The Stuoragurra Fault, evidence of neotectonics in the Precambrian of Finnmark, northern Norway

ODLEIV OLESEN

Olesen, O. 1988: The Stuoragurra Fault, evidence of neotectonics in the Precambrian of Finnmark, northern Norway. *Norsk Geologisk Tidsskrift,* Vol. 68, pp. 107–118. Oslo 1988. ISSN 0029-196X.

Several fault lines, of Late Glacial or Holocene age, occur along an 80 km long zone trending SW–NE on Finnmarksvidda. The faults appear as well defined, often linear steps in the otherwise smooth till cover. Northeast of the lake of Iešjav'ri the fault crosscuts glaciofluvial deposits, indicating that at least one section of the fault is of Holocene age. The maximum observed displacement is 7 metres. The western block is depressed. Electromagnetic (VLF) measurements indicate locally a southeasterly dip, which implies that sections of the Stuoragurra Fault are reverse or low angle thrusts. Older fracture zones in the area were identified by interpreting aeromagnetic data. This interpretation map yields distinct sets of dislocations whose main directions are 30°W, 5°E and 42°E. It is concluded that the Late Quaternary faults partly coincide with the older fault zones, but that Late Quaternary fracturing outside these zones also occurs locally. The recent seismicity occurs along an elongate cluster oriented NE–SW, about parallel to the neotectonic structures. This indicates that the mechanisms which produced the faulting are possibly still active. It is concluded that stress associated with spreading at the Mohns, Knipovich and Nansen Ridges, viscous drag force at the base of the lithosphere and colliding resistance along the southern border of the Eurasian plate are likely to be important contributors to the mechanism generating faults. The release of these stresses could, however, be related to the deglaciation period.

Odleiv Olesen, Geological Survey of Norway, P.O. Box 3006 Lade, N-7002 Trondheim, Norway.

It has generally been assumed that the postglacial emergence, which totally dominates the recent tectonics of Scandinavia, has a smooth pattern in time and space. As the earth's crust within the Baltic shield is fairly stable, earthquakes are relatively few and of low intensity (see Ahjos & Korhonen 1984). For this reason fault scarps that occur in many places have always been considered to be of pre-Quaternary age. During the last twenty years, however, the Late Quaternary faults shown in Fig. 1 have been documented in northern Finland (Kujansuu 1964) and in northern Sweden (Lundqvist & Lagerbäck 1976). Tanner (1930) had previously discussed evidence for Holocene faulting in the Fiskerhalvøya peninsula in the USSR close to the Norwegian border. Lundqvist & Lagerbäck (1976) and Lagerbäck (1979) have given a short summary of previous works dealing with Late Quaternary faulting in Scandinavia. To their list should be added two cases of displacement of Holocene shorelines in Norway, in Møre (Holtedahl 1959) and in Lofoten (Grønlie 1922), and a distinct fault in Nordmannvikdalen in Troms (Sollid & Tolgensbakk 1988). This NW–SE orientated fault (cf. Fig. 1) was discovered in 1978 during fieldwork on the map-sheet Kåfjord (Tolgensbakk & Sollid 1988). Based on investigations of marine sediments from interglacials, Mangerud et al. (1981) and Sejrup (1987) suggest a considerable long-term neotectonic uplift, 10–40 m, of western Norway during the last 125,000 years.

In connection with the debate on nuclear-waste storage, further geological and geophysical investigations of the neotectonic phenomena have been performed in Sweden (Mörner 1977; Lagerbäck & Witschard 1983; Henkel et al. 1983; Wahlström & Kulhánek 1983; Talbot 1986) and Finland (Kuivamäki & Vuorela 1985; Kukkonen & Kuivamäki 1985). For the same reasons, Adams (1981, 1984) described postglacial faults in eastern Canada which occur mostly as small-displacement thrusts in a broad arc from western Ontario to southern Newfoundland.

Recently a present active fault in Scandinavia has been detected. Bakkelid & Skjøthaug (1985) and Bakkelid (1986) found that a part of the town of Egersund in southern Norway has been upthrown approximately 4 cm relative to the other part of the town during the last 34 years. This displacement rate (~1 mm/year) is in the same magnitude as if the 5–10 m of displacement

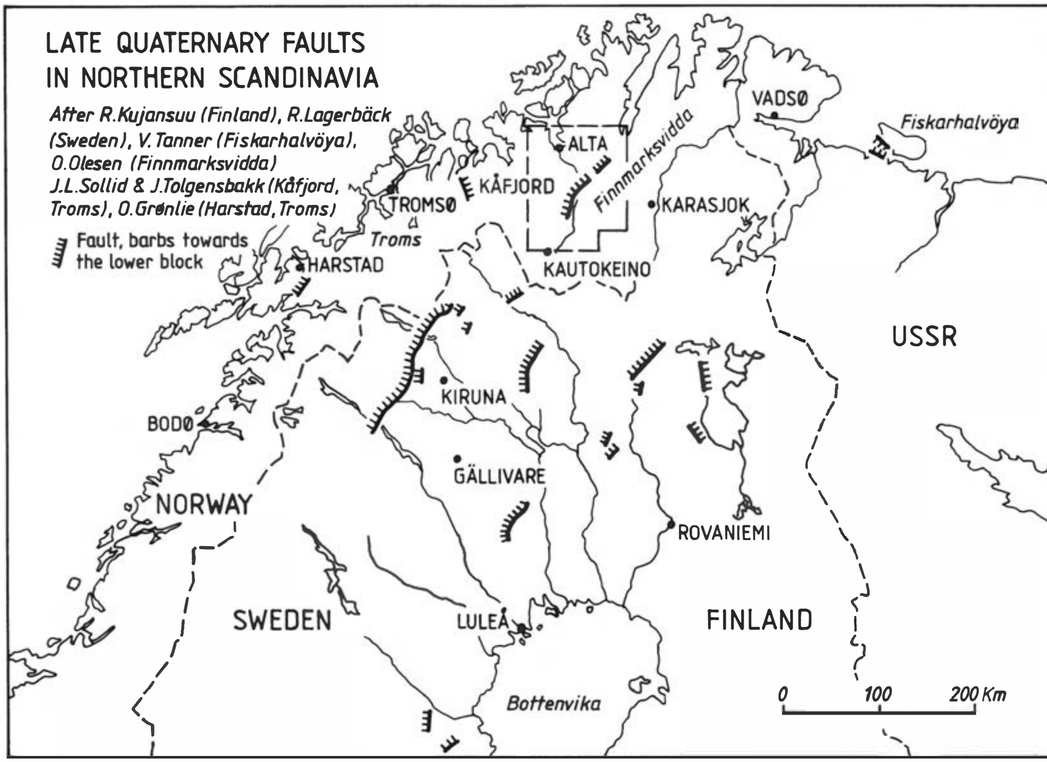

Fig. 1. Late Quaternary faults in northern Fennoscandia from Lagerbäck & Witschard (1983), Grønlie (1922) and Sollid & Tolgensbakk (1988). The Stuoragurra Fault is added to the map and an area covering this fault is framed.

often observed in Late Quaternary faults was distributed uniformly over a period of 10,000 years. The detection of the young fault in Egersund consequently throws new light on the previously mapped Late Quaternary faults. The possibility of present activity along these faults cannot be ruled out.

