A Proposed Deglaciation Chronology for the Trondheimsfjord Area, Central Norway

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Radiocarbon datings of the deglaciation of the Trondheimsfjord area strongly suggest that the coastal areas and the outer part of the fjord were deglaciated before 11000 B.P. During early Younger Dryas the inland ice advanced to the Tautra Moraines (10800–10500 B.P.). Further inland the Hoklingen Moraines (10300–10100 B.P.) and the Vuku Moraines (c. 9800 B.P.) were deposited during marked glacial advances. Other ice-marginal deposits are mostly dependent on local topography. Brief comments are given on the shoreline displacement during the deglaciation.

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Introduction

Moraines on the continental shelf off central Norway have been radiocarbon-dated to 13000 B.P. for the Storegga moraines and 12400 B.P. for the Haltenbank moraines (Bugge 1980). Andersen (1979), however, has assumed an approximate age of 15000 B.P. for the inner marginal moraines on the continental shelf outside Trøndelag. Radiocarbon datings from Hemnefjord (Lasca 1969), Bjugn (A. Kjemperud pers.comm. 1982) and Rissa (Bugge 1980, Løfaldli et al. 1981) strongly suggest that the outer part of Trondheimsfjord was deglaciated not later than Allerød. Previous datings from the Ekle–Tiller ice-marginal deposit, situated 10 km to the south of Trondheim, have indicated an early Younger Dryas age (Nydal et al. 1972). This deposit (Figs. 1 & 3) has been correlated with the Malvik moraine, the Tautra moraine and the prominant marginal moraines crossing the Fosen peninsula (Reite, in Oftedahl 1974, Sollid & Sørbel 1975, 1979, Sollid 1976). An early Younger Dryas age for these moraines is supported by radiocarbon datings of limnic sediments from the northeastern part of the Frosta peninsula (Kjemperud 1981). A Younger Dryas age was first proposed by Holtedahl (1928) and Undås (1942). Marginal moraines in the inner part of Trondheimsfjord have been tentatively dated to the Preboral Chronozone (Andersen 1979, Sollid 1979).

In recent years, mapping of Quaternary sediments by the Geological Survey of Norway has provided additional information on the stratigraphy and deglaciation (Reite 1975, 1976, 1977, 1980, 1982, in press., Reite & Sørensen 1980, Sveian 1981a, 1981b, 1981c, in press., Hugdahl 1980 and K. Bjerkli pers. comm. 1982). Shoreline displacements and vegetation history have been studied by the Institute of Botany, University of Trondheim (Kjemperud 1981, Selnes 1982).

The aim of this paper is to present the results of radiocarbon datings and propose a chronostratigraphy for the deglaciation of the Trondheimsfjord area, with special emphasis on the distinct marginal moraines which are considered to have been

