Deglaciation of the outermost Trondheimsfjord area, mid-Norway

DAG OTTESEN, BJØRN FRENGSTAD & KÅRE ROKOENGEN

Dag Ottesen, Norges geologiske undersøkelse, P.O.Box 3006-Lade, N-7002 Trondheim, Norway. Bjørn Frengstad & Kåre Rokoengen, Institutt for geologi og bergteknikk, NTH, Universitetet i Trondheim, N-7034 Trondheim, Norway.

The glacial history of the outer Trøndelag region has been investigated over several decades (e.g. Øyen 1915, Holtedahl 1929, Undås 1942, Richter 1957, Løfaldli et al. 1981, Reite et al. 1982, Sollid & Reite 1983, Reite 1990, 1994), and the existence of possible ice-front deposits at Ørland, both on land and in the fjord, has been discussed.

Seismic profiles provide important data for the understanding of the Quaternary geology in marine areas. Preliminary and scattered investigations have been carried out in the outer Trondheimsfjord area during the last 25 years, but the results have mostly been presented as internal reports (e.g. Oftedahl 1978, Lien 1980, Westgaard & Rokoengen 1986). Although no extensive treatment has been given, the existing data are quite interesting from a Quaternary geological point of view. In this contribution we describe the submarine glacial deposits in the area and present a suggested depositional model.

The topography in the outer parts of Trøndelag (Fig. 1) is strongly influenced by the bedrock geology and the tectonic history of the area. The valleys and fjords follow two main trends: NE-SW, paralleling the strike of the coastal gneisses and the Møre-Trøndelag Fault Zone (Grønlie & Roberts 1989), and NW-SE, almost perpendicular to the first direction and close to the direction of ice movement during the maximum of the last glaciation in Trøndelag (Reite 1990, 1994).

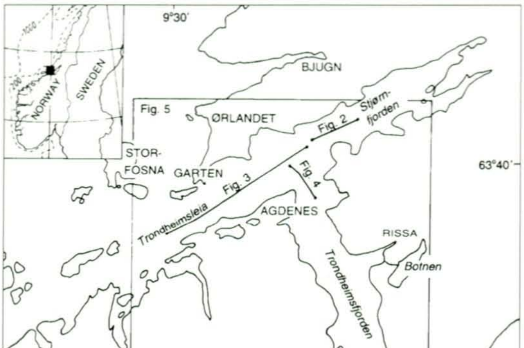

Fig. 1.Location map showing the studied area in the outermost Trondheimsfjord region. The locations of Figs. 2 and 3, 4 and 5 are indicated.

The main bathymetric features have been known for a long time (e.g. Holtedahl 1929), but new depth soundings by the Norwegian Hydrographic Service have provided much more detailed information. The sea bottom in the outer part of the Trondheimsfjord forms a quite regular surface with water depths increasing from less than 500 m north of Trondheim to 600 m south of the threshold at Agdenes (Fig. 1). The water depth at the threshold is about 340 m. The bathymetry in the NE-SW-trending fjord between Agdenes and Ørland is more complex, with a marked ridge across Stjørnfjorden. Towards the southwest the water depth increases gradually to about 430 m south of Garten.

The bathymetric features and the seismic data show three ridges of interpreted glacial origin: (1) across Stjørnfjorden; (2) across Trondheimsleia at Garten; and (3) across Trondheimsfjorden at Agdenes.

The ridge across Stjørnfjorden (Fig. 2) is about 4 km wide, with a relatively steep proximal slope towards the southwest and a gentle, distal, northeastern slope. In the proximal part of the ridge, the seismic profiles show a chaotic internal reflection pattern interpreted as representing morainic material. The central and distal parts of the ridge consist of well laminated sediments dipping gently and thinning out towards the east. The maximum sediment thickness of the ridge is 225 ms (approximately 190 m, Lien 1980). The ridge is thought to have been deposited by a glacier tongue from the southwest.

The ridge at Garten (Fig. 3) forms a conspicuous feature crossing the deepest part of the fjord. The ridge cannot be observed on bathymetric maps, because it is hidden beneath glaciomarine sediments on both sides. The main form has two smaller ridges on the top. The ridge is, at the most, 340 m high, with a steep eastern slope

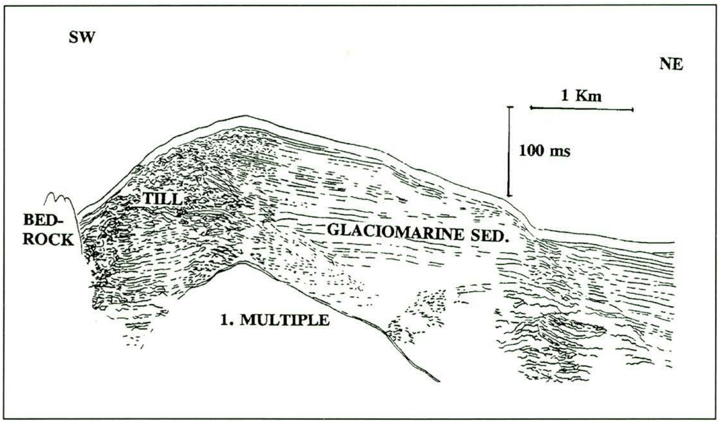

Fig. 2.Interpreted sparker profile showing the ridge across Stjørnfjorden. Modified