Description and age of the Stuoragurra Fault

During follow-up work of geophysical interpretations in the Nordkalott project, the first part of the Stuoragurra Fault was discovered in 1983 and reported by Olesen (1984). Stuoragurra means large gorge in Lappish and is named after a pass to the northeast of Masi, where the young fault occurs. The fault was originally named the Masi Fault, but this name had to be abandoned because it had already been used for the Masi Formation.

The fault line is shown in Fig. 2. It is relatively continuous for 80 km, from Skar'rejav'ri south of Masi in a northeasterly direction to Lævnjašjåkka west of Skoganvarre. The southern part of the Stuoragurra Fault is also shown on a 1:50,000 scale geological map by Solli (1984). The faults occur as marked, linear and sharp steps in the generally smoothed till cover (Fig. 3). Along the whole extension of the fault, the downthrown side is to the northwest. The maximum observed vertical displacement is 7 metres. The drainage is often influenced by these faults since the scarps seem to govern the location of streams and swamps.

The Finnmarksvidda terrain was extensively smoothed during glaciations. It seems unlikely that these marked structures, often located at an angle of 45° to the last direction of the ice-flow, could exist for a long time beneath an active inland ice. The faults must therefore be formed during or after the last deglaciation. On the basis of an existing Quaternary map (Olsen, in prep.),

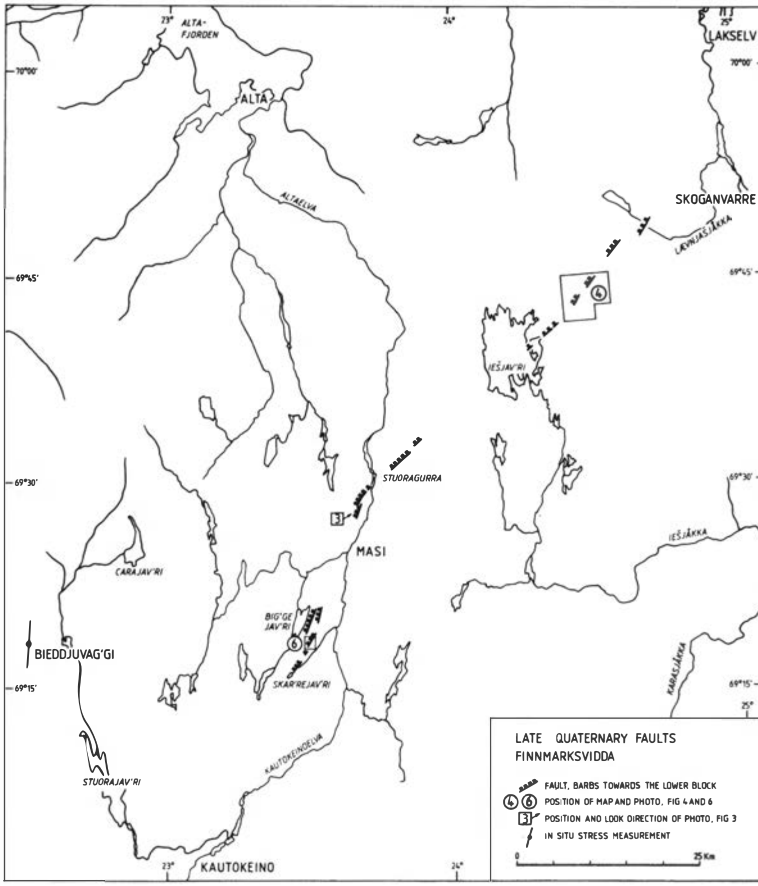

Fig. 2. Late Quaternary faults on Finnmarksvidda. *In situ* stress measurements from the Bieddjuvag'gi Mine (Berge & Li 1970; Stephansson et al. 1987) show that the maximum principal stress is compressional and horizontal. The azimuth direction of σ_{hmax} is N–S.

Fig. 3. Oblique aerial photograph of the Stuoragurra Fault (UTM 604500–7709000) looking NW, approximately 2 km north of Masi. The location is shown in Fig. 2. The fault crosscuts an elevation in the terrain. To the right is the maximum observed vertical offset along the fault, seven metres.

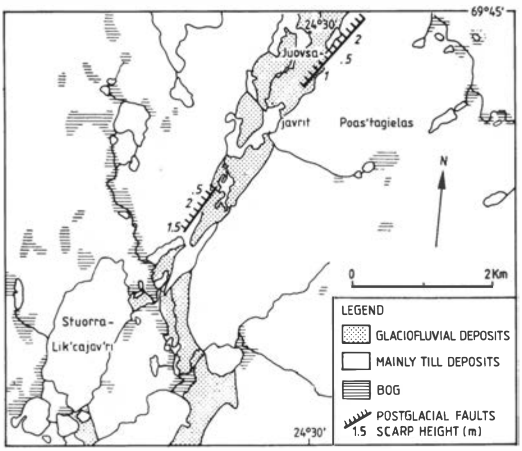

Fig. 4. Holocene faults northeast of the lake of Iešjav'ri superimposed on the Quaternary map from Olsen (in prep.). The faults crosscut glaciofluvial deposits which are interpreted to be less than 9,000 years old Olsen (in prep.). Numbers show observed scarp height. The location of the map is shown in Fig. 2.

the faults crosscut glaciofluvial deposits northeast of the lake of Iešjav'ri (Fig. 4). Thus, at least sections of the zone must have been formed after the deglaciation estimated to 9,000 BP (Olsen, in prep.).

The Stuoragurra Fault is mainly situated within the quartzites of the Masi Formation (Solli 1983) and the Skuvvanvarri Formation (Siedlecka 1985), and terminates towards amphibolites within the Karasjok Greenstone belt at the northeastern end (Siedlecka et al. 1985) (Fig. 5). At the southwestern end the fault terminates towards a pronounced positive Bouguer anomaly (Olesen & Solli 1985), suggesting that the Masi quartzite is underlain by amphibolites within the Kautokeino Greenstone Belt in this area. The area southwest of the lake of Iešjav'ri, where a section of the Stuoragurra Fault is missing, is also dominated by amphibolites. This phenomenon can be explained by quartzite being a more brittle rock, and consequently the stress only produces faults in the quartzite. A similar situation is also found in the case of the Late Quaternary Pärvie Fault in northern Sweden (Lagerbäck 1979). This fault is particularly developed in rocks of granitic composition and ends abruptly when it encounters basic rocks. It is also interesting to note that the Stuoragurra Fault occurs where the Bouguer gravity anomaly is low. According to Olesen & Solli (1985) this implies that the granitoid basement is situated closely underneath the Masi Formation, i.e. the amphibolites in the Gål'denvarri Formation (Solli 1983), which often occur in the position above the basement, are thin or absent. North of Masi (Fig. 5) the Late Quaternary fault touches the Kautokeino Greenstone Belt. The amphibolites in this area are flat-lying (Solli 1984) and from the Bouguer anomaly map (Olesen & Solli 1985) they can be interpreted to be thin (less than ~200 m).

