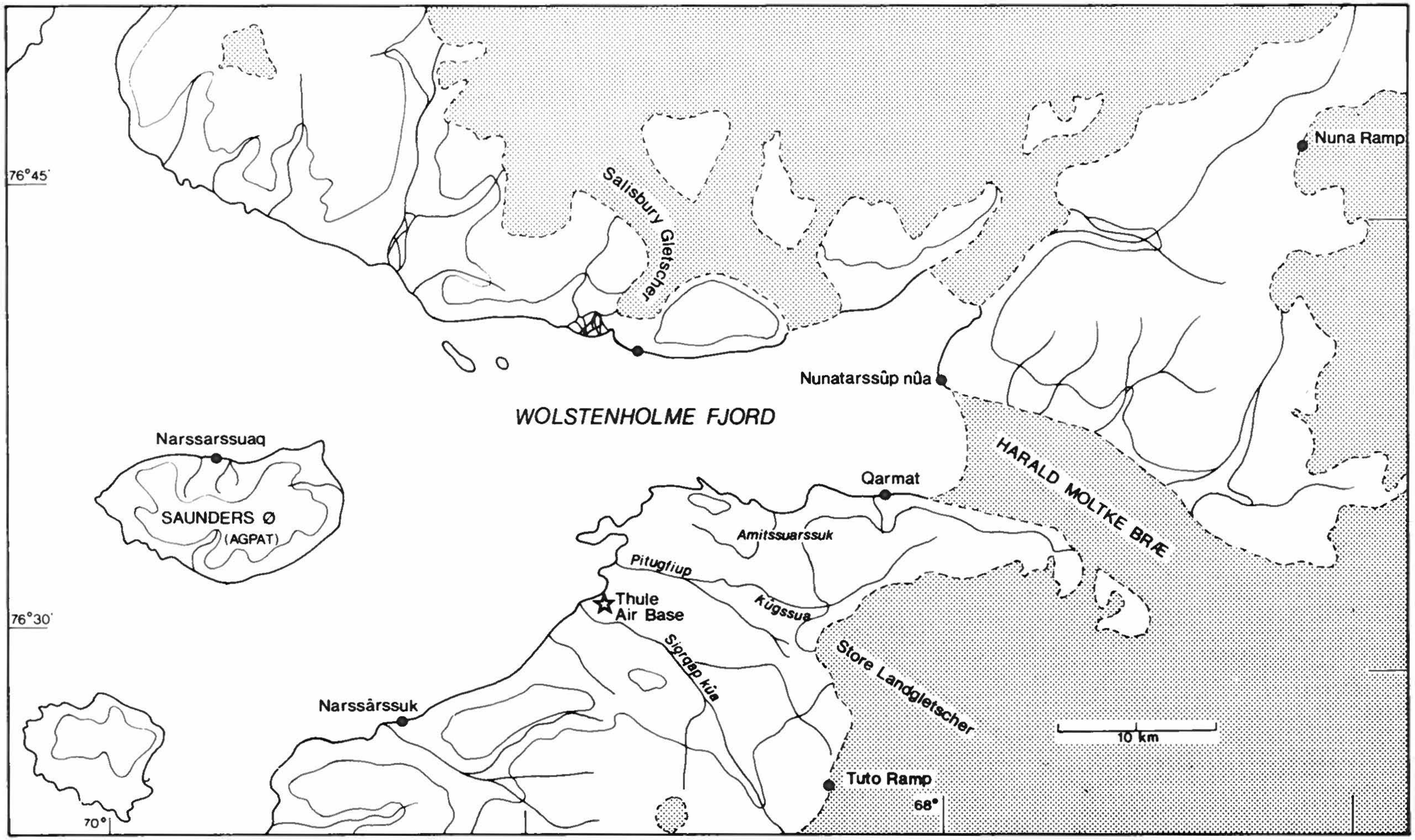


Fig. 1. The Thule area with localities described in this report. Black circles are principal studied sites. Present ice cover is shaded, thin line shows 300 m contour.

The pre-Holocene Quaternary: Lithostratigraphic and geomorphic evidence

MICHAEL HOUMARK-NIELSEN, MICHAEL KELLY, JON Y. LANDVIK and LENNART SORBY

Detailed lithostratigraphic evidence has been obtained from sections excavated in pre-Holocene deposits in three areas: Saunders Ø, Narssârssuk and Qarmat. The geology and geomorphology of the areas surrounding these sites has provided additional evidence.

Saunders Ø

(Michael Houmark-Nielsen and Lennart Sorby)

General site description

The island of Saunders Ø is situated at the mouth of Wolstenholme Fjord, about 20 km west of Thule Air Base (Fig. 1). The island forms a plateau at 300 m above sea-level with steep coastal cliffs. It is built up of Pre-cambrian sedimentary rocks (Davies *et al.* 1963, Dawes *et al.* 1982). A narrow beach is locally present. A thin till cover drapes the plateau with frequent boulders of crystalline rocks, showing that the island has been over-ridden by a glacier from the mainland. An embayment along the north coast at Narssarssuaq has been filled with Quaternary sediments belonging to a system of prograding alluvial fans (Fig. 2). In its western part, Narssarssuaq consists of a plateau at about 30 m above sea-level with raised beach ridges, the surfaces of which dip gently eastwards. An alluvial plain ending in a re-cent beach ridge and originating from two canyons, cuts off the plateau with beach ridges in the eastern area. A 20–30 m high coastal cliff exists along the 800 m long western coast of the plateau (Fig. 3), and reveal moder-ately eastward dipping strata composed of till, glacio-