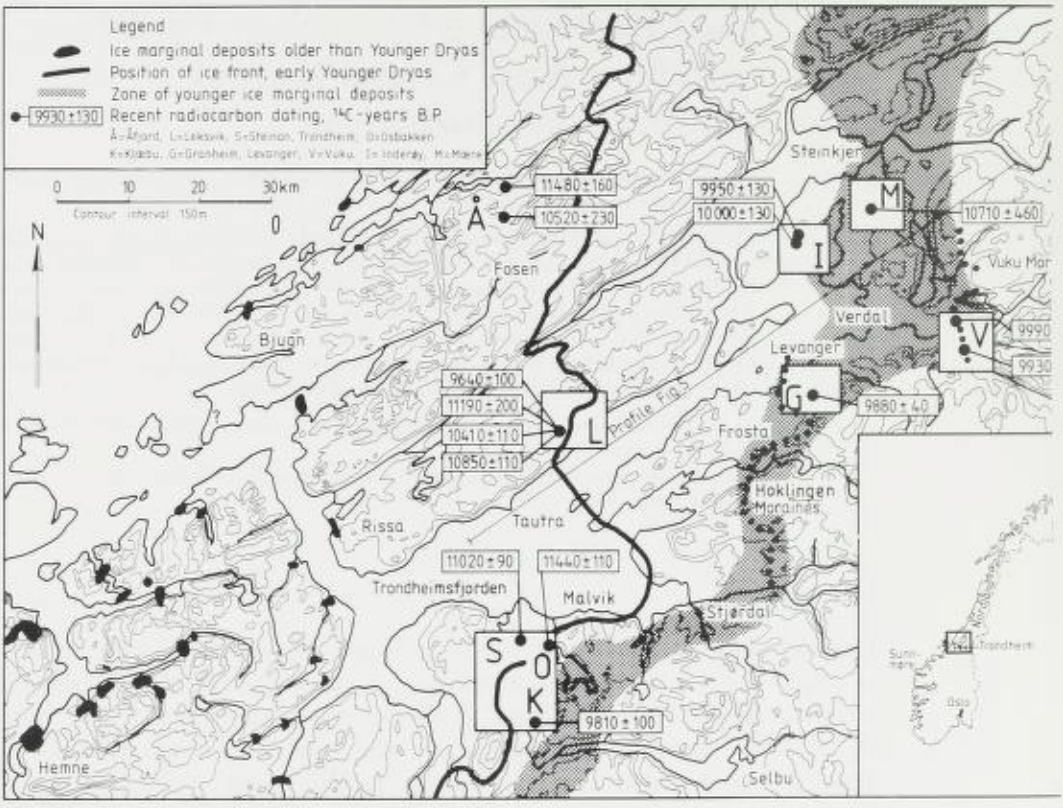

Fig. 1. Map of the Trondheimsfjord area showing ice-marginal features and recent radiocarbon datings. Frames mark the location of the more detailed maps shown in Figs. 2, 3 and 4.

deposited during the Younger Dryas and Preboreal Chronozones. The stratigraphic terminology adopted follows the proposals of Mangerud et al. (1974).

The Fosen Peninsula

Stratigraphical studies of limnic and marine sediments at Åfjord and limnic sediments at Leksvik (Figs 1 & 2) were carried out to date the distinct marginal moraines which cross the Fosen peninsula. The sampling sites at Åfjord are situated 15 km distal to these moraines, while those at Leksvik are in the marginal zone.

Åfjord. In a small basin 25 metres below the marine limit a glacial advance is represented by glaciomarine silt and clay. This bed is underlain by shell-bearing marine clay and overlain by limnic organic sediments. The shells (mostly *Macoma calcarea)* were dated to 11480 ± 160 B.P. (T–3655), and the transition marine/limnic sediments to 10040 ± 100 B.P. (T–3656A). In a small basin nearby, situated above the marine limit, a bottom gyttja sample was dated to 10520 ± 230 B.P. (T–3660A).