No reliable strike-slip displacement has so far been observed along the Stuoragurra Fault. The dip-slip movement is indicated by the irregular course of the fault and by crosscutting topographic featues in the terrain not being significantly displaced (Fig. 3). Any strike-slip displacement larger than 10 m does not seem to be likely. Where the till cover is thin, outcrops with brecciated rocks often occur, e.g. east of the lake of Big'gejav'ri (UTM 598600–769420) and northeast of the lake of Iešjav'ri (UTM 401500–7737400).

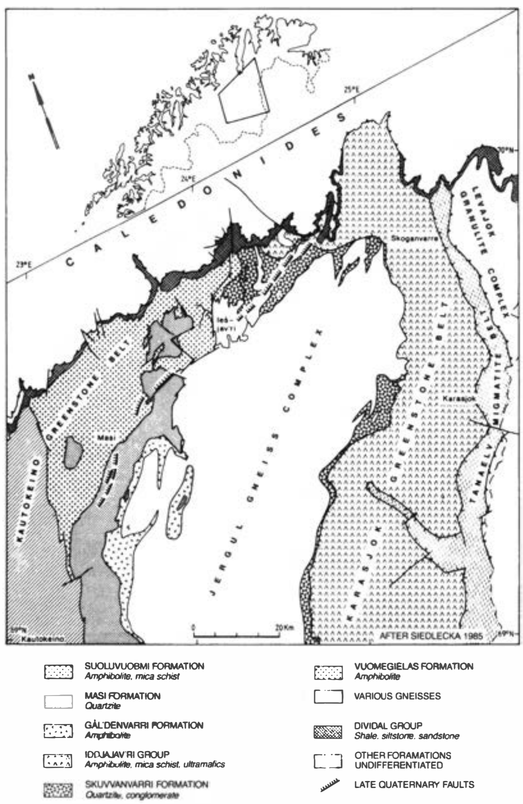

Fig. 5. Simplified geological map of Finnmarksvidda (Siedlecka 1985). The Stuoragurra Fault is added to the map.

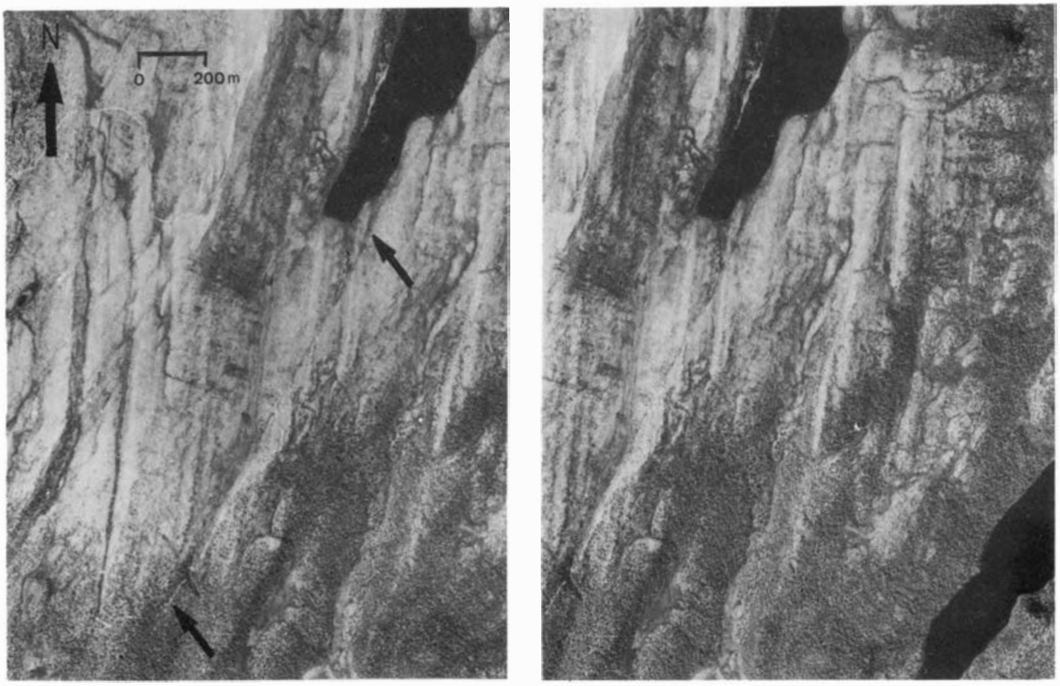

Fig. 6. A stereo-pair showing a section of the Stuoragurra Fault east of Big'gejav'ri (UTM 598000–7690000). The location is shown in Fig. 2. The direction of the Late Quaternary fault is NNE–SSW. The fault is shown by arrows. To the southwest a stream cuts across the scarp which is made up of till. To the northeast, however, where the till cover is thinner, the scarp consists of brecciated quartzite. The last ice-movement was from south to north. This direction is almost parallel to the strike of the bedding in the quartzite. The faults are unaffected by glacial activity and thus developed after the local glaciation.

In other places where the overburden is thicker, the whole escarpment consists of till. This can be seen east of Big'gejav'ri (UTM 598150–7690400) where a stream cuts across a 4 m high escarpment (Fig. 6).

Dislocation sets

Sixty to seventy percent of the Finnmarksvidda area is now surveyed with low-altitude geophysical (magnetic, electromagnetic and radiometric) measurements from helicopter. The survey was conducted at a measuring altitude of 50 m with 200–250 m line spacing. The whole of Finnmarksvidda had previously been covered by medium-altitude (150 m) aeromagnetic measurements with a line spacing of 1000 m in the Kautokeino area and 500 m in the Karasjok area. The flight direction was east–west.

The interpretation methods developed by Henkel (1975) have been applied to the aeromagnetic data from the Finnmarksvidda area. These methods include an estimation of magnetic dislocations. The term magnetic dislocations (Henkel 1979; Henkel et al. 1983) includes the phenomena: 1. Linear discordances in the anomaly pattern. 2. Displacement of reference structures. 3. Linear gradients. 4. Discordant linear minima. The first three phenomena in the anomaly pattern are effects arising from faulting. The last one is caused by oxidation of magnetite and formation of hematite along fracture zones (Henkel & Guzmán 1977), and is usually seen only on low-altitude measurements. It can consequently be assumed that magnetic dislocations are generally caused by faulting or fracturing.