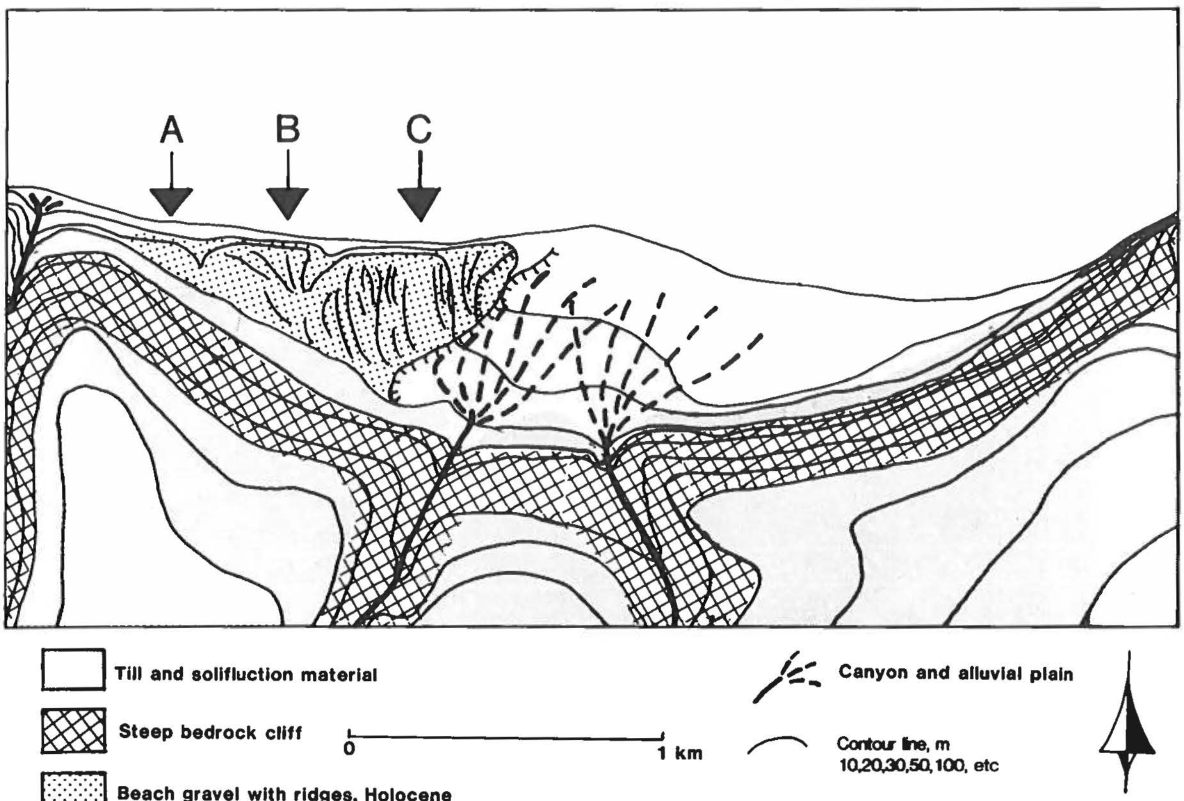


Fig. 2. Quaternary geology of Narssarssuaq, northern Saunders Ø. Letters mark described sections illustrated in Fig. 4. (Topography drawn by computer-assisted air photo stereometry by O. Winding, Geological Survey of Greenland).

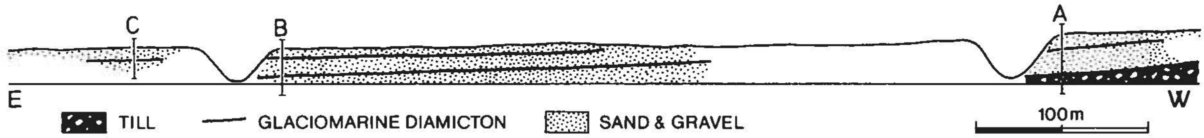


Fig. 3. Narssarssuaq, Saunders Ø, general stratigraphy of the coastal cliff. The section shows three successive transgression-regression cycles, each starting with glaciomarine diamicton or till. Letters mark described sections illustrated in Fig. 4.

marine diamictons and marine sand and gravels, as described in detail below.

Krinsley (1963), who previously investigated the cliff site, concluded that "marine till" is overlain by marine sand and beach deposits with a combined thickness of about 30 m. The upper half of the sequence was ascribed to the Holocene, whereas the lower half gave non-finite C-14 age. Observations by Blake (1975) indicated the presence of two diamict units interbedded and overlain by marine sand and gravel. A lower shell-bearing bouldery till is overlain by a sandy to gravelly coarsening upwards sequence. A thin till bed that overlies these strata was ascribed to the last glaciation. This till bed is covered by another muddy, sandy to gravelly coarsening-upwards sequence deposited during the Holocene. Blake (1975) reported non-finite C-14 ages from shells beneath the upper till bed. The need to reconcile the opposite viewpoints of Krinsley (1963) and Blake (1975) about the genesis of the diamict beds and subsequent glaciation history was one of the major tasks undertaken by the NORDQUA reinvestigation of the cliff.

Field observations

Detailed investigations of the sediments in three sections in the coastal cliff (Figs 2 and 4), and in two complementary sections in erosion valleys perpendicular to the coast, were undertaken. Sections A and C are those investigated by Blake (1975). Seven major sedimentary units, each composed of individual facies or facies associations, have been recognised. Facies associations largely comprise till, glaciomarine ice-rafted diamictons and marine mud, sand and gravels. The coastal cliff was partly snow-covered, preventing full visual correlation between diamict units as pictured in Fig. 3. However, field evidence supported by a number of laboratory analyses suggests the stratigraphic relationship shown on Fig. 4, and described below.

Lithostratigraphy

Unit S1 – This is a diamicton found in the lower part of section A. It could not be investigated in detail because it was covered by scree. The diamicton consists of a muddy matrix packed with stones and boulders primarily of crystalline basement rocks, and is the oldest visible sediment in the sequence (Fig. 3). A glacigenic origin, which is in accordance with Blake's interpretation, is ascribed to this unit because of its massive character with dominating exotic boulders and the lack of *in situ* shells. It was deposited either by melt-out or gravity flow processes from an active or stagnant glacier descending from the mainland towards the east.

Unit S2. – This unit overlies unit S1 and consists of a complex facies association. As a whole this unit is built up of muddy or sandy diamictons interbedded with marine shell-bearing mud and lenticular bodies of sand. A transitional facies at the boundary with unit S1 is thin matrix-supported gravel, grading into gravel with subrounded clasts. The matrix is sand grading to sandy silt with shell fragments.

Above the gravel, the lower part of unit S2 consists of a brown sandy-silty diamicton rich in subangular clasts with low sphericity. The sediment contains only few shell fragments. It is overlain by grey clayey and sandy mud with numerous shell fragments and occasional mollusc shells and a few clasts. It is interbedded with lenses of clay and muddy diamicton also containing shell fragments. Dropstones featuring both bottom and top contact structures (Thomas & Connell 1985), and clasts draped with clay laminae have been found in the sediment.

The upper part of the unit consists of massive beds of silt with clasts laterally grading into silty diamictons, and interlayered with silty diamicton and sand beds. Shell fragments occur mainly in the sand beds.

The clasts in this sediment are a mixture of local bedrock and far transported exotic basement rock types. The facies of unit S2 were deposited by gravity flow processes, rain-out from suspension of marine mud and drop and dump of ice-rafted debris. The overall muddy appearance and the presence of *in situ* shells in combination with ice drop structures, suggests deposition at some depth in a glaciomarine environment with influx of icebergs. This interpretation is contradictory to that of Blake (1975), who apparently combined our unit S2 with the underlying till bed (our unit S1), and described them both as shell-bearing till.

Unit S3. – A thin bed of normal-graded sandy diamicton forms the transition upwards into unit S3. It disconformably overlies unit S2 and comprises a thick sequence of stratified material with inclined alternating beds of clast-supported gravel and stratified sands, dipping about 30° NNE and containing shell fragments. Clasts of local origin totally dominate the material. Towards the top, unit S3 is made up of horizontally bedded sand and coarse gravel. Unit S3 is interpreted as foreset beds in a coarse clastic submarine delta fan. The clasts were probably derived locally through canyons to the west, and mixed with redeposited marine components during delta progradation. As the beds of the growing fan reached wave base, reworking of topset beds into littoral gravels shaped the uppermost part of this unit.