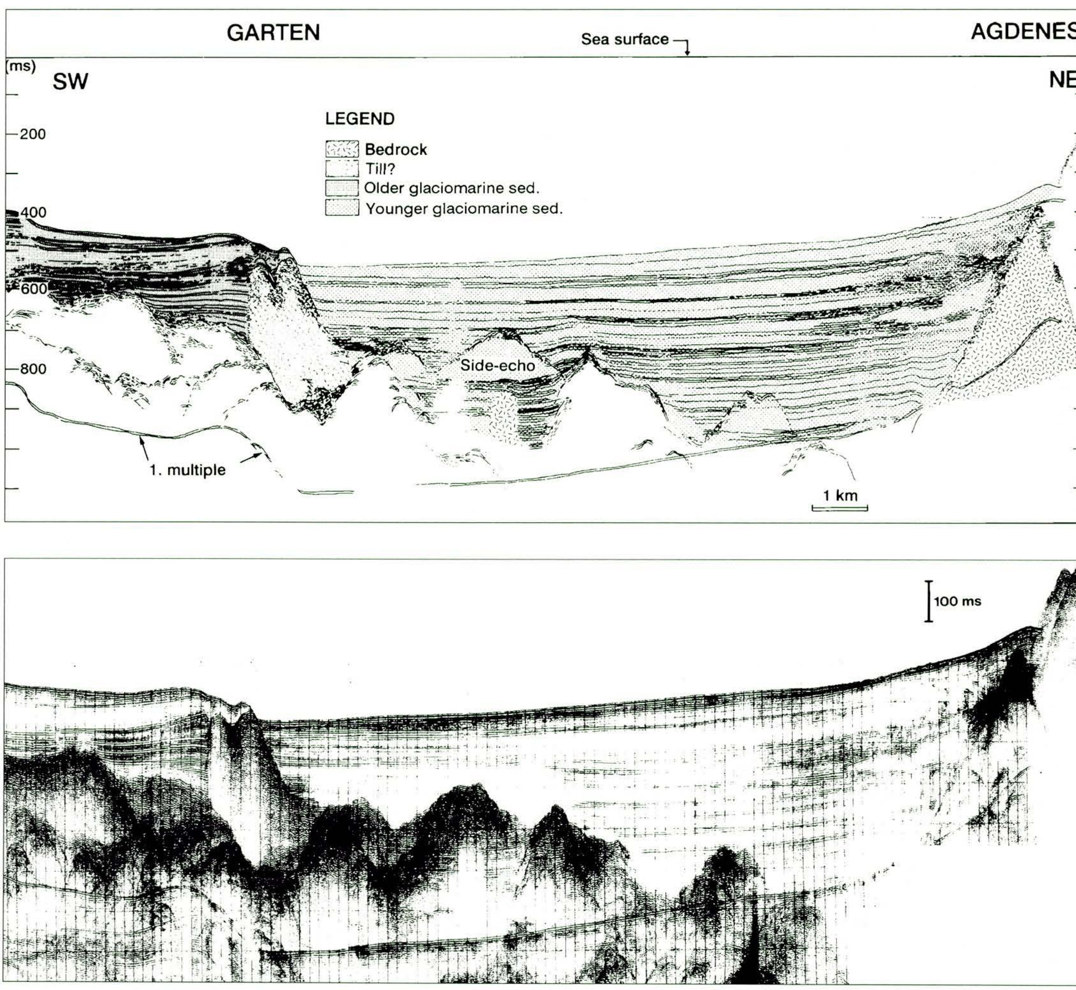

Fig. 3.Air-gun profile showing ridges and clay-filled basins in Trondheimsleia north of Agdenes. See Fig. 1 for location.

and a very steep slope on the western side. It shows no internal seismic reflectors. The ridge is either a morainic sill with a rocky core or it consists entirely of bedrock. In addition to the seismic profile in Fig. 3, there are several other seismic profiles which cross this profile just above and near the ridge. These profiles show that the sediments on the eastern and western sides of the ridge are not connected and were deposited at different times, with the oldest sediments on the southwestern side. This means that the ridge played an important role during deglaciation, regardless of the origin of the material in the ridge.

Fig. 3 shows the stratigraphy in the basin east of the ridge at Garten. The basin is about 13 km long from WSW to ENE, and it swings towards the southeast in its eastern part, ending against the threshold at Agdenes. In the shallowest part of the basin in the northeast the water depth is about 300 m; near the ridge at Garten it is about 430 m. The sediment layers dip gently and thin out towards the southwest, indicating that the source of the sediments was situated in the eastern part of the basin. To the northeast (Fig. 3), the laminated succession terminates against a steep bedrock surface. The basin with laminated sediments has an average width of 2 km, a maximum sediment thickness of 425 m (based on an acoustic velocity of 1700 m/s), and an average sediment thickness of 225 m.