To be able to reflect magnetic dislocations, the bedrock must contain sufficient magnetite and have variations in this content to ensure numerous anomalies on the aeromagnetic map. This is usually not a problem in Finnmarksvidda, where magnetic rocks are quite abundant. The reliability, however, of the dislocation map is higher in the areas covered by low-altitude measurements compared with the areas covered with

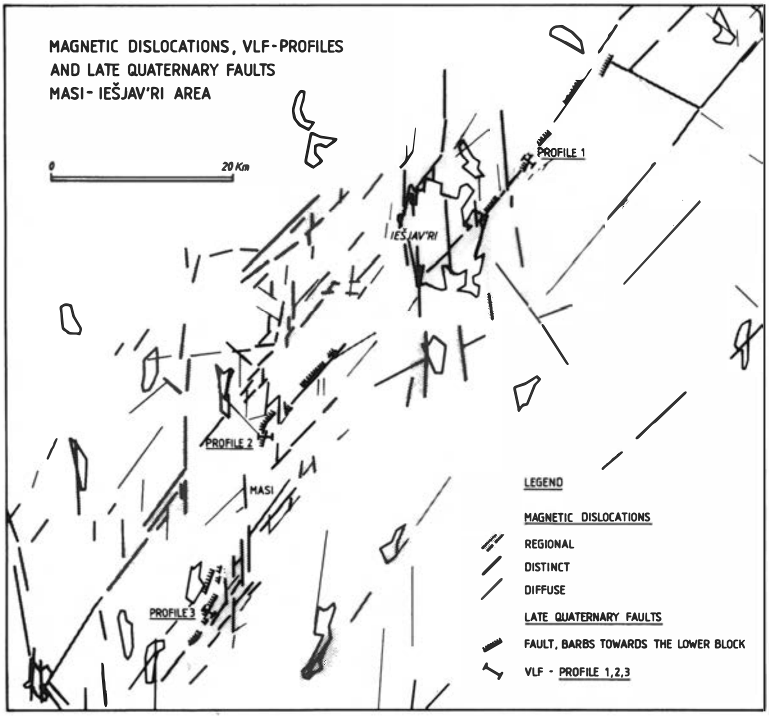

Fig. 7. Magnetic dislocations and Late Quaternary faults on northwestern Finnmarksvidda. Northeast and southwest of the lake of Iešjav'ri the Stuoragurra Fault coincides with northeast–southwest trending magnetic dislocations. North of Masi the Late Quaternary fault cuts across from following one magnetic dislocation to follow another south of Masi.

medium-altitude measurements, due to the inherent higher resolution.

The obtained dislocation map (Fig. 7) is treated statistically in order to obtain the characteristic properties of dislocations. The software system was developed by Rindstad (1980). The directions of dislocations are determined for each 1° interval. For each of these 1° steps all dislocations within a sector of ±2° are included. The distribution of all dislocations in Finnmarksvidda is shown as a rose diagram (Fig. 8). The upper half of the diagram shows the total length of dislocations within the 5° intervals while the lower half displays the number of dislocations within these intervals. There is a small difference between these two parts of the diagram. The NE–SW dislocations seem to be slightly longer than the others. Due to the averaging within the 5° sectors, the method involves some smoothing of the frequency distribution. Three directions dominate in the frequency distribution: 30°W, 5°E and 42°E. The 5°E trending dislocations may be the youngest because they seem to offset the 30°W and 42°E trending ones, but so far no systematic age relations have been observed. Thus, parts of the fracture system may have been activated at different times. This is also suggested by the existence and spatial distribution of the Late Quaternary faults. It is consequently the accumulated displacement that can be observed today.

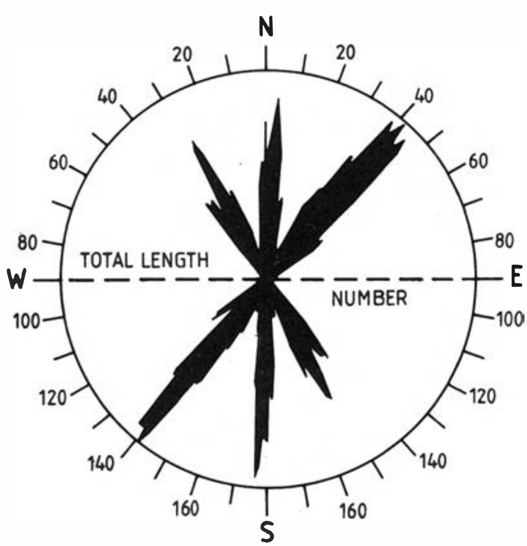

Fig. 8. Directions of dislocations on Finnmarksvidda.

The NW–SE and the N–S directions are very similar to directions of dislocations found in northern Sweden (Henkel 1979). The NE–SW direction is, however, 60°E in northern Sweden. Interpretations of lineaments from LANDSAT images of Finnmarksvidda (Rindstad & Follestad 1982) yield these direction: 30°W, 50°E and 85°E. The 85°E direction is unique, but the other two are very similar to the directions obtained from the aeromagnetic interpretations.

The connection of the Stuoragurra Fault to older fracture zones

One main direction of the dislocations, 42°E, coincides with the dominating directions of the Late Quaternary faults (Fig. 7). To the northeast, in the Iešjav'ri area, the Stuoragurra Fault coincides with an old fracture zone. To the west of the Kautokeino River the Stuoragurra Fault changes direction to NNE–SSW. From following one old fracture zone, the Stuoragurra Fault cuts across to follow another one south of the Masi settlement. This observation is supported by ground measurements using the VLF (Very Low Frequency) electromagnetic method. In regions of resistive soil and bedrock, the VLF method can be used to detect large water-containing fracture zones in the bedrock (Henkel & Eriksson 1980; Eriksson 1980). The three VLF profiles in Fig. 9 are located across three different parts of the Late Quaternary fault (Fig. 7). The fault crossings are marked with shading in Fig. 9. In two of these profiles the Stuoragurra Fault coincides with larger water-containing fracture zones (Fig. 7). In this context, it may be pointed out that such highly conductive fracture systems are frequent in the