A gully perpendicular to the coast exhibits a complex and muddy diamicton in the otherwise coarse clastic unit S3. It consists of a lower bed of clayey silty diamicton with far-transported clasts and shell fragments. It is conformably overlain by a thin sand bed rich in shells, which in turn is covered by a massive silt, rich in shell fragments and with bladed clasts of local character. Laterally, towards the coast, the diamicton wedges out and is replaced by sand. This subunit is probably a glaciomarine deposit, in its lower part deposited by rain-out of mud from suspension, gravity flows and ice-rafted debris. It

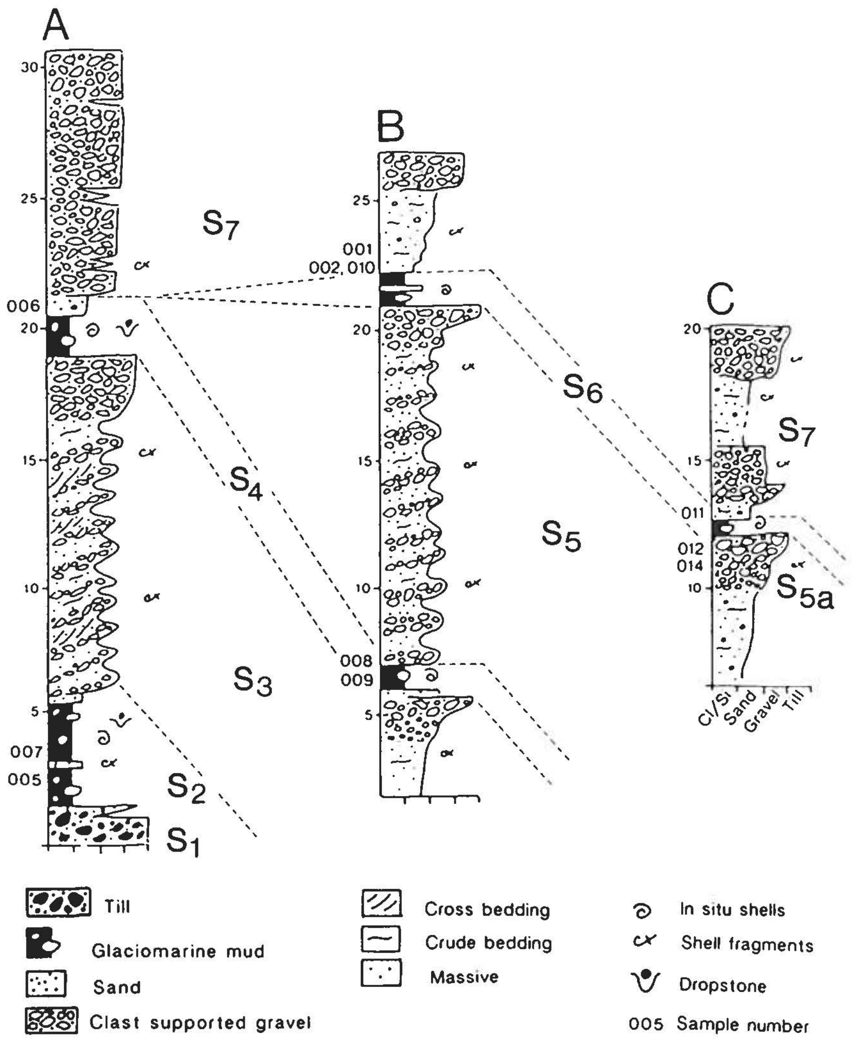


Fig. 4. Lithological sections and correlation at Narssarssuaq, Saunders Ø. Small numbers are m above sea level. Sample numbers refer to samples described in later chapters.

passes upwards into a gravity flow deposit. Unfortunately, the stratigraphic relationship of these sediments to units exposed in the coastal cliff is not fully understood.

Unit S4 – This unit conformably overlies unit S3. It is a horizon of crudely bedded diamicton and shell bearing mud and sand. The diamicton facies is silty with clasts of mainly local origin, although some are far transported. Dropstone structures sometimes occur in connection with clasts. Shell fragments occur in all facies. The unit forms the upper diamicton in section A, and the lower one in section B. It was deposited from gravity flows, rain-out from suspension of marine mud and ice-rafted debris. Sand was deposited by traction currents.

Unit S5. – This unit disconformably overlies unit S4. It consists of a thick coarsening upward sequence of alternating beds of clast-supported gravel and stratified sand. The beds contain shell fragments and dip 15° N. Unit S5 is found in the sections B and C. The interpretation is as for unit S3.

A matrix-poor gravel facies of littoral origin, which is gradually better sorted towards the top, occurs only in section C (subunit S5a), and is characterised by its abundant fragments of *Mytilus edulis* shells which gave a non-finite C-14 age (Blake 1975, 1987). TL-dating indicates that this is the youngest pre-Holocene sediment in the Saunders Ø sequence (see later sections by Funder and by Kronborg, Mejdahl & Sejrup).

Unit S6. – This unit is found above unit S5 in sections B and C. It is a muddy diamicton with mainly local clast material, containing shell fragments and sometimes crudely bedded mud and sand lenses. The diamicton is overlain by homogenous silt and laminated silt and sand. West of section B the unit thins out and is eroded away. This diamicton was described as "till-like sediment" by Blake (1975), and we suggest a glaciomarine origin because of the similarity with the older ice-rafted diamictons (units S2 and S4) in associations and sedimentary features such as dropstone structures, suspension fall-out, gravity flows and *in situ* shells. C-14 dating indicates an Early Holocene age, although TL-dating suggests an older age (Kronborg & Mejdahl, and appendix, this volume).

Unit S7. – This unit constitutes the uppermost facies in all sections and disconformably overlies the units below. It consists of a thick sequence of clast-supported sand and gravel. On the surface of the alluvial plain it forms several beach-ridges. In the poorly exposed section C there seems to be a gradual transition from unit S6 to S7. Shell fragments are frequent, and unit S7 is interpreted as littoral gravel, including both supra- and sublittoral facies.

Interpretation

Unit S1 was deposited by an ice stream originating to the east, filling up Wolstenholme Fjord. The till is provisionally correlated with the heavily soliflucted till that covers the plateau of the island, and signifies the last occasion when glaciers reached Saunders Ø, the Agpat stade (Houmark-Nielsen, this volume). During the melting of this ice sheet, the transitional facies between units S1 and S2 was deposited by melt-out from stagnant or active ice and redeposited by gravity flow processes in a near-shore submarine environment.

Unit S2 was deposited under glaciomarine conditions after melting of the ice on Saunders Ø. Glaciers had retreated eastwards and faunal analyses (Feyling-Hanssen & Funder, this volume) indicate marine conditions as favourable as those of today. Eventually a prograding delta (unit S3) was built out from the island, interrupted however by one or several phases of more distal marine sedimentation during halts in delta progradation. Delta sedimentation ceased and topset beds were reworked into littoral gravels.