The internal structures of the very marked ridge at Agdenes is shown in Fig. 4. The ridge comprises structureless material in the southeast, grading into layered sediments westwards. The structureless material is interpreted to represent till. Outcropping crystalline bedrock is found on both sides, extending from the present land areas.

Reite (1994) has dated shells from glaciomarine clays occurring on land at Ørlandet to about 12,000 years BP. This age is assumed to represent the time immediately after deglaciation of

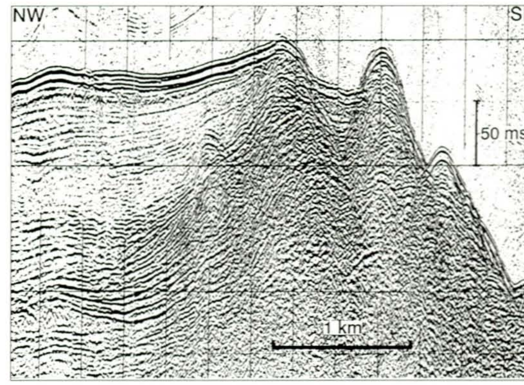

Fig. 4. Sparker profile across the threshold at Agdenes (IKU-profile T79-103, Bugge 1979). See Fig. 1 for location.

the area. We have tentatively correlated these clays with the laminated succession southwest of Garten (Fig. 3). A ^{14}C-date of a shell in glaciomarine clay from Rissa (Fig. 1) (Løfaldli et al. 1981) gave an age of 11,780±90 years BP (T-3034). Reite (1987) has dated shells in glaciotectonised clays to 12,080±150 years BP. These ages indicate that the period from the time of deglaciation at Ørlandet to the time that the ice retreated from the outer part of Trondheimsfjorden at Rissa was very short, probably between 100 and 500 years. A sediment thickness of 225 m gives an average sedimentation rate of between 0.5 and 2 m/year. 500 m-thick ice-front deposits in Ranafjord, northern Norway, in early Younger Dryas time give a sedimentation rate in the order 1 m/year (Andersen et al. 1982). This is between one and two orders of magnitude greater than the sedimentation rates during deglaciation in Cambridge fjord, Baffin Island (Stravers & Syvitski 1991). Elverhøi et al. (1983) have estimated the sedimentation rate 10 km in front of the glacier terminus in Kongsfjorden to be about 0.1 m/year.

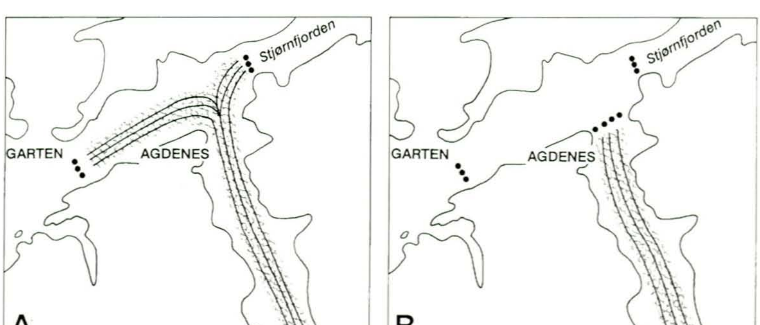

Fig. 5. Suggested model for deposition of the described sediments during deglaciation. A) Garten - Stjørnfjorden. B) Agdenes. Dots show where glacial ridges occur at Garten, Stjørnfjorden and Agdenes.

The major part of the layered sediments in the basin between Agdenes and Garten is believed to have been deposited during the deglaciation, when the ice front was situated at Agdenes. This is thought to have occurred in the Bølling, Older Dryas or early Allerød chronozone. Glaciomarine sediments of supposed Allerød age in Beitstadfjord in the inner part of the Trondheimsfjord indicate a very rapid ice retreat. During the Younger Dryas period, the glaciers advanced, but the ice front was still situated in the inner parts of the Trondheimsfjord (Reite 1990,1994); and sediments did not reach the basin in Trondheimsleia between Garten and Agdenes due to the presence of the threshold at Agdenes.

A deglaciation model explaining the observed features is presented in Fig. 5. A fjord glacier moving out of the Trondheimsfjord divided at the mouth of the fjord into two ice lobes, a minor one moving towards the northeast and the main one towards the southwest. The diverging ice built ice-front deposits which today are represented by the ridges across Stjørnfjorden and Trondheimsleia at Garten. At this standstill of the ice front, large volumes of fine-grained sediments were deposited in the basins outside the ridges. After this period the ice front retreated to the threshold at Agdenes, and left an empty basin. The infilling of this basin can clearly be seen in Figs. 3 and 4.

We agree with Reite (1994) that these sediments, both the ice-marginal and the glacio-marine layered sediments, were probably deposited by an unstable ice-front caused by calving and not by a climatic deterioration.

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