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Deglaciation of the Reisa Valley, Northern Norway, and Studies of Glacial Deposits and Dispersal Processes

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ABSTRACT

During the deglaciation of the Reisa valley area, the main valleys were occupied by large outlet glaciers flowing down to the fjords. Marginal moraines corresponding to ice front accumulations indicate the occurrence of four separate events marking glacial advances or stagnations. The oldest moraines, the Reisafjord moraines, are correlated with the Ra moraines of Younger Dryas age. The younger moraines are of Preboreal age, respectively 9900-9800 B.P., 9700-9500 B.P. and 9400 ± 250 B.P. Subsequently, the deglaciation was characterized by the effects of great glaciofluvial activity. Along the border between Finland and Norway, W of the Reisa valley, the meltwater drainage was ice-directed eastwards more or less transversely to the northerly directed ice movements. A series of overflow channels crossed the watershed. Case studies of outwash deposits show a complex genesis and provenance for these sediments. The lithological and geochemical compositions are generally different from those of the till deposits. Vertical variations in till composition are present. The deepest part of the till, just above bedrock, is usually locally derived. In the upper till, material transported over distance of more than 5 km predominates in the interior regions. In the central part of the Reisa drainage area, the till cover is thinner and the glacial drift is of more local origin. Till contains only 50% of the original content of red granite after 5-6 km transport.

RESUMEN

Durante el retroceso glacial en el área del Valle de Reisa, los principales valles estuvieron ocupados por glaciares marginales que descendían hacia los fiordos. Se han podido detectar cuatro momentos separados de avance o estancamiento de los hielos, marcados por las morrenas marginales correspondientes a acumulaciones del frente glacial. Las morrenas más antiguas, morrenas de Reisafjord, son correlacionables con las morrenas de Ra del Dryas reciente. Las morrenas más jóvenes son de edad Preboreal, 9900-9800 B.P., 9700-9500 B.P. y 9400 ± 250 B.P. respectivamente. Posteriormente el retroceso glacial se caracterizó por los efectos de una gran actividad fluvioglacial. A lo largo del límite entre Finlandia y Noruega, al W del Valle de Reisa, el drenaje del agua de fusión estuvo dirigido por el hielo hacia el Este, más o menos transversalmente a la dirección Norte del movimiento del hielo. Una serie de canales de desagüe cruzaban las divisorias. Los estudios realizados sobre sedimentos de estos depósitos proglaciales muestran una génesis y procedencia complejos. Las composiciones litológica y geoquímica son distintas, generalmente, de las de los tills. La composición del till presenta también variaciones verticales. La parte más profunda del till, en contacto con la roca, generalmente es de procedencia local. En las regiones interiores en la parte alta del till predomina el material transportado distancias superiores a los 5 Km. en la parte central de la cuenca de drenaje de Reisa el recubrimiento de till es más delgado y los depósitos glaciales tienen un origen más local. El till sólo contiene un 50% del contenido original en granito rojo después de 5-6 km. de transporte.

RESUM

Durant el retrocés glacial a l'àrea de la Vall de Reisa, les valls principals estigueren ocupades per glaceres marginals que baixaven cap els fiords. S'han pogut precisar quatre moments separats d'avanç o d'estancament dels gels marcats per les morrenes marginals corresponents a acumulacions del front glacial. Les morrenes més antigues, morrenes de Reisafjord, es poden correlar amb les morrenes de Ra del Dryas recent. Les morrenes més recents són Preboreals, 9900-9800 B.P., 9700-9500 B.P. i 9400 ± 250 B.P. respectivament. Posteriorment el retrocés glacial es caracteritzà pels efectes d'una gran activitat glacio-fluvial. A la zona fronterera entre Finlàndia i Noruega, a l'Oest de la vall de Reisa, el drenatge de l'aigua de fusió anava cap a l'Est degut al gel, més o menys transversalment a la direcció Nord del gel. Un seguit de canals de desguàs creuaven les divisòries d'aigües. Els estudis realitzats en sediments d'aquests dipòsits proglacials mostren una gènesi i procedència complexes. Les composicions litològica i geoquímica difereixen normalment de les dels tills. La composició del till presenta tanmateix variacions verticals. La part més profunda del till, en contacte amb la roca, generalment és de procedència local. A les regions de l'interior, a la part alta del till hi predomina el material transportat a distàncies superiors als 5 km. A la part central de la conca de drenatge de Reisa, el recobriment de till és més prim i els dipòsits glacials tenen un origen més local. El till, després de 5-6 km de transport, ja només te un 50% del contingut original de granit vermell.