Unit S4 represents a renewed transgression phase with sedimentation of glaciomarine mud and ice-rafted debris. Foraminifer assemblages indicate transition from high arctic to less extreme conditions (Feyling-Hanssen, this volume), suggesting proximity of a glacier when the base of this unit was deposited. Sea-level probably stood more than 20 m above present.

This transgression was followed by regression and deposition of coarse gravel by local streams and reworking of marine sediment, which accumulated as submarine fans ending up with littoral gravels, unit S5.

The marine clayey sediments in unit S6, reflect a third transgression followed by regression represented by sandy gravel with beach-ridges, unit S7. TL-dates, amino acid ratios, radiocarbon ages suggest that the sequence in units S6-S7, is of Late Weichselian to Early Holocene age (Kronborg, Mejdahl & Sejrup, and appendix, this volume). The underlying units, S2 to S5, are defined on similar grounds within the Thule aminozone (Sejrup, this volume), TL-dated to the time span 136–69 ka. Consequently the Agpat glaciation (unit S1) was older than this.

Narssârssuk

(Michael Kelly and Jon Y. Landvik)

A complex of Quaternary deposits occupies the low ground at the mouth of the Narssârssuk valley, and extends for some distance along the foot of the bedrock cliffs which bound the southern side of Wolstenholme Fjord (Fig. 5). Good exposures occur in these deposits in low cliffs along the coast. Older deposits and landforms cover the surface of the surrounding slopes and hill tops.

The Narssârssuk upland areas

The plateau areas, which extend up to 300–400 m on both sides of the Narssârssuk valley, are extensively covered with till, and bedrock exposures are rare. Where examined on the north side, the till is predominantly rich in coarse clasts with a sandy silt matrix. Erratic metamorphic rocks are frequent, as well as the local mudstones, sandstones and dolerites. The tills are highly cryoturbated and soliflucted. Weathering of the deposits, however, is only moderate, with granular surface roughening of metamorphic, dolerite and sandstone clasts, some disintegration of coarse gneisses, iron mobilisation and staining of basic rock clasts, and a general shallow oxidation of the deposit.

Relict ice margin features occur around the plateau in the form of benches up to 30 m high and low ridges and channels, all of which are much degraded by solifluction. Along the western edge of the plateau are low boulder ridges and channels (Figs 5 and 6) related to a +400 m thick ice stream in Wolstenholme Fjord.

Lowland areas

North of the Narssârssuk river is a massive body of deposits, extending up to 113 m a.s.l., which partially blocks the mouth of the U-shaped valley. Basically, the deposit consists of the remnants of a terrace 40–50 m above the river, and a major moraine ridge to the north (moraine I, Figs 5 and 7). The terrace surface is covered by sandy tills, and has a gradual slope in the up-valley direction. It exhibits shallow depressions and low ridges interpreted as meltwater channels and thermokarst collapse features. The morphology of this whole body suggests it is an ice-contact complex, formed as a moraine ridge and a kame terrace by a glacier in Wolstenholme Fjord, at a time when the valley was ice-free. On the southwest side of the river, breaks of slope may represent the continuation of this ice marginal deposit (Fig. 5). A second feature that can be related to the presence of ice in the fjord is a discontinuous moraine ridge up to 70 m a.s.l. which parallels the coast (moraine II, Figs 5, 7, 10). We propose to name these features the Narssârssuk moraines.

The deposits forming the main body of the ice contact feature consist of a complex of tills and sorted sediments >50 m thick. Their stratigraphy has not been worked out in detail, but on the steep slope adjacent to the river it appears to consist of five units (a-e, section K, Fig. 8), including an upper and lower series of diamictons alternating with sorted sediments with sands and gravels overlying silts. The lowest unit (d) of the upper diamicton, which outcrops at 65 m above sea-level, is notable in being rich in fragmented bivalve shells and having a matrix of grey clayey silt, in which the silt itself appears to be present as clasts. The unit is interpreted as a till formed from reworked marine silts.