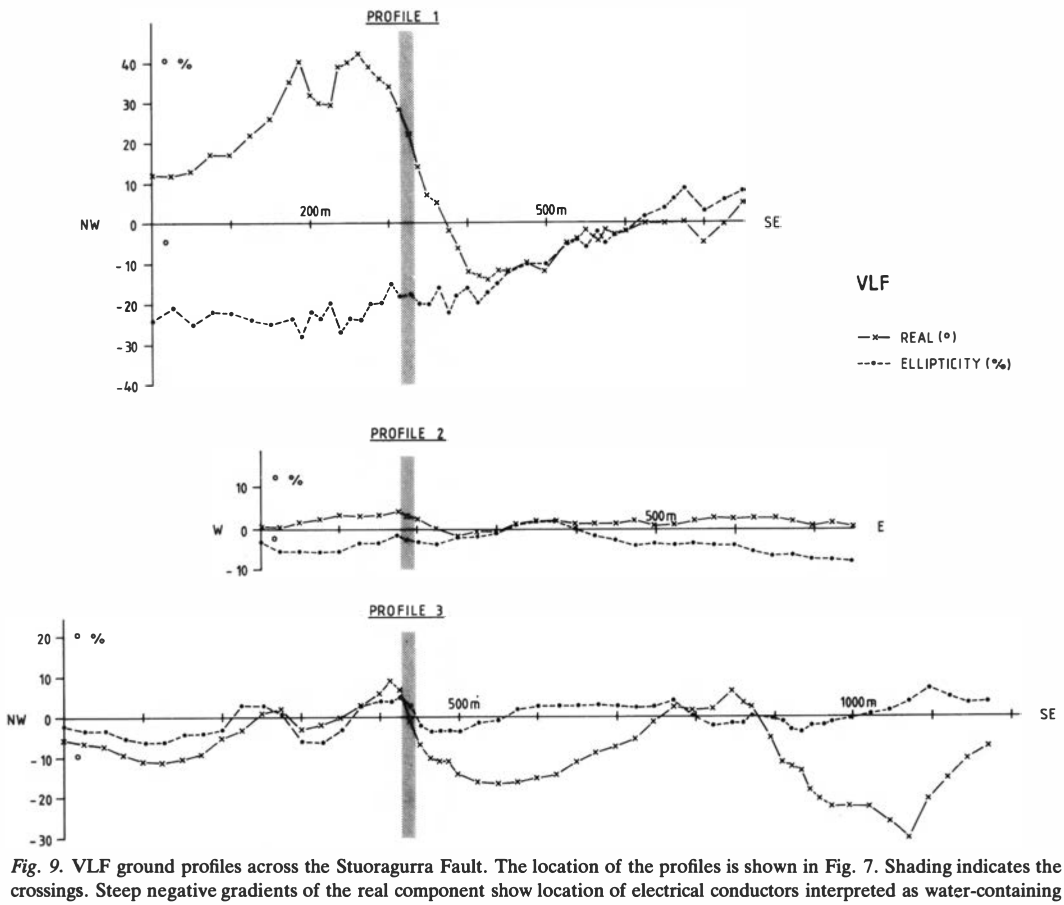

Fig. 9. VLF ground profiles across the Stuoragurra Fault. The location of the profiles is shown in Fig. 7. Shading indicates the crossings. Steep negative gradients of the real component show location of electrical conductors interpreted as water-containing faults.

Precambrian bedrock and are generally believed to be developed over a long period of time. The reason for this assumption is the close spatial relation of the Finnmarksvidda area to the Caledonian Front and the continental margin. The Late Quaternary motion consequently associates with fracture systems which have a considerably longer history. In the second profile shown in Fig. 9, however, the anomaly is very small. According to the previously mentioned aeromagnetic interpretations, the fault occurs where it cuts across from following one old fracture zone southwest of the lake of Iešjav'ri to follow another south of Masi (Fig. 7). This part of the fault consequently does not coincide with any older fracture zone. The shape of the VLF anomalies in profile 3 can be compared with standard curves by Kaikkonen (1979) suggesting that the conductor dips to the east. Additional VLF profiles south of Masi show similar results and therefore support the interpretation that sections of the Stuoragurra Fault are reverse faults or low-angle thrusts. It is more difficult to estimate the dip of the fault causing the large anomaly in profile 1 because a neighbouring fault is causing interference with the anomaly.

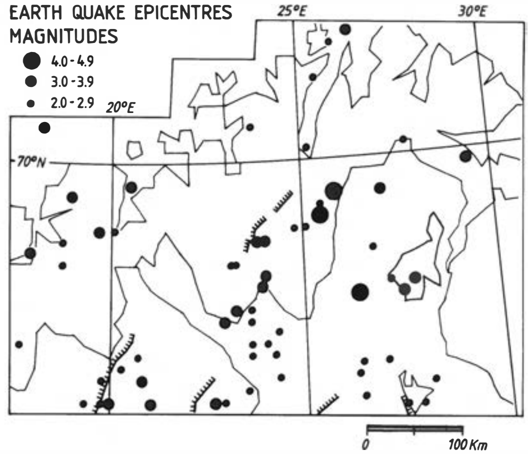

Fig. 10. Epicentral map of northern Fennoscandian earthquakes in the period 1758–1983 (Ahjos & Korhonen 1984). The Stuoragurra Fault and Late Quaternary faults in Finland and Sweden are shown.

Seismicity on Finnmarksvidda

In terms of the world-wide pattern of seismic activity, northern Fennoscandia is a stable area, but some seismically active zones occur (Husebye et al. 1978; Ahjos & Korhonen 1984), i.e. the Norwegian Shelf zone, the Norwegian Sea zone, the Bothnian zone and the Lapland zone. The Lapland zone, which has been interpreted to make up one NW–SE trending zone, may however, also include three shorter NE–SW trending zones. Figure 10, which is a part of the seismicity map of Fennoscandia compiled by Ahjos & Korhonen (1984), shows the location of earthquakes in Finnmark in relation to the Stuoragurra Fault. The earthquakes seem to make up a linear ca. 30 km wide cluster parallel to the fault. The location precision using macroseismic observations is probably better than 30 km for most small and medium-sized events (Husebye et al. 1978). The axis in this cluster is an extension of the northernmost of the three NE–SW trending zones within the Lapland zone. The axis is displaced approximately 30 km to the southeast of the fault, consistent with the observation that the faults dip to the southeast. This indicates that the forces which produced the Late Quaternary faulting in Finnmark may still be active. This possibility has previously been proposed by Lagerbäck (1979) for the Late Quaternary faults in northern Sweden. The focal depths to earthquakes in Fennoscandia are concentrated at 7–10 km, 20 km and 27 km (Ahjos & Korhonen 1984). The earthquakes on Finnmarksvidda could be generated at a fault plane dipping more gently than 45° to the southeast from the Stuoragurra Fault or they could be associated with another fault parallel to the Stuoragurra Fault. A microearthquake survey by Wahlström & Kulhánek (1983) has been performed along the Late Quaternary Lansjärv Fault. Several recorded events could be classified as being located near the fault and possibly associated with it.

Possible stress generating mechanisms

The fact that the Stuoragurra Fault terminates at greenstone belts at both ends does not necessarily mean that the stresses which caused the faulting are limited to the length of the fault zone. The deformation of the amphibolites in the greenstone belts is probably of a ductile or elastic nature and consequently does not involve faulting. The stresses may therefore have more regional importance than the length of the fault indicates. It is reasonable to assume that the Stuoragurra Fault and very similar faults in Finland and Sweden are parts of the same system. The faults are mostly parallel and are often extensions of each other (Fig. 1).