INTRODUCTION

The Reisa valley extends 120 km from the fjord at its mouth to the watershed along the border between Finland and Norway (Figs. 1 and 2). The drainage basin has an area of about 2500 km^2. The main valley is deeply cut into a plateau reaching altitudes of 1200-1300 m a.s.l. in the coastal part of the area. Towards the SE general altitudes decrease and the interior region consists mainly of a gently undulating plateau with elevations in the range of 500-600 m a.s.l. The bottom of the lower part of the valley is filled with loose deposits with thicknesses up to 200 m.

Most of the Reisa drainage area is situated in allochthonous Caledonian rocks, mainly meta-arkose and quartzite (Fig. 2). The inner part, the Čier'tegårsa area, belongs to the Precambrian basement. The predominant rocks are red and grey granite with belts and bands of amphibolite/greenstone and quartzite (Zwaan 1976).

DEGLACIATION

Glacial events

During the last Glacial (Weichsel) maximum, the whole area was covered by ice and the ice margin lay 50-100 km offshore (Fig. 1) (Andersen 1968, Sollid et al. 1973). When the ice sheet thinned, the high coastal mountains formed nunataks. The ice cap gradually split up and the main fjords and valleys were occupied by large outlet glaciers. During the deglaciation of the Reisa valley, marginal moraines were formed, corresponding to ice front accumulations in the main valley. These marginal deposits indicate four separate events marking glacial advances or stagnations (Bergstrøm & Neeb 1984).

The oldest moraines in the Reisa area, *the Reisafjord moraines,* correspond to an ice front in the fjord, about 10 km outside the mouth of the Reisa valley (Fig. 3a). The Reisafjord moraines are correlated with the Ra moraines or the Tromsø-Lyngen moraines of Younger Dryas age (Fig. 1). A radiocarbon date on shells from the Spåkenes end moraine in Lyngen gave 10. 350 ± 300 years B.P. (Marthinussen 1962).

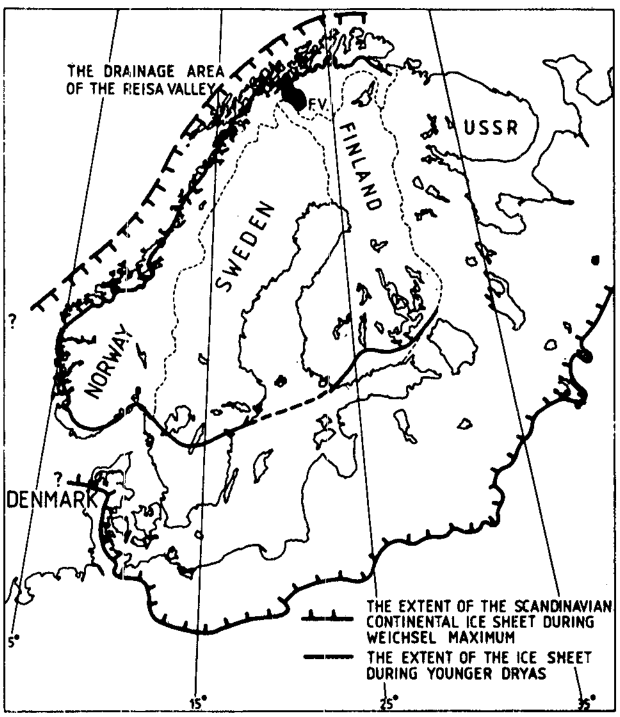

Figure 1. The extent of the Scandinavian continental ice sheet during the Weichsel maximum and the Younger Dryas. The shaded area is the drainage area of the Reisa valley. F.V.= the Finnmarksvidda plateau.

