# Deglaciation of the Trondheimsfjord area, Central Norway

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## Introduction

The purpose of this contribution is to provide an account of our present knowledge of Late Weichselian deglaciation of the Trondheimsfjord area. The results are based on two decades of mapping of Quaternary deposits in this part of the country. During the Weichselian maximum, Central Norway was completely covered by an inland ice that moved in a WNW direction. Later, the glacier flow became more dependent on the topography (Reite 1994). During the deglaciation, the Trondheimsfjord area was deeply submerged by the sea, and the fjords reached far up into the present valleys.

## Deglaciation of the coastal areas

In the coastal areas to the north and south of Trondheimsfjorden, terminal moraines are found in some of the fjords and locally in lowland areas, but cannot be traced into higher land (Fig. 1). These moraines were deposited by an unstable ice front caused by calving and not by a climatic deterioration (Kjenstad & Sollid 1982, Sollid & Reite 1983). They are not strictly synchronous as the glacier retreat by calving was highly dependent on water depth, exposure to wave activity and topographical conditions (Reite 1994). Generally, these terminal moraines, radiocarbon dated to c. 12,500 years B.P., are strongly reworked in the tidal zone during the shoreline displacement (Fig. 1& 2).

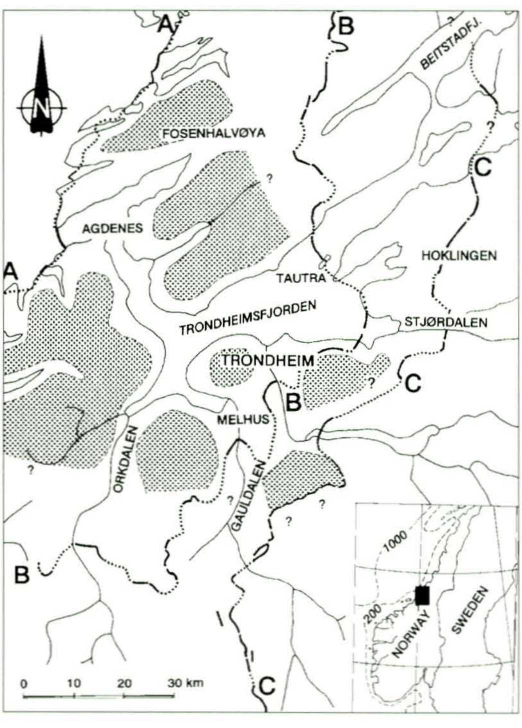


Fig. 1. Ice-marginal deposits in the Trondheimsfjord area. A - A Ice-marginal deposits in the coastal areas (c. 12,500 years B.P.). B - B The Tautra ice-marginal deposits (early Younger Dryas). C - C The Hoklingen ice-marginal deposits (late Younger Dryas). The shaded areas represent local ice caps left after calving in the fjords and the submerged parts of the present valleys. Modified from Reite (1994).

## Deglaciation of the outer parts of the fjords

After a readjustment of the glacier gradient, the calving continued into Trondheimsfjorden and other fjords. This process was accelerated by the great depth of the central part of most of these fjords compared to the much shallower thresholds at their mouths. Local ice caps with slight or no connection to the inland ice remained in the mountainous areas along the fjords (Fig. 1), and small ice-marginal deposits were formed in front of outlet glaciers (Reite 1994). As the western part of the area was deglaciated several hundred years before the central part, these ice caps are not synchronous. They were situated far below the glaciation limit, and probably existed for less than 100 years.

## Deglaciation of the central part of the Trondheimfjord area

The calving halted temporarily where the ice front reached shallower water in the fjords and lower parts of the present valleys that were submerged during the deglaciation. Glaciofluvial sediments accumulated along the ice margin, especially in the major valleys. High salinity led to flocculation of suspended material in silt and clay size fractions, and sedimentation occurred mostly within a few km from where the suspended material reached the fjords (Fig. 3). In Trondheimsfjorden, the calving during the Allerød chronozone continued to a position at least 15 km to the east of the Tautra ice-marginal zone (Figs. 1 & 2). Few distinct terminal morai-

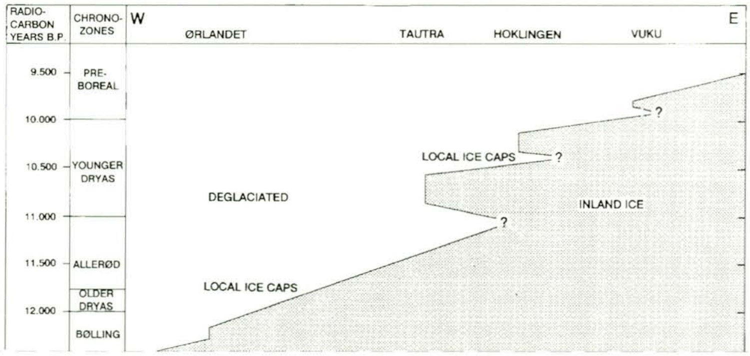


Fig. 2. Time-distance diagram for the deglaciation of the Trondheimsfjord area. Local ice caps left after fast calving in the fjords and submerged valleys are also indicated. Modified from Reite (1994).

nes were deposited during this part of the deglaciation. According to radiocarbon datings of molluscs and gyttja, the deglaciation of the outer part of the Trondheimsfjord area took place during the Older Dryas chronozone. The inland ice receded from the central part of the fjord in the middle of the Allerød chronozone and reached its easternmost position before the Younger Dryas glacier advance at the transition Allerød/Younger Dryas (Reite et al. 1982).