Factors believed to contribute to the stress field in northern Fennoscandia have been discussed by Husebye et al. (1978), Bungum & Fyen (1979), Lagerbäck (1979), Henkel et al. (1983) and Talbot (1986). They suggest that mainly two mechanisms, plate tectonics and glacio-isostatic uplift, may be responsible for the development of the faulting. The dominating type of Late Quaternary faults on Finnmarksvidda, as well as in the rest of northern Fennoscandia (Lagerbäck & Witschard 1983; Kukkonen & Kuivamäki 1985), is reverse or even low-angle thrust dipping to the southeast, indicating that compressional forces dominate the process. Talbot (1986) argues that this compressional stress regime in Fennoscandia is caused by a wrenching which is related to plate tectonics.

The present vertical motion of Fennoscandia as well as eastern Canada is thought to be induced by deglaciation (e.g. Peltier 1986). In eastern Canada, the stress associated with postglacial rebound does not generate its own earthquakes, but triggers earthquakes in pre-stressed regions. In doing so, the postglacial stress is rarely capable of dictating the focal mechanism of the earthquakes (Quinlan 1984). One of the important contributors to this earthquake generating stress field in eastern Canada is considered to be spreading (Mid-Atlantic) ridge stress (Hasegawa et al. 1985). Mörner (1980) also argues that the Fennoscandian uplift today is dominated by forces other than the isostatic.

Most *in situ* stress measurements in the Precambrian of Finnmark and adjacent areas in Sweden and Finland (Stephansson et al. 1987) show that the maximum principal stress is compressional and essentially horizontal. The azimuth direction of σ_{hmax} is N–S (Fig. 11), and the size is mainly 10–15 MPa at the surface. Plate tectonic stress, as illustrated in Fig. 11, can account for the compressional stress and fairly uniform azimuth direction in the upper crust of northern Fennoscandia. This stress is caused by ridge push associated with spreading at the Mohns, Knipovich and Nansen Ridges, transform resistance mainly along the Spitsbergen and Molloy fracture zones (Vogt 1986), continental drag force and colliding resistance along the southern border of the Eurasian plate (Fig. 11). A ridge represents an enormous mass of rock rising several kilometres above the abyssal ocean floor. The force exerted from this body is substantial. The Eurasian plate has the highest portion of continental area of all plates (Cox & Hart 1986). Mantle drag force is a resistive force that is weak beneath oceans and may be strong beneath the continents (Fig. 11). The absolute velocity vector found from the motion of the Eurasian plate relative to hotspots has a northwestern direction in northern

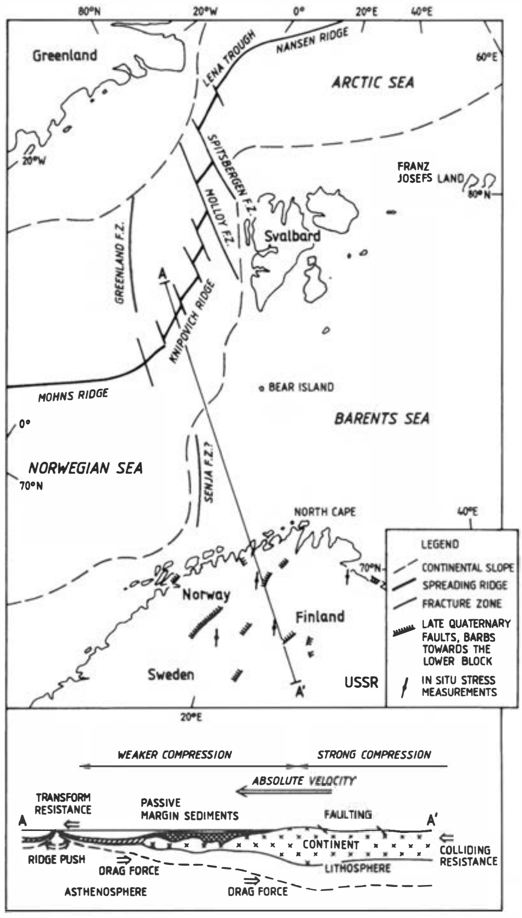

Fig. 11. Important plate tectonic structures in the Norwegian Sea and Barents Sea areas (after Vogt 1986) and late Quaternary faults in northern Fennoscandia (Grønlie 1922; Lagerbäck & Witchard 1983; Olesen 1985; Tolgensbakk & Sollid 1988). Direction of maximum principal stress from *in situ* stress measurements (Stephansson et al. 1987). Profile A–A[1] illustrates the plate tectonic forces causing stress in northern Fennoscandia (modified after Cox & Hart 1986). The absolute velocity of the Eurasian plate has a northwestern direction in northern Fennoscandia (Chase 1978). The direction of the viscous drag at the base of the lithosphere is consequently to the southeast.

Fennoscandia (Chase 1978). The direction of the viscous drag at the base of the lithosphere is consequently opposite. Collisional resistance along the southern border of the Eurasian plate will contribute to a compressional regime within this plate. The stress pattern induced by plate tectonic forces may however be modified by stress induced by glacio-isostatic uplift, sedimentary loading, thermal stress (Turcotte & Oxburgh 1976) and membrane stress (Turcotte 1974). The observed stress regime and distribution of earthquakes make it difficult to relate them exclusively to glacio-isostatic uplift (Bungum & Fyen 1979; Klein & Barr 1986; Talbot 1986). Based on the correlation between regional and global seismic activity, Båth (1984) also suggested that regional seismic activity in Sweden is linked to the global activity by plate tectonics, rather than land uplift after the deglaciation.

In situ stress measurements from the Bieddjuvag'gi Mine (Berge & Li 1970; Stephansson et al. 1987) show that σ_{hmax} is compressional with a N–S direction and a magnitude of 15 MPa at a depth of 100 m. This represents approximately 12 MPa at the surface (T. H. Hansen, pers. comm. 1987). The angle between the directions of σ_{hmax} and the faults is approximately 40° (Fig. 2), which could indicate that the faults are Riedel-shears. This, however, is puzzling because strike-slip components along the faults do not seem to be significant.

Late Quaternary faults seem to occur more frequently in northern Fennoscandia compared with southern Fennoscandia. Since compression due to ridge spreading is expected to be present over a wide region, the recent faults are probably due to the steep uplift gradient in the northern region. On the map of present rate of land uplift in Fennoscandia (Bjerhammer 1980) the change in present land uplift along profiles perpendicular to the coast seems also to be larger in Lapland than in southern Fennoscandia. Several factors, however, make the discovery of moderately high faults more difficult in southern Fennoscandia. These limiting factors include (Lagerbäck 1979): (1) denser afforestation, (2) a frequent rough relief (3) human activity in the landscape, such as agricultural pattern, timber fellings and roads, (4) abrasion and sedimentation below the highest shoreline.