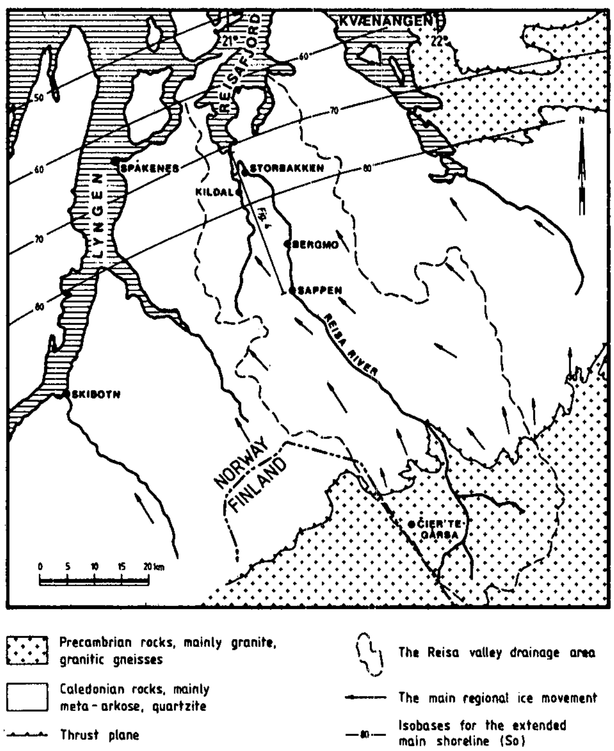

Figure 2. Location map showing the Reisa valley drainage area, the main regional ice movement and isobases for the extended main shoreline. Location of the shoreline profile in Fig. 4 is shown. Bedrock geology simplified after Zwaan (1976).

After the Reisafjord event the ice front retreated rapidly to the mouth of the Reisa valley. An end moraine ridge was formed at Storbakken-Andsjø. Based on corresponding lateral moraines the extent and the relief of the glaciers during *the Storbakken event* are reconstructed (Fig. 3b). During this event, the large tributary valley, Samueldalen, was ice-free, except in the outer part, where an ice lobe from the glacier in the Reisa valley flowed westward and filled the lower part of Samueldalen. The front delta formed at Kildal is correlated with the Storbakken end moraine. Towards the south the ice lobe dammed a small lake.

After the Storbakken event the ice front retreated about 15 km inward to Bergmo where a 3 km long icefront sandur delta was deposited. The marine limit is determined as 75 m a.s.l. The extent of ice during the *Bergmo event* is reconstructed (Fig. 3c).

The youngest marginal moraines are called the *Sappen mopen moraines.* No marked indication of the contact of the ice front is observed in the Reisa valley, but distinct lateral moraines indicate an ice front position at Sappen during this glacial event (Fig. 3d). The valley floor is here distally filled up with outwash deposits. Numerous kettles indicate that bodies of stagnated ice were isolated from the ice front during the sedimentation.

Longitudinal profiles of the glaciers during the glacial events show an average gradient varying between 40 and 20 m/km during the Storbakken and Bergmo event. Near the front the ice-surface was steeper, while in the inner part, more than 30 km from the front, the gradients are more gentle (8-10m/km). During the Sappen event the gradients were generally lower, as a result of thinner glaciers, less ice supply and consequently less dynamic activity in the ice.

Shorelines

The moraine sequence is correlated and dated with reference to Marthinussens (1960) shoreline sequence. The shoreline relation diagram is constructed normally to the isobases for the extended main shoreline (S_0) (Figs. 2 and 4). The shorelines are dated by means of marine limit (ML) and radiocarbon dates (Andersen 1968, 1975 and Corner 1980).

The ML corresponding to the Storbakken event is plotted in the diagram (Fig. 4) and represents a shore level between the shorelines P_{11} and P_{10}, indicating an age between 9750 B.P. and 10.000 B.P. The Bergmo event corresponds to a level between the shorelines P_{10} and P_9, which are dated to 9750 B.P. and 9500 B.P. respectively. Determination of the ML corresponding to the Sappen event is problematic, due to the fact that the ice-front accumulations distally to Sappen are generally built up higher than the ML. Probably the ML lies between the P_9 and P_8 shorelines, i.e. between 9500 B.P. and 9350 B.P.

Deglaciation of the upper part of the Reisa valley

Subsequent to the Sappen event, a favourable climate resulted in rapid downwasting of the ice sheet accompanied by a rapid recession of the glaciers to the inner plateau areas. No evidence of any readvance or halt of the front has been found. The final deglaciation was characterized by the effects of great glaciofluvial activity. Along the border between Finland and Norway, the meltwater drainage was ice-directed eastwards towards the Reisa valley more or less transversely to the northerly directed ice movements (Bergstrøm 1981). A series of successive overflow and lateral channels crossed the watershed. Outwash deposits were accumulated at the mouth of some of the large overflow channels and canyons, partly in contact with the ice margin or in small ice-dammed lakes.

