The Ymer-Formation – an interglacial sequence in northeasternmost Greenland

CHRISTIAN HJORT AND ROLF W. FEYLING-HANSSEN

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Christian Hjort, Dept. of Quaternary Geology, Lund University, Sölvegatan 13, S-223 62 Lund, Sweden; Rolf W. Feyling-Hanssen, Dept. of Micropaleontology, Geological Institute, Aarhus University, DK-8000 Aarhus C, Denmark.

Kilen is a flat stretch of land around 81°10'N in northeasternmost Greenland (Fig. 1), reaching 35 km into the Flade Isblink ice-cap complex and with 15 km coast along the Nordøstvandet polynya. Its Quaternary deposits were for the first time reconnoitered in 1980, during the Swedish Ymer-80 expedition (Hjort 1981a), and studied in more detail in 1985, during the Danish-Swedish Kilen-85 expedition.

The sediments constituting the Ymer-Formation are 6–10 m thick and exposed in the so-called Ymer-cliffs (Ymer-klinterne), along c. 1 km of the northern major river on Kilen (Fig. 1). The top of the sequence is 15–20 m above present sea-level.

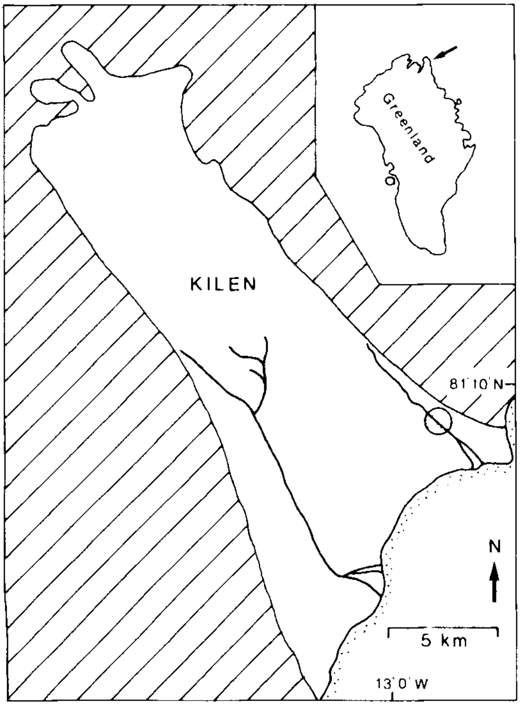

Fig. 1. Kilen, with inset map of Greenland. Glaciers are striped, the coastline enhanced by dotting and the Ymer-cliffs indicated by the shaded circle.

Lithostratigraphy

The Ymer-Formation consists of four beds (B-E in Fig. 2). It is under- and overlain by diamictons interpreted as tills (A and F).

Bed A. – Silty matrix supported diamicton with many clasts (boulders – gravel) and shell fragments. Interpreted as a till, or a very proximal glaciomarine sediment.

Bed B. – Similar to Bed A, without a marked boundary between them. But here bivalve shells in life position show a clear glaciomarine origin.

Bed C. – Gradual transition from B. Stratified sand with many dropstones and with bivalves and balanids in life position. Intrabeds of cobble-gravel, extremely rich in reworked shells, are a characteristic feature. Interpreted as a sub-littoral, distal glaciomarine sediment.

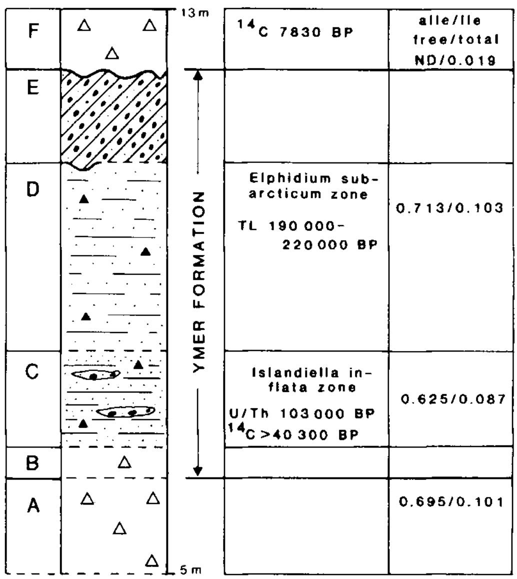

Fig. 2. Stratigraphy of the Ymer-cliffs.

Bed D. – Gradual transition from C. Mainly horizontally stratified, well sorted mainly medium sand with scattered dropstones and with some bivalves and balanids in life position. Interpreted as a distal glaciomarine sub-littoral/innershelf sediment. An overprint of thrust faults, spaced a few meters apart and dipping 30–40° towards c. 90°, indicates later overriding by a glacier from about east.