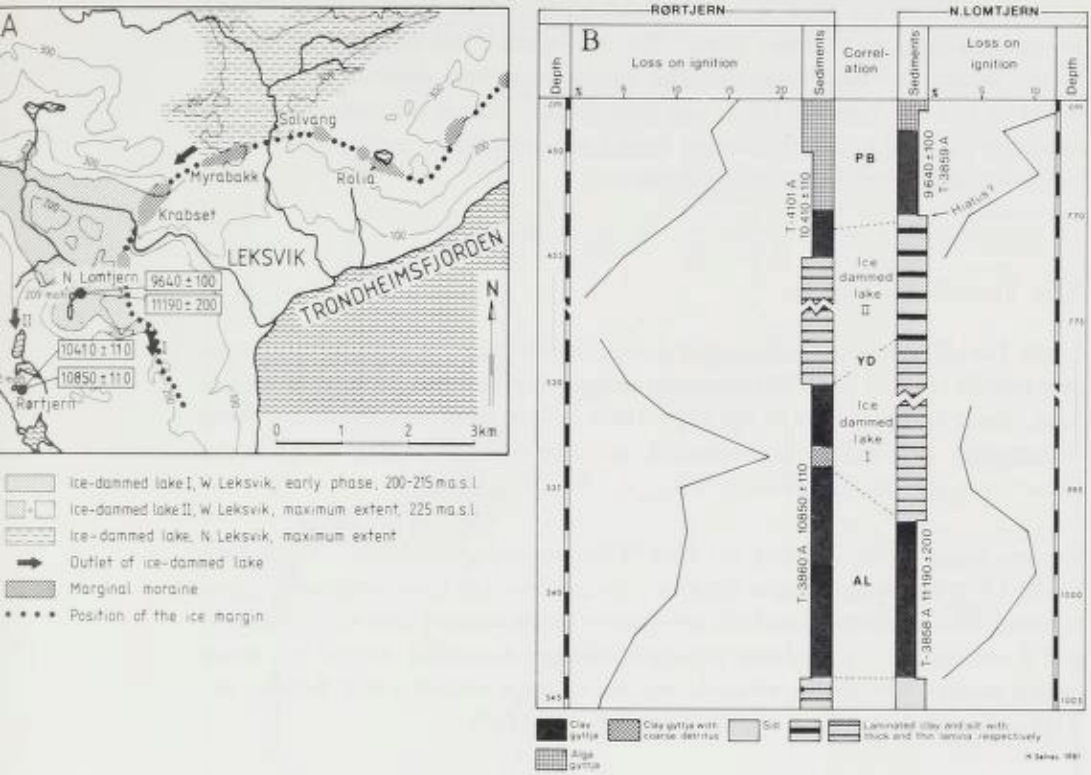

Fig. 2. A: Map of the Leksvik area showing ice-marginal deposits, glacier-dammed lakes and radiocarbon datings.
B: Stratigraphy and radiocarbon datings from the two basins Rørtjern and N. Lomtjern.

Leksvik. At Leksvik the stratigraphy of two small basins, N. Lomtjern and Rørtjern has been studied; both basins are situated above the marine limit. With the exception of a possible hiatus in N. Lomtjern, the basins represent continuous limnic sedimentation from Allerød up to present (Fig. 2). This conclusion is based on the nature of the sediments, the location of marginal moraines, pollen stratigraphy and radiocarbon datings.

Palynological investigations of the organic Allerød sediments suggest a cold steppe/arctic flora, indicating proximity to the inland ice (Selnes 1982). The laminated clay and silt in Lomtjern is interpreted as varves deposited in a glacier-dammed lake which existed during the first half of Younger Dryas (lake I). Rørtjern, on the other hand, was not influenced by lake I. The slightly coarser beds in Rørtjern are considered to be sediments deposited by the river from Lake II, which came into existence when the inland ice experienced a small advance, causing a temporary shift of the threshold. At that time the ice front was situated very close to Lomtjern, where thick laminae of coarser material were deposited.

The datings from *Åfjord* and *Leksvik* and the studies of marginal moraines indicate that the prominent marginal moraines crossing the Fosen peninsula are

synchronous with the Leksvik ice-marginal deposits. The advance of the inland ice occured early in Younger Dryas. The stratigraphy and radiocarbon datings further suggest that the average shoreline displacement from the middle of Allerød to the end of the Younger Dryas was only about 2 metres per century. As only one basin situated below the marine limit has been studied, no conclusions can be drawn on the possibility of transgressions.

The Trondheim region

Large, but discontinuous, ice-marginal deposits are found at Ekle, Tiller, Reppe and Malvik (Figs. 1 & 3). Shell-bearing marine clays situated close to the marine limit, distal and proximal to the Ekle–Tiller ice-marginal deposit and overlying this deposit, were radiocarbon-dated. A spinal segment of a whale found in the foreset beds was also dated (Fig. 3B).

Steinan. Some 2 km distal to the Ekle–Tiller ice-marginal deposit, shells were found 15 m below the marine limit in glaciomarine clay containing ice-dropped material. The 50 cm-thick bed of shell-bearing clay is situated close to the bedrock, and is overlain by 1.5 m of clay without ice-dropped material. No till was found in this section. The shells *(Hiatella arctica, Chlamys islandica* and *Balanus sp.)* were radiocarbon-dated to 11020 ± 90 B.P. (T–3296).

Tiller. A spinal segment of a big whale was found at 15 metres depth in the foreset beds of the glaciofluvial ice-marginal deposit at Tiller. Several years later it was radiocarbon-dated to 10990 ± 190 B.P. (T–787).