TILL DEPOSITS-DIRECTION AND DISTANCE OF TRANSPORTATION

The till deposits in the Čier'tegårsa area are mainly transported from SSE and S (Fig. 2). Only small changes in the direction of ice movements are observed during the last glaciation. The ice flow was more or less directed towards the Reisa valley, which functioned as a large drainage channel towards the NW. On the Finnmarksvidda plateau further east the ice direction has not been so stable. Olsen & Hamborg (1984) have reconstructed three different ice movements, based mainly on till fabrics. The directions were to the ENE-NNE (oldest), NNW and N (youngest). However, on the southwestern part of the Finnmarksvidda, (SSE of the Čier'tegårsa area) the youngest northerly ice movement was influenced by the Reisa valley drainage and directed towards this valley system in a northwesterly direction (Olsen et al., in prep.).

Most of the tills in the interior regions, SE of Čier'tegårsa, are transported from a distance of more than 5 km, except in the deepest part, just

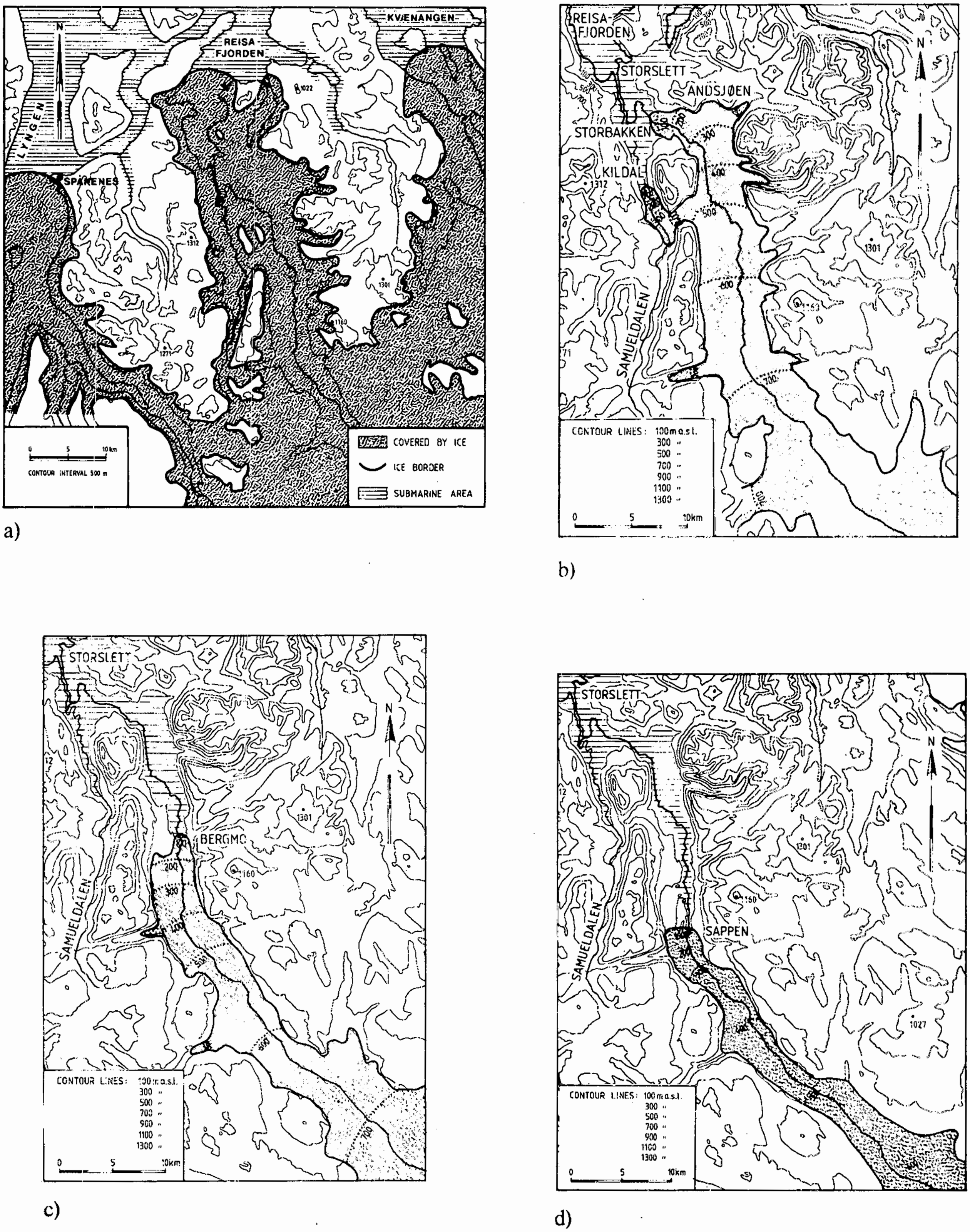

Figure 3. Reconstructions of a) the Reisafjord event, b) the Storbakken event, c) the Bergmo event and d) the Sappen event.

above bedrock, where the content of local rocks is usually high. In areas with thick and continuous cover of till deposits, it has been observed that 50% of the coarse material in the upper till has been transported more than 15 km.

The till cover becomes thinner and exposed bedrock more frequent in the mountainous Caledonian regions north of the Čier'tegårsa area. Samples from the upper till (0.5 m depth) are analysed for the content of Precambrian red granite in the clast fractions 4-8 mm and 8-16 mm. The results are projected on profiles parallel to the direction