Silts with fragmented shells also floor the flat-lying

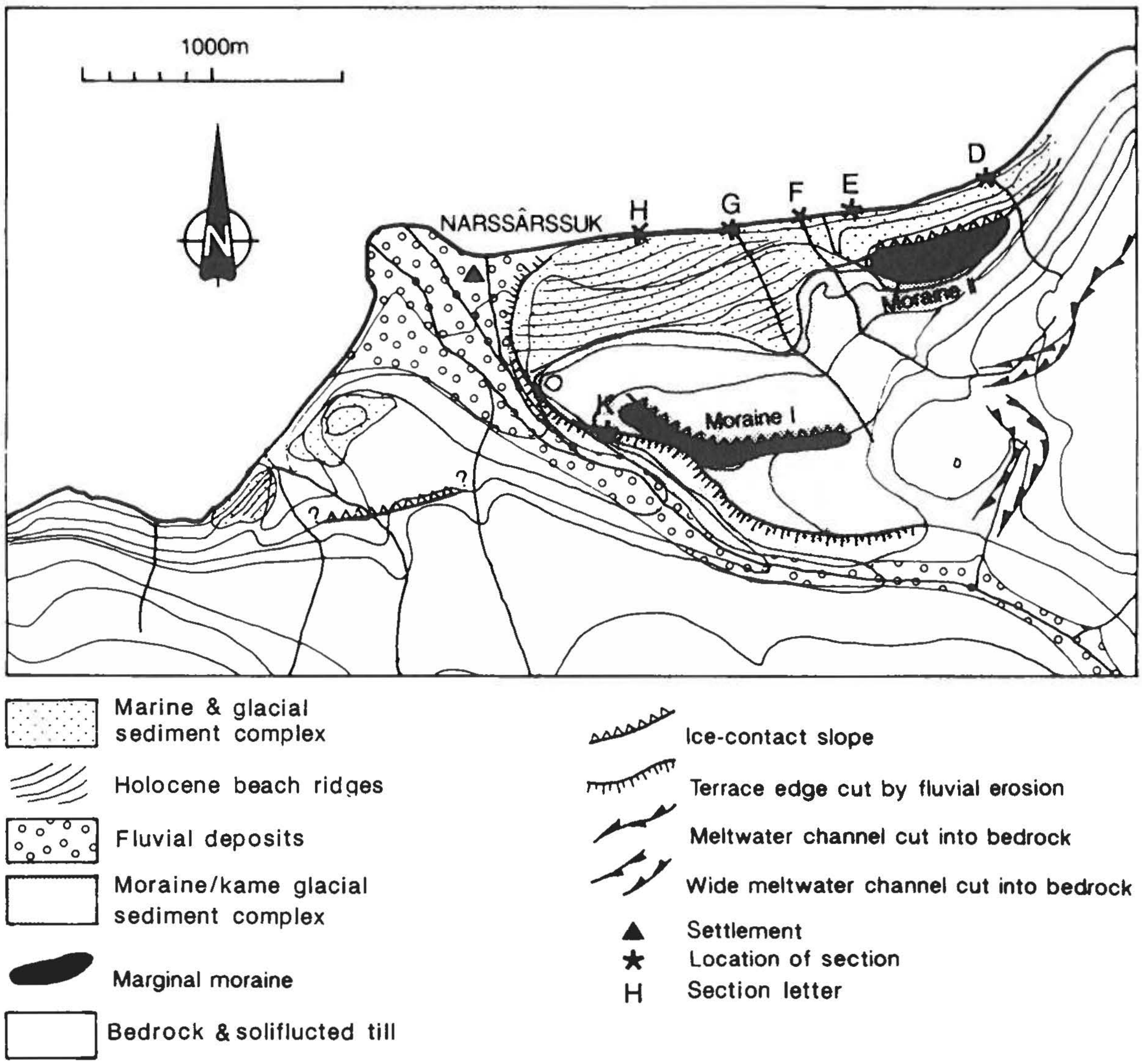


Fig. 5. Map of the Narssârssuk area showing major Quaternary features. Letters refer to sections described in text. Moraines are shown on Fig. 7. (Topography drawn by computer-assisted air photo stereometry by O. Winding, Geological Survey of Greenland).

area at *c.* 50 m a.s.l., below the steep northern side of moraine I (Fig. 5).

The clasts in these tills and gravels are the same suite of rocks as in the plateau tills, and the surface of the deposit exhibits the same degree of weathering. South of the river, exposures at the coast reveal 9 m of shell-free laminated sands with graded bedding, on 4 m of till. These may be proximal glacio-lacustrine turbidites.

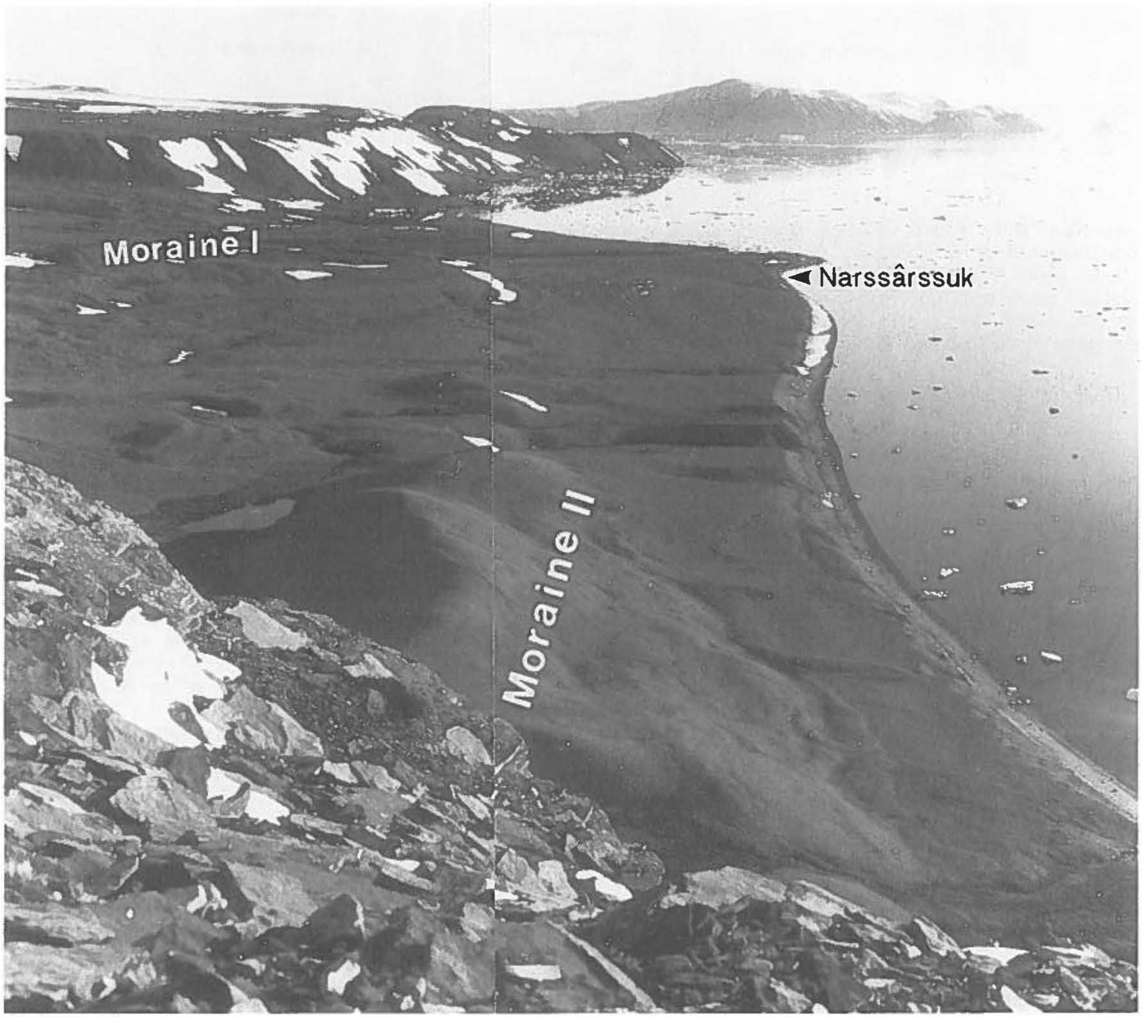
Lithostratigraphy

Exposures along the 2 km of low coastal cliffs show a complex stratigraphy with considerable lateral variation. In the excavated and measured profiles six units (N1 – N6) can be identified (Fig. 8). Most of these main units can be correlated laterally by following their boundaries across poorly exposed ground as breaks in slope and sediment colour changes.

Unit N1. – The lowest unit is exposed at the base of section E; it is a compact, over-consolidated diamicton with many clasts in a predominantly silty matrix. The diamicton is rich in shell fragments and, as with the unit in the ice contact complex, it is interpreted as a till largely made of reconstituted marine sediment. The presence of whole *Hiatella arctica* shells in this unit in a nearby, incompletely investigated profile may indicate a larger scale slice of derived material, or even the presence of less disturbed, *in situ* marine muds.

Fig. 6. Large spillway c. 200 m above sea-level, formed by drainage from Wolstenholme Fjord into Narssârssuk valley (Photo J. Landvik).

Fig. 7. The Narssârssuk area looking towards the southwest. Moraines I and II (Narssârssuk stade) and localities of sections described in text are marked. (Photo K. S. Petersen).



