Greenland waters.

The world's northernmost land

In the summer of 1978 members of a surveying expedition from the Geodetic Institute in Copenhagen discovered a tiny island lying 1400 m to the north of Kaffeklubben Ø, which hitherto had been recognised as the northernmost land in the world (Lillestrand *et al.*, 1970). The latitude of the new island is 83°40′23″N (H. Andersson, personal communication). It measures *c.* 50 × 50 m and reaches an altitude of scarcely one metre and has been named Oodaaq Ø. In 1979 we visited the island. It is composed of sorted silt, sand and gravel covered by a veneer of rounded boulders, and is a beach ridge resting on sublittoral marine sediments. The silt contains well preserved *in situ* shells of marine organisms, noteworthy for their thinness. Otherwise these shells rarely survive to be found as subfossils. The shells have been identified at the Zoological Museum in Copenhagen and comprise the following species:

Bryozoa	*Porella concinna* var. *belli* (Dawson)
Gastropoda	*Margarites groenlandicus* (Gmelin)
Bivalvia	*Hiatella arctica* (Linné)
	Lima hyperborea (Jensen)
Polychaeta	serpulidae sp. (gen. et sp. indet.)
Echinoidae	*Strongylocentrotus pallidus* G. O. Sars
	Strongylocentrotus droebachensis O. F. Müller

Although the contemporary fauna along the north coast of Greenland is totally unknown it seems likely that these species all occur in the area at present.

The tiny island forms the northernmost extension of a large, shallow water area with many other small islands; the whole area is, apparently, an abraded till deposit. The largest of the islands is Kaffeklubben Ø which is a ridge 30 m high and 700 m long, running in a direction perpendicular to that of the North Greenland coast. The surface sediments are of the same type as those found on Oodaaq Ø. By analogy with features found in the adjacent coastal area, both islands, lying on the same axis, could be interpreted as the remnants of kames, however Davies' (1961) interpretation of Kaffeklubben Ø as a terminal moraine, deposited by a glacier debouching from valleys in the coastal area, cannot be excluded.

Among the boulders found on the two islands one rock type is especially interesting. It is an andesitic porphyry which is the single dominating rock type on both islands (e.g. Davies, 1961, table 1). In the adjacent coastal areas this type of boulder is very rare, and the distribution pattern suggests that the boulders were not dropped by floating ice, but were transported by a glacier. Acid volcanics are known from only one area in North Greenland, 70 km to the west of Kaffeklubben Ø, where they occur in the Kap Washington Group of sediments and volcanics (Dawes, 1976). The porphyry erratics from the two small islands are not identical with, but very similar to, rock types known from the Kap Washington Group (A. K. Higgins, personal communication); this suggests that glaciers may once have moved towards the north-east, along the north coast of Greenland. This contention finds some support in observations in the coastal area where melt water channels and ice marginal deposits show a general gradient declining towards the east. The sparsity of porphyry erratics in the coastal area could be a result of a seaward push of up-stream ice masses by local tributary valley glaciers.

A minimum date for the deglaciation of the north coast of Greenland is provided by a C-14 date of 8450 ± 120 years BP for shells collected at Kap Morris Jesup (sample K-3287, GGU 223212).

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