Bed E. – Locally graded and locally erosional contact with D. Cross-stratified cobble-gravel to pebble-gravel, sometimes with a sandy or silty matrix and mostly with well rounded material. The bedding dips 10–20° towards 220–260°. Interpreted as subaqueous ice-marginal/proximal outwash, indicating a depositing stream from about east.

Bed. F. – Sharp erosional contact with E, with various small-scale thrusts and folds indicating ice movement from northeast-east. Silty matrix supported diamicton with many clasts and an abundance of reworked bivalve shells. Interpreted as a glaciodynamically disturbed glaciomarine deposit (deformation till).

Thus the lower boundary of the Ymer-Formation is the A/B boundary, marked by the appearance of bivalves in life position. The upper boundary of the formation is the distinct erosional contact between beds E/F.

The lithostratigraphy indicates (1) deglaciation, (2) a gradually more distal and probably also more shallow glaciomarine environment, (3) a glacier approaching the site again (from the east, i.e. from the present shelf area) and, finally, (4) overriding of the site (as indicated by the thrust faults in Bed D).

Biostratigraphy

Marine shells are found in all beds in the sequence, and in situ shells in Beds B, C and D. Samples for studies of foraminifera were only collected from Beds C and D.

Molluscs and balanids

Bed A. – Reworked shell fragments which according to their amino-acid characteristics are *Hiatella arctica* (H. P. Sejrup pers. comm.).

Bed B. – *Hiatella arctica, Mya truncata* and *Pecten groenlandicus* in life positions.

Bed C. – *Hiatella arctica, Mya truncata, Astarte borealis* and *Balanus balanus* in life positions. The same species also occur redeposited.

Bed D. – *Hiatella arctica, Mya truncata, Astarte borealis, Serripes groenlandicus, Clinocardium ciliatum, Macoma calcarea, Portlandia arctica, Arca glacialis* and *Balanus balanus* occur, many in life or near life positions.

Bed E. – Fragments of *Hiatella arctica* and *Mya truncata*.

Bed F. – Reworked *Hiatella arctica, Mya truncata* and *Astarte borealis* are abundant.

The molluscs and balanids indicate a shift from a poor high arctic pioneer fauna (Bed B), via a fauna very rich in individuals although not very diverse (Bed C), on to a rather diverse fauna (Bed D) containing both distinctly cold water species like *Portlandia arctica* and *Arca glacialis* and for the latitude rather temperate ones like *Serripes groenlandicus* and *Clinocardium ciliatum*. *Serripes* and *Clinocardium* characterize many Mid-Flandrian (Holocene climatic optimum) sediments further south in East Greenland, but so far *Serripes* has only been reported this far north from the Plio-Pleistocene Kap København sediments in Peary Land (Funder et al. 1985), and *Clinocardium* has been found only once, in an undated deposit in the same area (Laursen 1954). *Macoma calcarea*, a characteristic species in Flandrian sediments further south, had never before been found this far north (Bennike et al. 1986). The shells are also rather large, the longest being c. 8 cm.

Foraminifera

Both samples contained foraminifera, the one from Bed C 1,900 specimens/100 g and the one from Bed D 2,400. They were all benthonic and rather poorly preserved. Samples were treated according to Feyling-Hanssen (1983).

Bed C. – *Islandiella inflata* zone: High frequency (32%) of *Islandiella inflata* and dominance (35%) of *Nonion orbiculare*. There were 25 species in all, those reaching more than 1% being: *Elphidium subarcticum* (5%), *Elphidium excavatum* (4%), *Buccella frigida* (4%), *Elphidium asklundi* (3%), *Cassidulina reniforme* (3%), *Cibicides lobulatus* (2%), *Islandiella helenae* (2%) and *Cassidulina teretis* (2%). This fauna reflects arctic shallow-water conditions (45% shallow-water specimens), probably an innermost shelf/sub-littoral environment of 20 m depth or less. It also suggests slightly warmer conditions than today.

Bed D. – *Elphidium subarcticum zone: Elphidium subarcticum* (45%) dominates, followed by *Nonion orbiculare* (30%) and *Elphidium albiumbilicatum* (14%). There were 14 species in all, those reaching more than 1% being: *Buccella frigida* (5%), *Rosalina wrightii* (2%) and *Elphidium asklundi* (2%). *Islandiella inflata* is present but rare (1%). This fauna is mainly arctic and indicates very shallow water, possibly 10 m or less (92% shallow-water specimens). But *Elphidium albiumbilicatum* is boreo-arctic and also indicates reduced salinity.