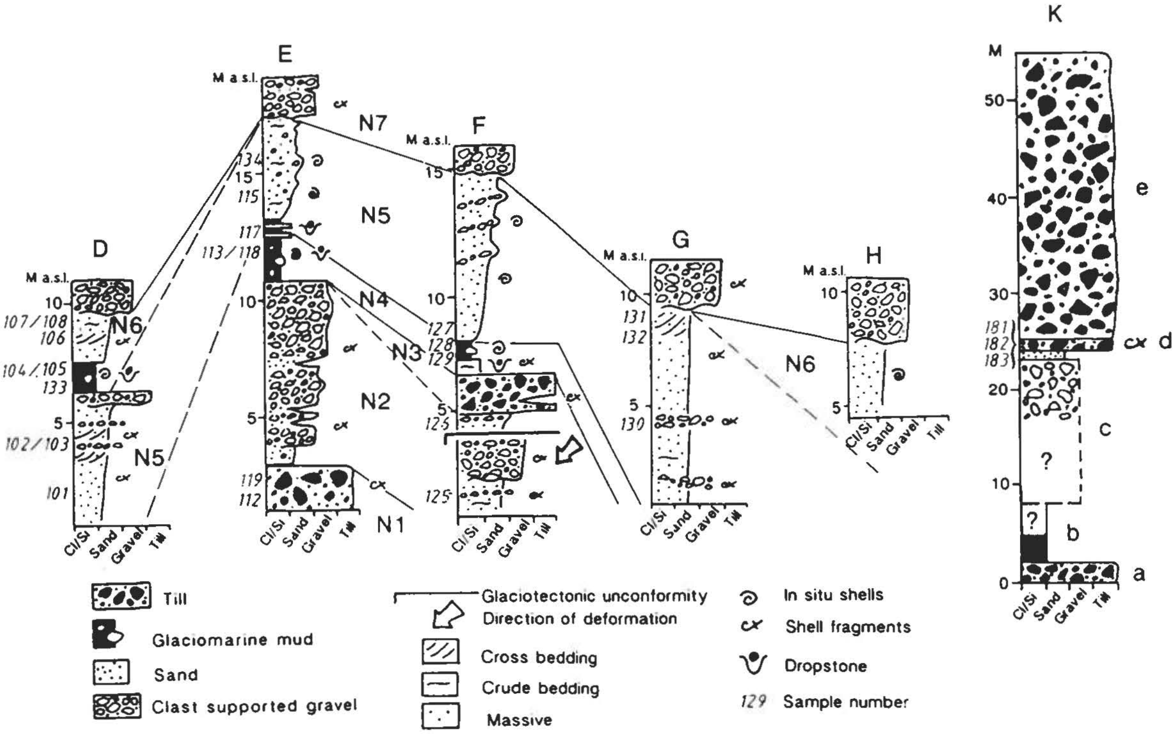


Fig. 8. Lithological sections from Narssârssuk. Solid lines are correlations traced in the field. Small numbers are m above sea level. Notice difference in vertical scale for section K. Sample numbers refer to samples described in later chapters.

Unit N2. – This is a thick sequence of coarse clastic sediments, predominantly crudely bedded gravels and boulder gravels. Exotic rocks form a significant portion of these, indicating glacially related transport from the inland areas. The sediments are locally glaciotectonically deformed (Fig. 8, section F), and the trend of the fold axis shows ice push from the fjord.

Unit N3. – This unit is a gravelly sandy diamicton containing large boulders and shell fragments which is interpreted as a basal till, exposed only in section F. This till unconformably overlies the gravels of unit N2, and wedges out to the northwest against the thicker development of the gravels. The till and the top of the gravels (unit N2) can be correlated by the high boulder content at this level of the cliff, and the boundary with the overlying clayey silts (unit N4, Fig. 8).

We consider that units N1, N2 and N3 are genetically related glacial and proximal glacial facies. The latter were probably submarine, judging from the evidence of the overlying marine unit (see below). North of sections E and F the gravels (unit N2) pass laterally first into a poorly investigated, thick sequence of bedded sands, variously dipping to the northeast and southwest, and then back into bedded gravels.

Unit N4. – This unit consists of 3 m of clayey silts with clasts which become less frequent upwards (N4). Whole *Hiatella arctica*, partly in life position, occur in several horizons, the lowest *c.* 30 cm above the base of the unit. These are associated with thin sand laminae with rust coloration indicating that decrease in mud supply and more aerobic conditions favoured colonisation by a benthic fauna.

Unit N5. – Conformably overlying unit N4 is a thick sequence of sands beginning with laminar bedded silty sands with faunas in life position of *Mya truncata* and *Serripes groenlandicus* together with burrow traces. The dominant sand grain size becomes coarser upwards in Sections E and F and gravel layers occur, probably representing lag gravels from periods of wave erosion. Internal structures include planar and cross lamination marked by heavy mineral laminae, colour mottling suggestive of bioturbation and sparse trace fossils in the form of vertical burrows with escape structures, all of which suggest a shallow-water marine depositional environment.

In section G the sediments are also interbedded coarse and fine sands and thin gravels. At the top, 1.4 m of delta-bedded sands with laminae of organic detritus include mosses. Individual beds are also rich in *Mytilus edulis* fragments.

Occasional clasts, presumably dropstones, occur throughout the sequence.

Unit N6. – This unit is exposed at each end of the series of sediments. It is composed in its lower part of a bed of glaciomarine mud with shell fragments and large clasts, grading upwards into laminated sandy silt with *Hiatella arctica* in life position. Amino acid ratios indicate a Late Weichselian/Early Holocene age for this unit (see Sejrup, this volume).

Unit N7. – The uppermost unit in most of the coastal exposures is a sandy gravel, the surface of which forms a gravel pavement. In the central sector this pavement has low coast-parallel beach ridges which extend up to a minimum altitude of 36 m a.s.l., where they are overridden by solifluction. These are considered to be Holocene in age, formed by the reworking of the older sediments during the Holocene transgression/regression. In section H, sands with abundant mollusc shells have given Holocene radiocarbon dates (see appendix), and may be referred to this unit, which together with unit N6 seems to represent a Late Weichselian-Early Holocene transgression-regression cycle.

Interpretation

Based on the stratigraphy in the sections at Narssârssuk and the geomorphic evidence from the area, the following geological history is suggested:

1. The till deposits and features on the plateau clearly belong to a phase of retreat of an ice sheet which must have essentially covered the whole area. Krinsley (1963) mapped these plateau tills out to the south west coast at Kap Atholl and this ice sheet phase is correlated with the Agpat glaciation (see Houmark-Nielsen, this volume). Retreat of the ice sheet resulted in the deglaciation of the land and area, whilst the 200 m deep Wolstenholme Fjord trough was still filled with ice. The large spillways running from the fjord side of the mountain into the Narssârssuk valley (Figs 5 and 6) were probably formed during this retreat. Identification of the Agpat glaciation in the lowland and coastal sections is necessarily speculative. However, the stratigraphically lowest glacial unit found, i.e. the till at the base of section K, may belong to this ice sheet phase.

2. The coarsening-upwards sequence, revealed both in section K and in the coastal sections (units N1-N3), suggests a readvance of ice in the fjord in the Narssârssuk stade. The lateral margin of the glacier lay across the mouth of the valley (moraine I), where it first overrode glacial lake sediments and marginal outwash, to finally lay down tills, which included marine sediment carried up from the fjord floor. The lithologically similar reworked marine sediment at the base of the coast sections (unit N1) may correlate with this event.