of the latest regional ice movement and presented in Fig. 5. The curves in the diagram start at the Precambrian boundary and the initial point indicates the mean content of red granite from the upper till that overlies the northern areas of Precambrian rocks. After a glacial transport of 5-6 km towards NNW-N onto the Caledonian rocks, the content of red granite decreases to half of the original value. However, an average content of 4-5% persists as far as 20 km from the Precambrian boundary. About 30 km from this contact the content is diminished to about 1%.

The relatively rapid decrease of red granite away from the boundary of the Precambrian rocks suggests a predominantly basal transportation of the till in the ice with great comminution of rock particles. Glacial erosion in the Caledonian rocks and enrichment of local material with dilution of the original glacial drift has also taken place. The red granite transported over a long distance (> 30 km) has presumably been carried mainly in a supra - and englacially position.

Tills, deposited in the main Reisa valley, often seem to have a longer and more complex glacial transport than the corresponding tills in the surrounding mountainous areas. They are more or less influenced by glaciofluvial activity with incorporation of sorted sediments eroded and washed away from the interior regions. Some of this material origginates from the Precambrian area and was an important supply of red granite to the Reisa valley system.

ČIER'TEGÅRSA OUTWASH DEPOSIT

During the regional geochemical prospecting in the interior area, attention was drawn to some of the outwash deposits, owing to anomalously high values of copper and nickel (Lindahl et al. 1979). A detailed provenance investigation was therefore