## Glacier advance to the Tautra ice-marginal deposits

The deglaciation during the Allerød chronozone was followed by a marked glacial readvance caused by the Younger Dryas cooling. During this event, Allerød sediments were overrun by the inland ice and the Tautra ice-marginal deposits were formed (Figs. 1, 2 & 3). They can be traced almost continuously from Melhus to the northern part of the Fosen Peninsula. In higher areas these ice-marginal deposits appear to be push moraines; in lowland areas glaciofluvial sediments also occur, commonly with lenses of till in their proximal part, indicating oscillations of the ice front. The position of the inland ice during the glacial advance to the Tautra ice-marginal zone compared to that of late Allerød, shows that there was a considerable increase in the thickness of the inland ice during this advance. Distinct shorelines in solid bedrock are found just outside the ice margin during the Tautra glacial advance but not elsewhere in the Trondheimsfjord area, indicating a colder climate than for the rest of the deglaciation. Radiocarbon datings of molluscs, whale bones and gyttja indicate that the Tautra ice-marginal deposits were formed 10,800-10,500 years B.P.

## Deglaciation after the Tautra event

At the middle of the Younger Dryas chronozone the recession of the inland ice continued to positions 20-50 km to the east of the Tautra ice-marginal deposits (Fig. 1). This recession halted temporarily at rock thresholds and valley spurs, and ice-contact deltas, kame terraces, sandurs and a few terminal moraines were formed. Fast calving in the fjords and submerged valleys left local ice caps in higher areas. Terminal moraines and glaciofluvial ice-marginal deposits were formed in front of outlet glaciers from these ice caps, that had little or no connection to the inland ice. The climate during middle Younger Dryas, judged from the fast retreat of the inland ice and the occurrence of large glaciofluvial deposits,

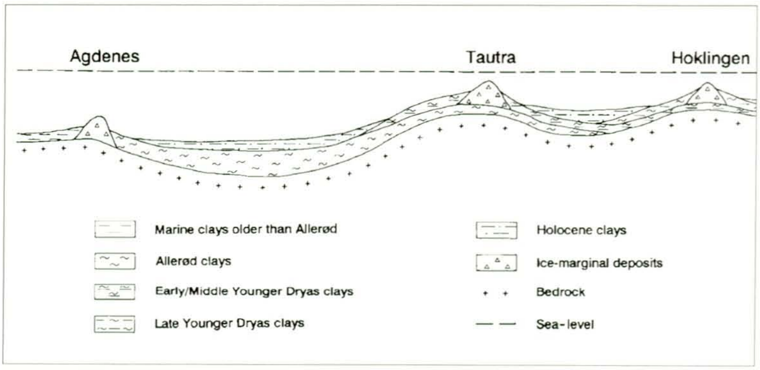


Fig. 3. Stratigraphy (simplified) of areas below the upper marine limit in the Trondheimsfjord area (see Figs. 1 & 2). Thin till layers from glacial readvances are not shown. Most marine clays were deposited within a few km from where the meltwater streams reached the sea. Holocene clays were deposited during the shoreline displacement.

may have been warmer than during the Tautra and Hoklingen events. However, the climate was no doubt colder than during the Allerød chronozone. Due to a colder climate, ice caps formed during the deglaciation shortly after the Tautra event may have existed for a longer time than those from the Allerød retreat, perhaps for 100-200 years.

## Glacier advance to the Hoklingen ice-marginal deposits

The recession from the Tautra ice-marginal deposits was followed by a glacial advance of at least 10 km to the Hoklingen ice-marginal deposits (Figs. 1 & 2). The inland ice increased in thickness and advanced across sediments deposited during the recession (Fig. 3). In higher land, the Hoklingen ice-marginal zone consists of distinct terminal moraines that appear to be push moraines. In lowland areas, both terminal moraines and glaciofluvial ice-marginal deposits occur. Radiocarbon datings of molluscs and peat strongly indicate that the Hoklingen ice-marginal deposits were formed during late Younger Dryas, c. 10,300 years B.P. (Reite et al. 1982, Sveian 1989).

## Deglaciation after the Hoklingen event

During the retreat of the inland ice from the Hoklingen ice-marginal zone, the ice front was temporarily halted at favourable positions in the valleys and large glaciofluvial deltas, kame terraces, eskers and sandurs were deposited. Some terminal moraines were also formed; the most distinct of these are the Vuku ice-marginal deposits, dated to early Preboreal (Reite et al. 1982, Sveian 1989). This part of the deglaciation took place during a marked climatic amelioration, and is characterised by a fast thinning of the inland ice, leaving the last remnants of ice in depressions in the terrain.

## Climatic changes during the deglaciation of the Trondheimsfjord area

Areas deglaciated during Older Dryas and the first half of the Allerød chronozone are characterised by few and small glaciofluvial deposits. During the second half of the Allerød chronozone, glaciofluvial deposits were formed in the lower parts of most valleys; this may indicate a climatic amelioration. The Tautra and Hoklingen ice-marginal deposits, caused by the marked Younger Dryas cooling, consist of terminal moraines deposited by marked glacial readvances, but in the major valleys glaciofluvial sediments also occur. In areas deglaciated after the Tautra and before the Hoklingen glacial advances, large glaciofluvial deposits occur, indicating a warmer climate than during the Tautra and Hoklingen events. This is also indicated by the marked recession before the glacial advance towards the Hoklingen ice-marginal deposits. At the transition Younger Dryas/Preboreal a marked climatic amelioration took place that led to a fast thinning of the inland ice.

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