Ekle. The foreset beds of the glaciofluvial ice-marginal deposit at Ekle are overlain by glaciomarine clay containing a few shells of *Portland arctica,* suggesting arctic water. This bed is overlain by sandy clay with *Mya truncata, Astarte elliptica* and *Balanus sp.* The fauna thus suggest that the inland ice had receded from Ekle–Tiller before this clay was deposited. This is also supported by the grain-size distribution, indicating shallow water conditions. Radiocarbon datings have given results of 10150 ± 100 B.P. (T–854) and 10230 ± 130 B.P. (T–786) for *Mya truncata* and *Balanus,* respectively. The Ekle ice-marginal deposit is underlain by at least 15 metres of marine clay, probably of late Allerød age.

Osbakken. At Osbakken, a few hundred metres proximal to the supposed position of the Ekle–Tiller–Reppe–Malvik ice front, a shell-bearing marine clay was found close to the marine limit. The clay is not overlain by till. The shells (dominated by *Macoma calcarea* and *Balanus sp.)* were radiocarbon-dated to 11440 ± 110 B.P. (T–4242).

Klæbu. Shells were found close to Sørborgan farm, Klæbu, when marine clay was removed from an almost vertical cliff. This locality is situated 15–20 metres below

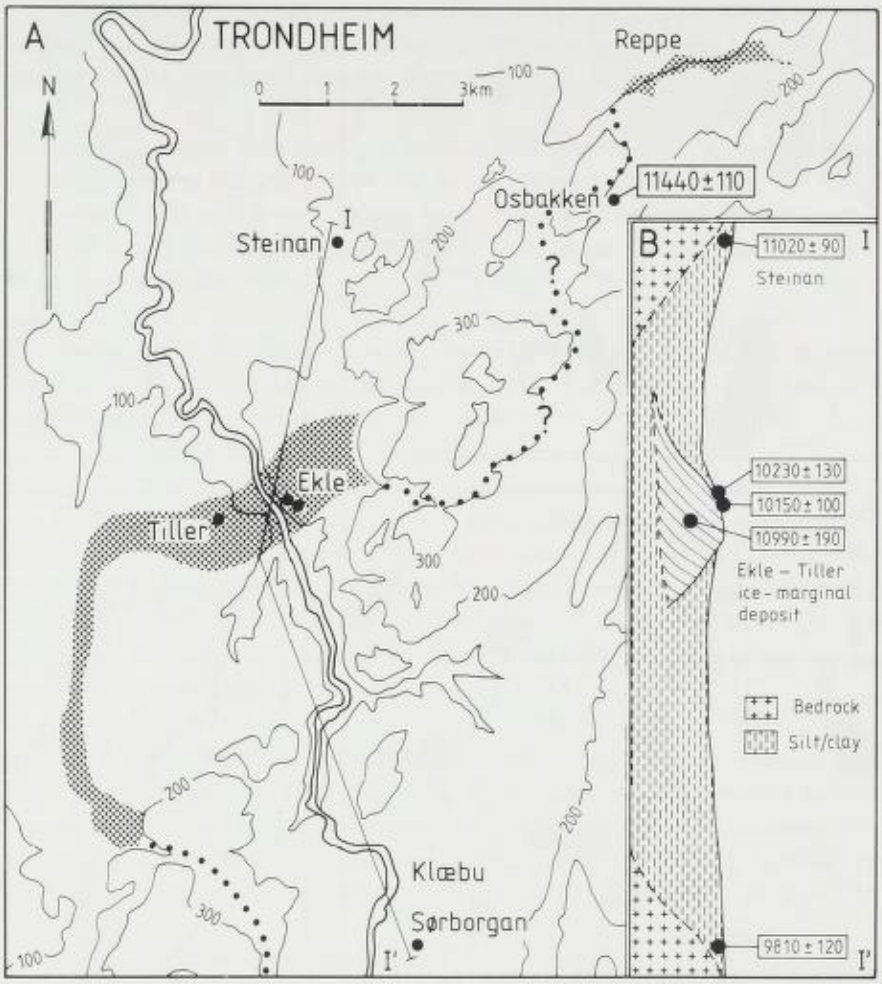

Fig. 3: A: Map of the Trondheim area showing ice-marginal deposits (shaded areas), reconstruction of the ice margin (dotted) and the radiocarbon dating at Osbakken.
B: Profile Steinan–Ekle–Sørborgan with radiocarbon datings.

the marine limit. The shells were radiocarbon-dated to 9810 ± 120 B.P. (T–3113).