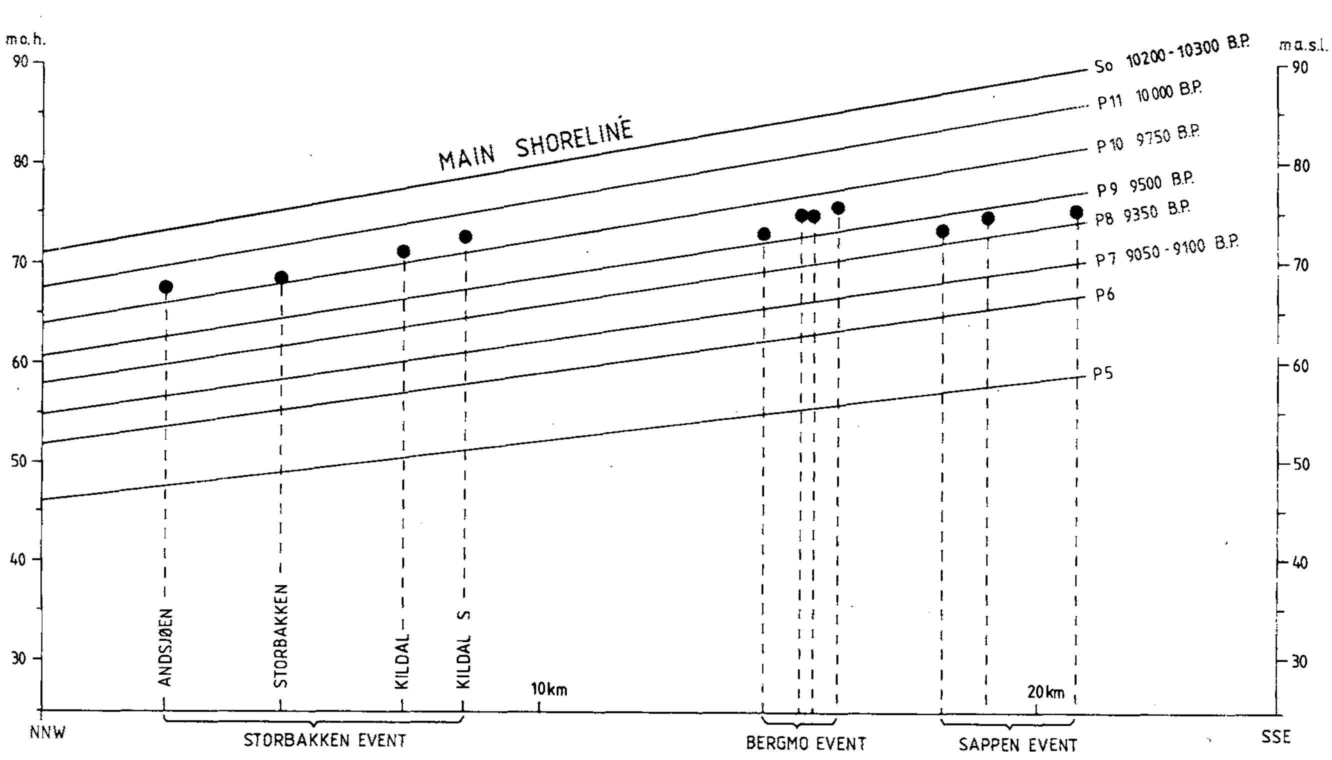

Figure 4. Shoreline relation diagram with ML localities correlated to the Storbakken, Bergmo and Sappen events.

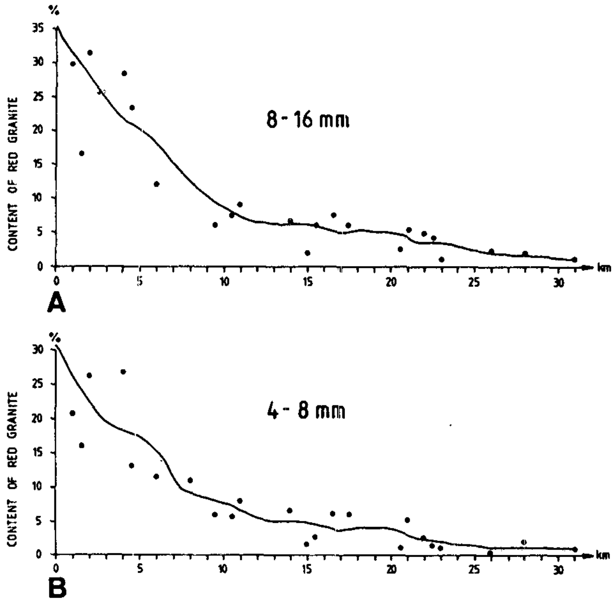

Figure 5. Variation in the content of red granite in tills along a profile parallel to the main regional ice movements. The curves are based on the running mean of the granite percentages.
A. Fraction 8-16 mm.
B. Fraction 4- 8 mm.

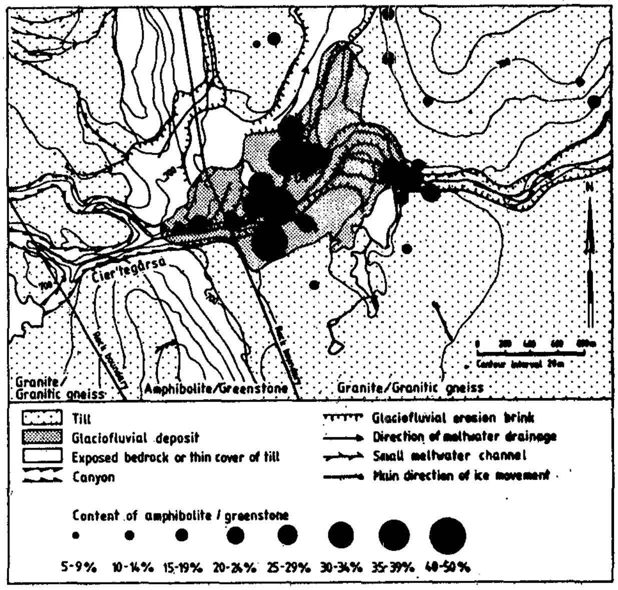

Figure 6. The distribution of amphibolite/greenstone (fraction 4-8 mm) in the Čier'tegårsa outwash deposit and the surrounding till deposits.

carried out on the outwash deposits at the mouth of the Čier'tegårsa canyon (Figs. 2, 6 and 7).