The Stuoragurra Fault and the Pärvie Fault in Sweden coincide with a physiographic border. The mountainous area to the northwest has an average higher elevation than the area to the southeast. The ice was consequently thickest in the southeastern area. This would involve more depression during the glacial age and consequently a greater contribution to the following postglacial stress regime. The differential loading of ice across a prestressed fault line might consequently be sufficient to cause fracturing and reactivation of the fault, and so produce a fault scarp.

Conclusions

The occurrence of several Late Glacial and Holocene fault lines in Norway as well as in the rest of Fennoscandia suggests that fault movements play an important part in the postglacial regional uplift. The recent discovery of an active fault at Egersund in southern Norway supports this hypothesis.

The seismicity in the Finnmarksvidda area shows a cluster of earthquakes parallel to the Stuoragurra Fault, located approximately 30 km to the southeast of the fault. This is consistent with the observation that sections of the Stuoragurra Fault are reverse, upthrown towards the northwest. The forces which produced the Late Quaternary faulting may consequently still be active. The fracturing has mostly occurred along old fracture zones, but occasionally also in relatively unfaulted rocks. The stresses which caused this faulting most likely have a regional distribution. The limited length of the Stuoragurra Fault is probably due to termination towards amphibolites where the defomation can be more ductile or elastic. In this regional compressional system it is natural to incorporate the Late Quaternary faults in Sweden and Finland.

Important contributors to the fault generating mechanisms are believed to be stress associated with spreading of the Mohns, Knipovich and Nansen Ridges and viscous drag underneath the lithosphere. The release of these stresses can, however, be related to the deglaciation period. The contribution of the different plate tectonic forces to the observed stress is however puzzling and it is not likely that significant progress will be made until an improved understanding of the dynamics of the Late Quaternary faults is possible and more fault-plane solutions are available. Further investigations, especially in the coastal area of Norway, may also show that Holocene faulting is more widespread than previously known.

Acknowledgements. – The present study was partly carried out during the author's stay at the Department of Physics, University of Toronto. Support for this visit by the Geological Survey of Norway and the Royal Norwegian Council for Scientific and Industrial Research (Grant 2822) is gratefully acknowledged. I thank E. Dalsegg, L. Eriksson, T. Forslund, T. H. Hansen, H. Henkel, A. Krill, O. B. Lile, L. Olsen, J. R. Rønning, A. Sindre, O. M. Sæther, T. Torsvik and G. West for assistance and discussions. I am also grateful to Gunnar Grønli for drawing the figures and Tove Aune for word-processing the manuscript.

Manuscript received October 1987

References

Adams, J. 1981: Postglacial faulting: A literature survey of occurrences in eastern Canada and comparable glaciated areas. *Atomic Energy Canada Ltd. Technical Record TR–142*, 63 pp.

Adams, J. 1984: Glacial and postglacial stress changes in Ontario and Quebec: Their implications for rock fracture studies. Atomic Energy Canada Ltd. Unpublished Report AECL–7822, 191–199.

Ahjos, T. & Korhonen, H. 1984: On a catalogue of historical earthquakes in Fennoscandian area. *Institute of Seismology, University of Helsinki, Report S–10*, 23 pp.

Bakkelid, S. & Skjøthaug, P. 1985: Aktive geologiske forkastninger i Eigersund – foreløpige resultater. *Norges geografiske oppmåling. Publikasjon nr 2*, 13 pp.

Bakkelid, S. 1986: The discovery in Norway of a strongly active geological fault and some of its practical consequences. *Proceedings of the 10th General Meeting of the Nordic Geodetic Commission*, Sept.–Oct., Helsinki, 237–245.

Berge, I. & Li, B. 1970: Bergmekanisk undersøkelse ved Biddjovagge Gruber A/S. Unpublished report. Bergmekanikklaboratoriet, Institutt for gruvedrift, Norges tekniske høgskole, 17 pp.

Bungum, H. & Fyen, J. 1979: Hypocentral distribution, focal mechanisms, and tectonic implications of Fennoscandian earthquakes, 1954–1978. *Geologiska Föreningen i Stockholm Förhandlingar 101*, 261–271.

Båth, M. 1984: Correlation between regional and global seismic activity. *Tectonophysics 104*, 187–194.

Bjerhammar, A. 1980: Postglacial uplifts and geopotentials in Fennoscandia. *In*: Mörner, N. A. (ed.), *Earth Rheology, Isostasy and Eustasy*. John Wiley & Sons, New York, pp. 323–326.

Chase, C. 1978: Plate kinetics: The Americas, East Africa, and the rest of the world. *Earth and Planetary Science Letters 37*, 355–368.

Cox, A. & Hart, R. B. 1986: *Plate Tectonics. How it Works.* Blackwell Scientific Publications, Palo Alto, California, 381 pp.

Eriksson, L. 1980: Elektriska och magnetiska metoder för påvisande av svaghetszoner i berg (Abstract in English). Unpublished Geophysical Report, Sveriges geologiska undersökning, SGU, 8012. 17 pp.

Grønlie, O. T. 1922: Strandlinjer, moræner og skjælforekomster i den sydlige del av Troms fylke. *Norges geologiske undersøkelse 94*, 39 pp.

Hasegawa, H. S., Adams, J. & Yamazaki, K. 1985: Upper crustal stresses and vertical stress migration in eastern Canada. *Journal of Geophysical Research 90*, 3637–3648.

Henkel, H. in Witschard, F. 1975: Description of the geological maps Fjällåsen NV, NO, SV, SO. *Sveriges geologiska undersökning Af 17–20*, 97–125.

Henkel, H. 1979: Dislocation sets in northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 100 (1978)*, 271–278.

Henkel, H. & Guzmán, M. 1977: Magnetic features of fracture zones. *Geoexploration 15*, 173–181.

Henkel, H. & Eriksson, L. 1980: Interpretation of low altitude airborne magnetic and VLF measurements for identification of fracture zones. *In*: Bergman, M. (ed.) *Subsurface Space*. Pergamon Press, Oxford.

Henkel, H., Hult, K., Eriksson, L. & Johansson, L. 1983: Neotectonics in northern Sweden – geophysical investigations. Svensk Kärnbränsleförsörjning AB/Avdeling KBS Unpublished Technical Report 83–57, 64 pp.

Holtedahl, H. 1959: Den norske strandflate med særlig henblikk på dens utvikling i kystområdene på Møre. *Norsk Geografisk Tidsskrift 16*, 285–305.

Husebye, E. S., Bungum, H., Fyen, J. & Gøystdal, H. 1978: Earthquake activity in Fennoscandia between 1497 and 1975 and intraplate tectonics. *Norsk Geologisk Tidsskrift 58*, 51–68.

Kaikkonen, P. 1979: Numerical VLF modeling. *Geophysical Prospecting 27*, 815–834.