The datings from the *Trondheim region* suggest that the Ekle–Tiller ice-marginal deposit was formed in the first part of Younger Dryas. The dating from Osbakken indicates, however, that the marginal moraines at Reppe and Malvik might be slightly older. More radiocarbon datings are needed to solve this question. The datings from several localities situated close to the marine limit indicate that the average shoreline displacement has been less than 2 metres per century during the later part of Allerød and Younger Dryas.

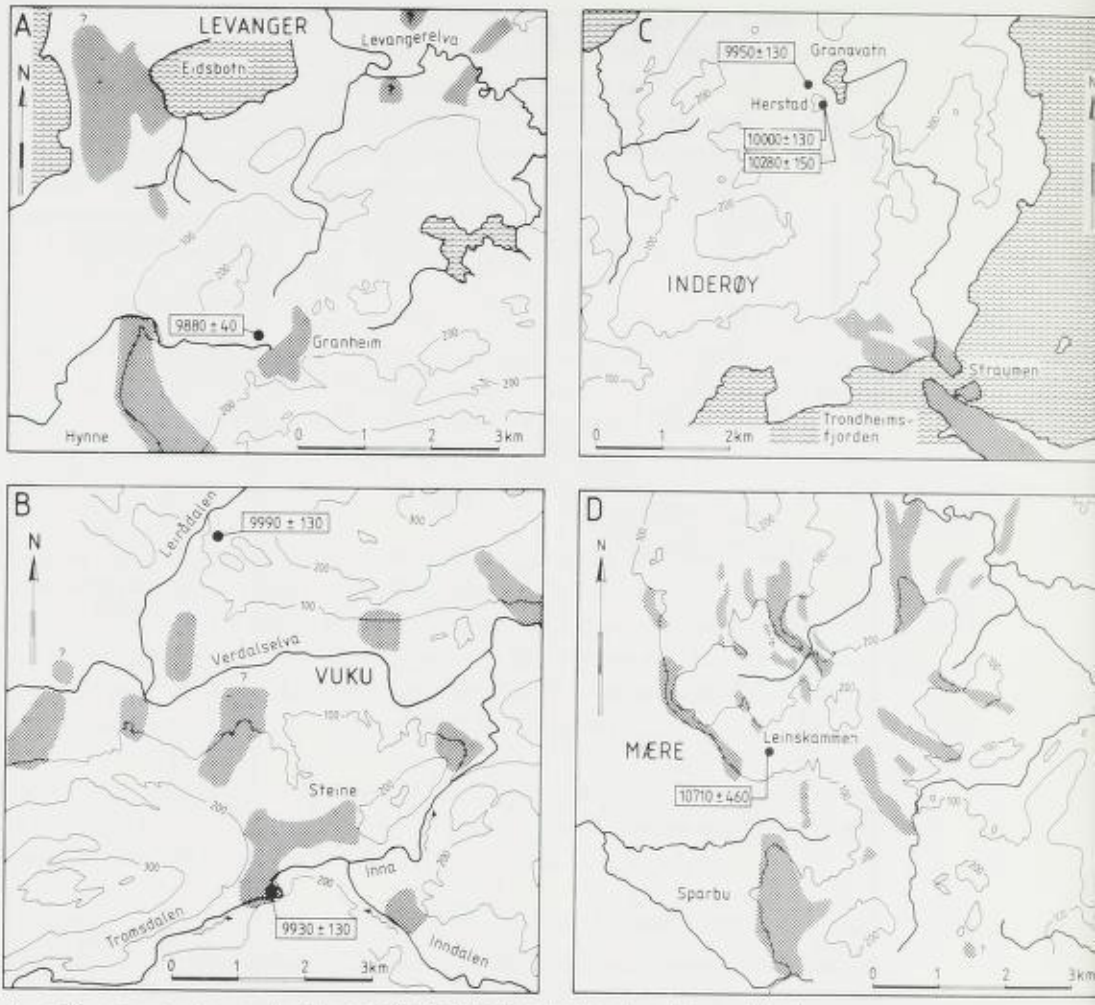

Fig. 4: Maps showing ice-marginal deposits (shaded areas) and radiocarbon datings. A: the Levanger area, B: the Vuku area, C: the Inderøya area and D: the Mære area.