The canyon cut through a hill of amphibolite-greenstone with granitic gneisses on both sides. The outwash deposits were accumulated in contact with the ice margin in the east, partly in small marginal ice-dammed lakes. Terraces at heights between 690 and 660 m a.s.l. indicate fast lowering of the water table and the base of erosion during the formation of the deposits.

The distribution of *amphibolite/greenstone* (fraction 4-8 mm) shows that the highest terrace (680-690 m a.s.l.) consists of only 10-20% of these rocks (Fig. 6). On the lower terrace, c. 670 m a.s.l. there is a marked increase up to 40-50%. The content in the lowest terraces (660-665 m a.s.l.) is more variable, but still relatively high. In the tills the content is only 10-15%.

The content of *granitic gneisses* is relatively high in the upper outwash terrace, low in the middle terrace and more variable in the lowest ones.

The distribution pattern for *copper* show a marked contrast between the outwash deposits and the till (Fig. 7). The interpretation of geochemical patterns in glaciofluvial deposits involves a consideration of the sorting processes during meltwater transport and sedimentation. Concentrations of heavy minerals occur in some layers. However, the generally high concentrations of copper in the outwash deposits cannot be explained by the sorting of heavy minerals alone.

The *genesis* of these deposits is interpreted as follows: During the early deglaciation, the Č canyon was partly filled with till, deposited by the ice moving transversely to the canyon. The litho-

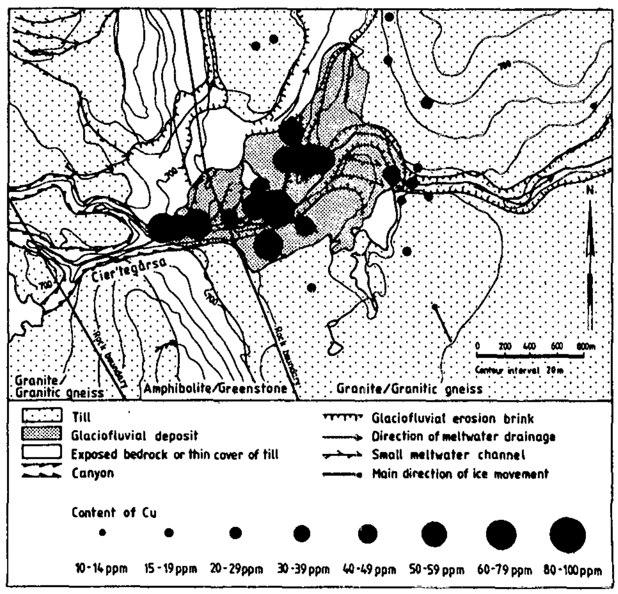

Figure 7. The distribution of copper (fraction <2 mm) in the Čier'tegårsa outwash deposit and the surrounding till deposits.

logical composition of this till was normal for the area, with a content of amphibolite of about 10-20% and granitic gneisses 60-70%. Geochemically, the till deposits were influenced by hydromorphic processes. Ground water from the local bedrock drained to the canyon. Because of the high background values in these amphibolite/greenstone rocks, a local enrichment of copper and nickel in the till took place. When the overflow drainage through the canyon started, the meltwater erosion was intense in the till and the material was transported down to the margin of the eastern ice. The sediments were partly deposited towards the ice margin, but a great deal was washed away laterally or sublaterally to the north. The highest terraces therefore consist mainly of washed till with the original composition almost intact. Gradually, as the ice melted and the base of erosion dropped, the meltwater removed most of the till and started eroding the bedrock. More material from the local rocks was transported to the mouth of the canyon and deposited in the middle terrace. The deposition of the lowest terraces is more complex due to erosion in the older glaciofluvial terraces. If this model of genesis is tolerably correct, it indicates roughly a maximum vertical erosion in bedrock of 10 m in the Čier'tegårsa canyon during the deglaciation.

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