The gradual retreat of the ice margin from the coastal region produced the complex of landforms (Fig. 5), and the ice-proximal deposits found in the coastal exposures (Fig. 8); the till (units N1 and N3), coarse gravels (unit N2) and turbidites. We assume that deposition of the till (unit N3) occurred as a minor readvance during this phase, which is also in accordance with the direction of deformation seen in the underlying gravels, which is from the fjord.

3. The succeeding coarsening-upwards sequence of marine sediments (units N4 and N5), laid down after the last retreat of the ice margin, was a consequence of the change in sediment supply, from ice front to river and coast erosion, superimposed on a lowering of sea-level. Sea-level regression can be attributed to the glacioisostatic rebound following the Narssârssuk stade ice advance. The position of the coastline during this interval is not known, but it could be expected to be higher than the Holocene marine limit from the greater degree of ice cover, and it may be represented by the benches developed around 50 m a.s.l.

Non-finite radiocarbon dates (see appendix), amino acid values (Sejrup, this volume) and biostratigraphic data suggest that this period of marine sedimentation dates from an Early Weichselian warm period (Feyling-Hanssen & Funder, this volume).

4. The succeeding long interval up to the Late Weichselian and Holocene is not represented in the stratigraphy of the area. Sea-level was probably below that at present and processes on land were predominantly erosional. In the Late Weichselian/Early Holocene a marine transgression brought sea-level to at least 36 m a.s.l., followed by a gradual regression. The initial transgression recorded by the diamicton (glaciomarine mud) in unit N6 may be synchronous with the Late Weichselian/Early Holocene glacier advance of the Wolstenholme Fjord stade, known from the interior fjord region.

Qarmat and the adjacent area

(Michael Kelly and Jon Y. Landvik)

Pitugfiup kûgssua and adjacent valleys

In addition to widespread till deposits the area around the valleys of Pitugfiup kûgssua and Siorqap kûa (Fig. 10) are notable for the development of meltwater deposits and landforms. A system of meltwater channels, formed in tills and outwash gravels, cut across the upper Siorqap kûa with an east – west alignment with the uppermost end forming the watershed between this valley and the southerly flowing Narssârrsuk drainage system, down which meltwater must have flowed. In part the channels also drain into the system of deep gorges formed in the easily eroded Proterozoic rocks, where subglacial or marginal glacial meltwater cut through the plateau margin to the lower base level of the fjord area. Outwash gravels form the floor of the valley of Pitugfiup kûgssua, where they have been worked extensively for construction purposes.

All of these deposits have the same degree of weathering and degradation as the deposits around Narssârssuk, and they appear to be part of the same sequence. An ice margin on the Narssârssuk-Siorqap kûa watershed would correspond approximately with an ice front in the fjord near Narssârssuk. It is therefore likely that the deposits in these valleys date from the retreat stages of the Narssârssuk glacial phase.

Along the northern edge of the area are a series of ice marginal deposits and landforms which contrast with those to the south in their degree of weathering, preservation and continuity. This is the Wolstenholme moraine system, mapped by Krinsley (1963) and named informally by Kelly (1985). On the steep sides of the innermost part of Wolstenholme Fjord they comprise a series of lateral moraine ridges and benches, the uppermost at *c.* 250 m a.s.l. being in places 5 m high. At Amitsuarssuk valley (Fig. 10) the outer part of the

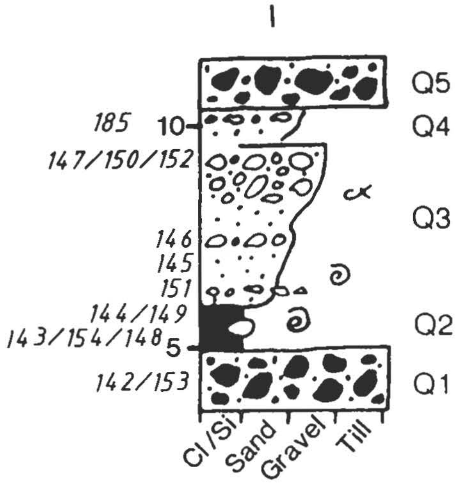


Fig. 9. Lithological log from section at Qarmat. Small numbers are m above sea level. Sample numbers refer to samples described in later chapters. Symbols as in Fig. 8.

system swings south to occupy the watershed between this valley and Pitugfiup kûgssua. Glacio-lacustrine deposits are common in the former valley, in part overlain by till and coarse outwash sediments, i.e. dating from a readvance stage. The moraine system does not extend beyond the narrow section of the fjord and the ice terminus was presumably fixed by the widening of the fjord, implying a floating terminus.

The state of weathering of these deposits is relatively slight, with surface clasts showing less granular disintergration and oxidation than in the older deposits to the south, whilst the depth of oxidation also appears to be less, around a few cm compared with *c.* 10 cm. Although a detailed study of the degree of weathering of the two sets of deposits has not been carried out, the contrast in their overall appearance and the evidence of a readvance are taken to indicate that a substantial period intervened between them.

Deposits comparable in age to the Wolstenholme moraine system do not occur in front of the ice caps along the eastern margin. In fact their present margins appear to be lying on deposits and landforms formed during retreat of the ice margin of the Narssârssuk stade; thus, during this century the Store Landgletscher advanced across a meltwater channel, cut in rock, from the earlier glaciation. (See also Reeh et al., below).

Qarmat, lithostratigraphy

The pre-Holocene deposits mentioned by Kelly (1980a) cover a small area on the south side of the inner part of Wolstenholme Fjord, close to the mouth of a stream. It lies about 1.5 km in front of the terminus of the lateral moraine from the historical readvance of Harald Moltke Bræ. The steep slopes above are covered with till and moraines of the Wolstenholme moraine system. The succession is shown in Fig. 9.

Unit Q1. – This unit is a red tinged diamicton with a sandy silt matrix, shell fragments, fine gravel and coarser clasts. It is interpreted as a till, although it might be a proximal glaciomarine sediment. Above this is a coarsening-upwards sequence of marine sediments.

Unit Q2. – This is a grey green marine diamicton of sandy silt with dropstones. At the base is a horizon with *Hiatella arctica* in life position, and near the top another with *Mya truncata* similarly in life position.

Unit Q3. – This unit consists of 2 m fine to coarse grained sands, with thin gravel layers as well as several horizons with shells in life position – *Mya truncata* and *Serripes groenlandicus*.

Unit Q4. – This unit unconformably overlies Unit Q3, and consists of 1.7 m of fine gravel with a sand matrix, indistinctly bedded in units of a few centimetres thickness, some of which show trough cross stratification. The bedding in the gravel dips offshore in the direction of the present stream, and the sediment is interpreted as fluvial. Its TL-age is 58 ka (Kronborg & Mejdahl, this volume). This sediment provides a glimpse from a long-lasting hiatus in the record, and shows that at this time the glacier in the fjord was not further advanced than now.

Unit Q5. – The topmost unit is a 1.4 m cryoturbated diamicton, clast rich with a silty sand matrix, interpreted as a till.