The Verdal region

Numerous ice-marginal deposits occur in this region. A distinct marginal moraine can be traced from Eidsbotn at Levanger to Hynne, lake Hoklingen and further towards Stjørdal (Figs. 1 &4A), and possibly to the western part of the lake Selbusjøen. Evidence of another glacial advance is found at Vuku. This advance can also be traced in a few localities to the north of Vuku and possibly at Steinkjer. Most of the other marginal deposits in this region were formed when the ice front was temporarily halted at bedrock thresholds and other topographic obstacles. They consist mostly of glaciofluvial material. A detailed reconstruction of the ice front is hardly possible for these deposits.

Marine shells situated in the ice-marginal deposits and distally and proximally to them were radiocarbon-dated, as was a peat sample overlying basal till. The datings all give minimum ages for the deglaciation.

Granheim, Levanger. At a locality a few hundred metres distal to the Granheim ice-marginal delta and 2 km proximal to the Hynne moraine, shells were found in marine clay 25 m below the marine limit (Fig. 4A). The shells *(Mya truncata)*, collected in a 3 m-thick clay bed probably close to the bedrock, were dated to 9880 ± 40 B.P. (T–3997).

Leirådalen. Shells *(Mytilus edulis,* with a few *Hiatella arctica* and *Balanus sp.)* were found in a clay 40 m below the marine limit at Leirådalen (Fig. 4B). The shell-bearing clay was radiocarbon-dated to 9990 ± 130 B.P. (T–3999).

Tromsdalen. The Steine ice-marginal delta represents the marine limit, 180–185 m a.s.l. The southern part of the deposit crosses the mouth of Tromsdalen (Fig. 4B). Situated upon the delta is a 20 m-high mound of sandy and gravelly till, containing large blocks of shell-bearing marine clay deposited by a glacial advance. The shells (mostly *Mytilus edulis)* were radiocarbon-dated to 9930 ± 130 B.P. (T–3998); this is a maximum age for this glacial advance and a minimum age for the first ice recession at Vuku.

Herstad. A peat sample was collected in a 2 m-thick bog at the farm Herstad øvre, 40 m above the marine limit (Fig. 4C). The pollen content point to a pioneer vegetation, at least in the lowermost 0–4 cm of the organic sediment. The lowermost part of the sediment was radiocarbon-dated to 10000 ± 130 B.P. for the soluble fraction; and the insoluble fraction to 10280 ± 150 B.P. (T–4259).

Granavatn. Shells were collected from a sandy silt and clay 147 m a.s.l., about 200 m west of lake Granavatn (Fig. 4C). The shells *(Mya truncata)* were found 0.5–1.5 m below the surface in a bed more than 2 m thick. The sediments indicate a sea level higher than 155 m, which is not more than 10–15 m below the marine limit. The shells were radiocarbon-dated to 9950 ± 130 B.P. (T–4257).

Leinskammen. Leinskammen is located between two of the prominent ice-marginal deposits at Mære (Fig. 4D). Only 1.5 g of shells *(Balanus sp.* and probably *Hiatella arctica)* were collected at 168 m a.s.l. in a laminated silt and clay, which is overlain by 1.5 m of coarse-grained beach gravel. The shells date a sea level slightly higher than 170 m, very close to the marine limit. The radiocarbon age is 10710 ± 460 B.P. (T–4258). Unfortunately the sample was too small to give a more precise date.