Thus both the molluscs and foraminifera show that the Ymer-Formation represents a true interglacial, with somewhat warmer conditions than during the present one.

Chronostratigraphy

Absolute dating of the sediments has been attempted using the ^{14}C-, U/Th- and TL-methods, relative dating using amino acid (alle/Ile) ratios and biostratigraphic dating through foraminifera.

Absolute and relative dating

Bed A. – Amino acid analyses of shell fragments (*Hiatella arctica*) gave as means alle/Ile free 0.695, total 0.101.

Bed C. – Shells from life/near life positions (both shells still together) were ^{14}C-dated to >40,300 B.P. (Lu-1884, Håkansson 1982) and U/Th-dated to 103,000 B.P. (E. Holm, Lund University Radiophysical Institute). Amino acid means were alle/Ile free 0.625, total 0.087 (*Hiatella arctica*)

Bed D. – TL-dated to 190,000–220,000 B.P. (V. Mejdahl, Risö; regeneration method, Mejdahl 1986). Amino acid means were alle/Ile free 0.713, total 0.103 (*Mya truncata*).

Bed F. – Dislocated shells ^{14}C-dated to 8,380 ± 80 B.P. (Lu-2605; sea-corrected age 7,830 B.P., Hjort 1973). Amino acid means were alle/Ile free non-determinable, total 0.019 (*Hiatella arctica*).

The ^{14}C-date from Bed C gives a minimum age. The U/Th-date may also do this, as that sandy-gravelly sediment must constitute a rather open system, at least during non-permafrost conditions, like when transgressed by the sea. The TL-date from Bed D could, however, represent a more accurate age (the accumulated dosis vs TL-temperature plateau covers c. 200°C). The very young ^{14}C-age of shells from Bed F shows that the E/F contact represents a very long hiatus.

The amino acids show (1) that the beds constituting the Ymer-Formation (and the Bed A diamicton) have a similar and rather constrained age, but that the diamicton on top of the sequence (Bed F) is much younger. An EDT-run (Effective Diagenetic Temperature; e.g. Miller et al. 1983; Miller & Mangerud 1985 – using the computer program of G. H. Miller, INSTAAR, Univ. of Colorado) gives ages between 220,000–270,000 B.P. for EDT −5°C and between 600,000–750,000 B.P. for EDT −10°C. As the present mean annual temperature (MAT) on Kilen is between −15°C and −20°C (−18°C at Station Nord, 100 km to the W) a higher EDT than −5°C seems unrealistic, even including rather long periods of submergence. Thus, although EDTs should be used with utmost caution, the alle/Ile ratios indicate that the Ymer-Formation is at least older than the last (Eemian) interglacial.

Biostratigraphic dating

The foraminifera, especially the *Islandiella inflata zone* fauna, suggest that the Ymer-Formation neither dates from the Lower Pleistocene (absence of *Elphidiella hannai* and *E. rolfi*), nor from the uppermost Pleistocene (co-occurrence of *Islandiella inflata* with *Cassidulina teretis*). A Middle Pleistocene age, perhaps Holsteinian, is suggested.

The mollusc faunas do not give any clues to the age of the formation.

Conclusion

The lithostratigraphy illustrates a shift from a glacial and/or ice-proximal glaciomarine environment to a more distal sub-littoral/innershelf environment, and then back to a very proximal glaciomarine one, with later overriding by a glacier from the present shelf area. Mollusc stratigraphy shows a change from a high arctic pioneer fauna to an interglacial one indicating warmer conditions than those attained during the present interglacial. The foraminifera corroborate both the shallow-water origin of the central interglacial beds (C, D) and that comparatively warm temperatures prevailed at the time of their deposition.

The foraminifera indicate a Middle Pleistocene, possibly Holsteinian interglacial origin (240,000 or 330,000 B.P., Miller & Mangerud 1985). This estimate is supported by the single TL-date, and is not contradicted by the ^{14}C- and U/Th-dates, or by the amino acid ratios.

The Ymer-Formation thus seems to fill part of the gap between the Plio/Pleistocene sediments found at 82°30'N at Kap København in Peary Land (Funder & Hjort 1980; Funder et al. 1984, 1985) and at 70°N at Lodin Elv in Jameson Land (Feyling-Hanssen et al. 1983), and the mainly Eemian/Weichselian/Flandrian sequences known from several parts of northeastern Greenland (e.g. Funder & Hjort 1973, 1980; Funder 1978, 1984, in press; Hjort 1979, 1981b; Hjort & Björck 1984).

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