Klein, R. J. & Barr, M. Y. 1986: Regional state of stress in Western Europe. *Proceedings of the International Symposium on Rock Stress Measurements*, Stockholm, Sept. 1986, 33–44.

Kuivamäki, A. & Vuorela, P. 1985: Käytetyn ydinpolttoaineen loppusijoitukseen vaikuttavat geologiset ilmiöt Suomen kallioperässä (Abstr. in English). Geologian tutkimuskeskus, ydinjätteiden sijoitustutkimukset. Unpublished Report YST–47.

Kujansuu, R. 1964: Nuorista sirroksista Lapissa. Summary: Recent faults in Lapland. *Geologi 6*, 30–36.

Kukkonen, I. & Kuivamäki, A. 1985: Geologisia ja geofysikaalisia havaintoja Pasmajärven ja Suasseljän postglasiaalisista siirroksista (Abstr. in English). Geologian tutkimuskeskus, ydinjätteiden sijoitustutkimukset. Unpublished Report YST–46, 14 pp.

Lagerbäck, R. 1979: Neotectonic structures in northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 100 (1978)*, 271–278.

Lagerbäck, R. & Witschard, F. 1983: Neotectonics in northern Sweden – geological investigations. Statens kärnbränsleförsörjning AB/Avdeling KBS. Unpublished Technical Report 83–58, 58 pp.

Lundqvist, J. & Lagerbäck, R. 1976: The Pärve fault: A late-glacial fault in the Precambrian of Swedish Lapland. *Geologiska Föreningens i Stockholm Förhandlingar 98*, 45–51.

Mangerud, J., Sønstegaard, E., Sejrup, H. P. & Haldorsen, S. 1981: A continuous Eemian–Early Weichselian sequence containing pollen and marine fossils at Fjøsanger, western Norway. *Boreas 10*, 137–208.

Mörner, N. A. 1977: Rörelser och instabilitet i den svenske berggrunden. Kärnbränslesäkerhet, Stockholm. Unpublished Technical Report 18, 36 pp.

Mörner, N. A. 1980: The Fennoscandian uplift: Geological data and their geodynamical implications. *In*: Mörner, N. A. (ed.), *Earth Rheology, Isostasy and Eustasy*. John Wiley & Sons, New York, 251–284.

Olesen, O. 1984: Postglacial forkastningssone ved Masi, Finnmark. Abstr. NGF IX Landsmøte, Tromsø Jan. 1985. *Geolognytt 20*, p. 50.

Olesen, O. 1985: Sen-/post-glaciale forkastninger ved Masi, Finnmark. Unpublished Report Norges geologiske undersøkelse, NGU, 84.171, 27 pp.

Olesen, O. & Solli, A. 1985: Geophysical and geological interpretation of regional structures within the Precambrian Kautokeino Greenstone Belt, Finnmark, North Norway. *Norges geologiske undersøkelse 403*, 119–129.

Olsen, L. in prep.: Karasjok. Quaternary geological map, scale 1:250,000 with description. Abstract in English. Geological Survey of Norway.

Patterson, W. S. B. 1972: Laurentide ice sheet: Estimated volumes during Late Wisconsin, *Reviews of Geophysics and Space Physics 10*, 885–917.

Peltier, W. R. 1986: Deglaciation-induced vertical motion of the North American continent and transient lower mantle rheology. *Journal of Geophysical Research 91*, 9099–9123.

Prest, V. K. 1983: Canada's heritage of glacial features. *Geological Survey of Canada Miscellaneous Report 28*, 119 pp.

Quinlan, G. 1984: Postglacial rebound and the focal mechanisms of eastern Canadian earthquakes. *Canadian Journal of Earth Sciences 21*, 1018–1023.

Rindstad, B. 1980: Digitale metoder for behandling av lineamenter med eksempler fra Finnmark. *Unpublished Report Norges geologiske undersøkelse, NGU, 1561–02*, 21 pp.

Rindstad, B. & Follestad, B. 1982: Digital methods for lineament analysis. *Proceedings EARSEL-ESA Symposium, Igls, Austria.* 211–214.

Sejrup, H. P. 1987: Molluscan and foraminiferal biostratigraphy of an Eemian–Early Weichselian section on Karmøy, southwestern Norway. *Boreas 16*, 27–42.

Siedlecka, A. 1985: Geology of the Iešjav'ri–Skoganvarre area, northern Finnmarksvidda, North Norway. *Norges geologiske undersøkelse 403*, 103–112.

Siedlecka, A., Iversen, E., Krill, A. G., Lieungh, B., Often, M., Sandstad, J. S. & Solli, A. 1985: Lithostratigraphy and correlation of the Archean and early Proterozoic rocks of Finnmarksvidda and the Sørvaranger district. *Norges geologiske undersøkelse 403*, 7–36.

Solli, A. 1983: Precambrian stratigraphy in the Masi area, Southwestern Finnmark, Norway. *Norges geologiske undersøkelse 380*, 97–105.

Solli, A. 1984: Masi, foreløpig berggrunnsgeologisk kart 1933 IV, M 1:50,000. *Norges geologiske undersøkelse.*

Sollid, J. L. & Tolgensbakk, J. 1988: Kvartærgeologisk og geomorfologisk kartlegging på Svalbard og fastlands-Norge utført ved Geografisk institutt, Univ. i Oslo. *Abstract 18. Nordiske Geologiske Vintermøte, København*, 380–381.

Stephansson, O., Särkkä, P., Myrvang, A., Hansen, T. H., Väätäinen, A., Dahlström, L. O., Bergström, K. & Fjeld, O. K. 1987: Fennoscandian rock stress data base – FRSDB. *Research Report TULEA 1987:006.*

Talbot, C. 1986: A preliminary structural analysis of the pattern of post-glacial faults in northern Sweden. Svensk kärnbränsle-försörjning AB/Avdeling KBS. Unpublished Technical Report 86.20, 36 pp.

Tanner, V. 1930: Studier över kvartärsystemet i Fennoskandias nordliga delar. IV. *Bulletin de la Commission Géologique de Finlande 88*, 594 pp.

Tolgensbakk, J. & Sollid, J. L. 1988: Kåfjord, kvartærgeologi og geomorfologi 1:50,000, 1634 II. Geografisk institutt, Universitetet i Oslo.

Turcotte, D. L. 1974: Membrane tectonics. *Geophysical Journal of the Royal Astronomical Society 36*, 33–42.

Turcotte, D. L. & Oxburgh, E. R. 1976: Stress accumulation in the lithosphere. *Tectonophysics 35*, 183–199.

Vogt, P. R. 1986: Geophysical and geochemical signatures and plate tectonics. *In*: Hurdle, B. G. (ed.), *The Nordic Seas.* Springer Verlag, New York, 413–662.

Wahlström, R. & Kulhánek, O. 1984: The Lansjärv fault – seismically active or dead? *Geologiska Föreningens i Stockholm Förhandlingar 105 (1983)*, p. 334.