An adjacent exposure showed more than 8 m of subrounded to rounded clast-supported cross-bedded gravels with foreset beds dipping towards the fjord. These are overlain by 11 m of clast supported diamicton dominated by flat-lying subrounded boulders, some of them > 1 m in diameter, in a sand and gravel matrix. This unit is capped by 2 m of Holocene beach gravels. The relationship of these beds to those in the neighbouring sequence is uncertain but the two lower units may be proximal glacial facies related to unit Q5.

Interpretation

The northern half of the Thule mainland was occupied be the retreating ice margin during the Narssârssuk stade (unit Q1). The importance of meltwater phenomena from this interval suggests an ameliorating climate and rapid retreat.

The succeeding marine sediments (units Q2-Q3) therefore correlate with the marine beds (units N4-N5) at Narssârsuk. Like them, they show a changing marine environment, with loss of ice margin influence, changing sources of sediment and decreasing water depth. Amino acid analyses (Sejrup, this volume) agree with this correlation.

The TL-age of 58 ka for the fluvial sediment of unit Q4 indicates that at this time the fjord glacier in Wolstenholme Fjord was not further advanced than at present.

The subsequent ice advance of the Wolstenholme Fjord stade deposited the Wolstenholme moraine system at its maximal and early recessional stages, and unit Q5 is assigned to this phase. The relative freshness of the deposits of this advance suggests correlation with the Late Weichselian glaciation which affected West Greenland (Kelly 1985). In this case, the Holocene marine transgression and the raised marine sediments

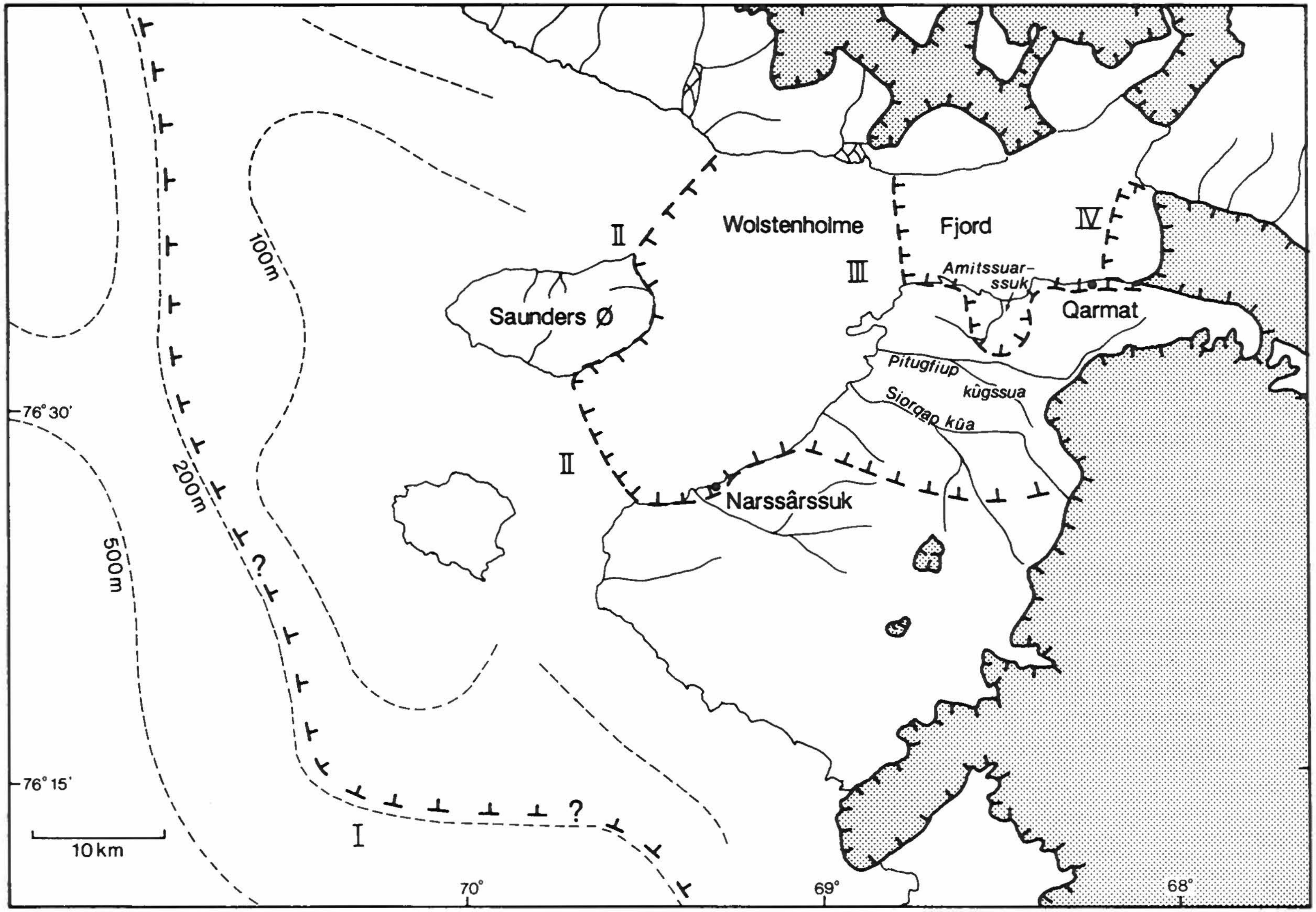


Fig. 10. Postulated ice margin positions in the Wolstenholme Fjord area during the Agpat glaciation (I), the Narssârssuk and Wolstenholme Fjord stades (II, III), and in historical times (IV).

preserved in the area can be related to the glacioisostatic movements of the Wolstenholme Fjord stade.

Summary of regional glaciation history

(M. Kelly and J.Y. Landvik)

The lithostratigraphic and geomorphic evidence from Saunders Ø and the Thule mainland records the occurrence of at least three glacial – deglacial cycles; maximum ice margin positions during each are shown in Fig. 10.

1. The Agpat glaciation, in which an ice sheet ostensibly covered the whole land area, and extended onto the shelf. The subsequent deglaciation, which may have been associated with interglacial environmental conditions (Feyling-Hanssen & Funder, this volume), brought the ice margin north of Narssârssuk, at least.

2. The Narssârssuk stade, during which ice advanced in Wolstenholme Fjord as far south as Narssârssuk. In the northern fjord arm it did not reach Narssârssuaq on Saunders Ø, but may have been held at the narrowest point between Saunders Ø and the north coast of Wolstenholme Fjord, where morainic features were observed by Poul Frich (pers. comm. 1987). Deglaciation resulted in an ice cover hardly more, or perhaps even less extensive than at present, which is compatible with the interglacial environmental conditions suggested by Feyling-Hanssen & Funder (this volume).

3. The Wolstenholme Fjord stade resulted in a limited ice advance to the mouth of the inner part of Wolstenholme Fjord.

4. A minor readvance has taken place during historical times and probably reached a maximum in 1920 (Koch 1928). This is recorded by fresh unvegetated moraine some kilometres in front of the present glacier terminus.