The datings from the *Verdal region* indicate that Levanger and Inderøy were deglaciated before 10000 B.P. The datings from Mære, Leirådalen and Tromsdalen strongly suggest that Levanger and Inderøy were deglaciated in Younger Dryas, and also that the main valley at Verdal was deglaciated at that time. This

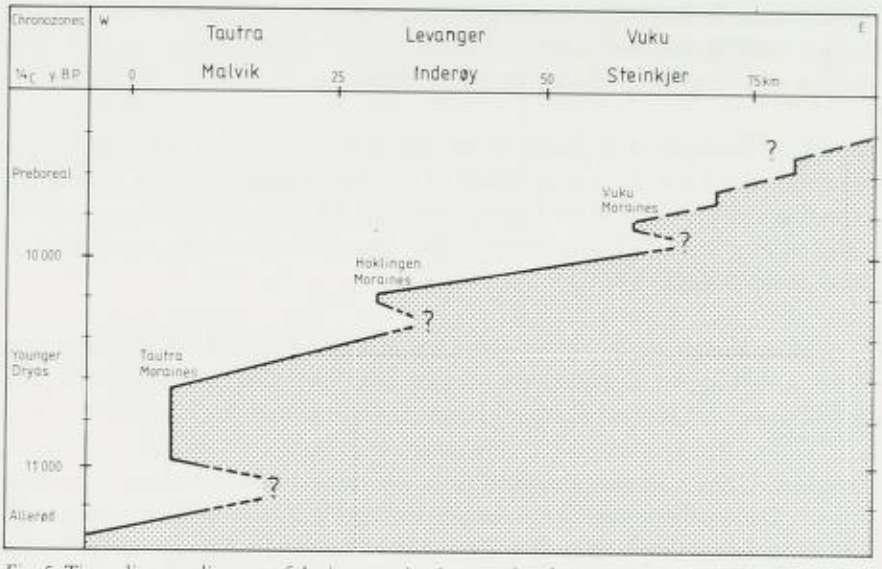

Fig. 5: Time-distance diagram of the ice recession in central and eastern parts of the Trondheimsfjord area.

is in agreement with the datings of gyttja from Frosta, the oldest of which gave Younger Dryas ages (Kjemperud 1981). The shells found in till at Tromsdalen must have been transported by a glacial advance to the Vuku area early in Preboreal.

Conclusions

From the existing data the following preliminary conclusions can be drawn:

- The coastal areas and the outer part of the fjord were deglaciated not later than Allerød, when the front of the inland ice receded to a position to the east of Trondheim, and also at least 10 km to the east of Tautra. The innermost Allerød ice front position is still unknown. (Figs. 1 & 5).
- At the beginning of Younger Dryas a glacial advance took place to the Fosen peninsula, Leksvik, Tautra, Malvik and Trondheim. These ice-marginal deposits are here named the *Tautra Moraines*. The ice recession which followed this advance probably took place in the middle of Younger Dryas.
- The glacial advance to the distinct marginal moraines at Levanger, Hynne, Hoklingen, towards Stjørdal and possibly to the western part of Lake Selbusjøen occurred during the second half of Younger Dryas. We propose to name these ice-marginal deposits the *Hoklingen Moraines*.
- The Younger Dryas chronozone in the Trondheimsfjord area includes the Tautra Moraines and the Hoklingen Moraines, and probably also some ice-marginal

deposits to the east of the Hoklingen Moraines. The deglaciation pattern resembles that found in the Oslo region (Sørensen 1979) and in Nordland (Andersen et al. 1981). This is not in agreement with most previous investigations which have suggested that only the Tautra advance took place during Younger Dryas.

- The glacial advance at Vuku, which can be traced to the north of Vuku and possibly to Steinkjer, took place early in Preboreal. We propose to name these deposits the *Vuku Moraines*. To the south of Vuku the ice margin should be situated to the east of the shaded zone in Fig. 1, where scattered marginal moraines occur.

- With the exception of the Hoklingen Moraines and the Vuku Moraines most ice-marginal deposits in the Verdal region are controlled mainly by local topography. A detailed reconstruction of the ice recession is therefore difficult.

- The average shoreline displacement during the second half of Allerød and throughout Younger Dryas was small compared to that found by Kjemperud (1981) for the Preboreal. A fairly stable sea level has also been found in Nordland (Rasmussen 1981) and in Sunnmøre (Lømø & Lie 1981) for Allerød and the first half of Younger Dryas.

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