

A contemporary small-scale thrust-fault near Lebesby, Finnmark

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A displaced drillhole in phyllites in a road-cut at Skogvika, Laksefjord, Finnmark, shows a reverse-fault offset of 5.8 cm, the thrust vector directed towards 118°. The thrust-fault parallels the 40° dipping, axial surface slaty cleavage of Caledonian folds. The displacement has occurred at some time during the 3-year period between the summers of 1986 and 1989. It is suggested that this very recent reverse slip, which is about coaxial with the contemporary, regional, horizontal compressive stress in northern Fennoscandia, can be explained as resulting from a release of accumulated strain energy, triggered either by a seismic event or perhaps by the actual blasting of the road-cut. Aseismic creep may also have contributed to the overall finite displacement.

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Introduction

Although it forms part of a relatively stable continent, northern Scandinavia experiences a fair amount of seismotectonic activity which tends to be concentrated along certain composite fracture zones (Husebye et al. 1978; Bungum 1989; Talbot & Slunga 1989; Bungum et al. 1991). Little is known about the incremental strains produced by these irregular seismic events. On the other hand, a good deal of field evidence has accrued in recent years, aided by aerial and satellite photography, supporting the observation of late- or post-glacial faulting (Kujansuu 1964; Lundqvist & Lagerbäck 1976; Lagerlund 1977; Lagerbäck 1979, 1990; Olesen 1988; Bäckblom & Stanfors 1989). Many of these neotectonic faults are recording recent and variable motions along pre-existing much older structures.

The purpose of this short contribution is to report evidence of an extremely recent, small-scale, reverse-fault movement in phyllites along the eastern side of Laksefjord, south of Lebesby, in Finnmark. In this particular case the reverse-slip motion, less than 6 cm, is recorded by an offset in a road-cut drillhole and must have occurred at some time, or times, during the years 1986 to 1989.

Regional setting

The Lebesby district of eastern Laksefjord is underlain by metasedimentary rocks of assumed latest Proterozoic age forming part of the Kalak (KNC) and Laksefjord Nappe Complexes (LNC) of Caledonide tectonostratigraphy. The strongly mylonitic NE–SW trending contact between the amphibolite-facies Kalak rocks and underlying lower greenschist-facies LNC metasediments is exposed just south of the settlement Lebesby (Fig. 1).

The road-cut locality featured in this account occurs in the dominantly phyllitic Friarfjord Formation (Føyn 1960, 1979; Føyn et al. 1983) of the LNC.

During a major phase of the protracted Caledonian orogeny, the age of which has not yet been determined precisely, the LNC rocks were strongly folded and acquired their metamorphic fabric. In the area considered here the pervasive slaty cleavage of the Friarfjord Formation phyllites is axial planar to NE–SW trending tight folds which are overturned towards the southeast. In addition, there is a variably developed NW–SE trending stretching lineation, which reflects the southeastward thrusting of the LNC in Caledonian time.

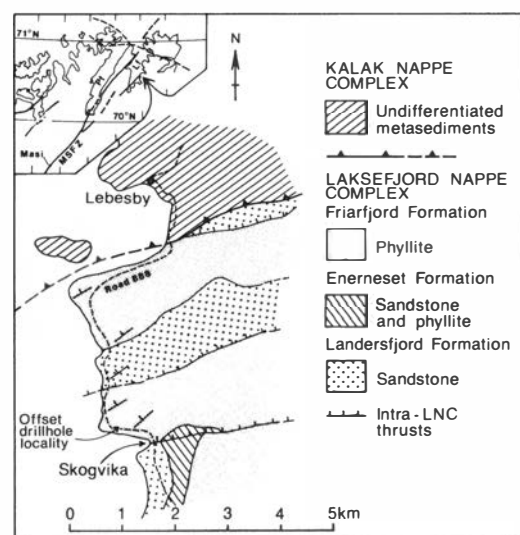


Fig. 1. Simplified geology of the Lebesby-Skogvika area showing the location of the offset drillhole. Dip/strike symbols indicate tectonically modified bedding. The slaty cleavage/schistosity is broadly strike-parallel to bedding, though of variable dip depending on fold-limb location. On the inset map, the Mierujavri-Svæholt Fault Zone (MSFZ) and basement fault southwest of Lebesby are indicated.

Drillhole offset

The Friarfjord Formation is well exposed along the coast and in road-cuts at Skogvika, south of Lebesby (Fig. 1). The road 888 was widened by blasting in the early summer of 1986 and asphalted one year later (Lars Haukvik, pers. comm. 1990). The drillhole offset was recorded by the present writer in 1989 during geological mapping on 1:50,000 map-sheet 'Lebesby' 2136 II. It is located at grid-reference MU004229 on a stretch of road trending ca. E–W.

At this locality the Friarfjord Formation comprises a dark grey phyllite with slightly paler grey silty layers and thin beds of grey silty sandstone. The sequence is inverted just here, with bedding dipping to the northwest at 55° – 60° and the slaty cleavage dipping in the same direction at just less than 40° , strikes diverging by only 10° . In the vicinity, mesoscopic folds plunge at low angles to the northeast, and a stretching lineation within the cleavage plunges towards 318° – 320° .

The road-cut is here from 6.5 to 7.0 m in height, and the road is at ca. 80 m a.s.l. The ground above the road-cut rises gradually towards the north-northeast to a hilltop at 160 m a.s.l. positioned some 300 m from the road. The displacement of the steeply inclined drillhole, at ca. 2 m above road level, has occurred along a 7–9 mm thick, conspicuous, movement surface which is exactly parallel to the prominent, 40° -dipping, slaty cleavage (Figs. 2 and 3). It was impossible to take a sample of the actual fault rock product along this thin slip surface, which in part appears as a weathered-out feature. Careful measurement of the reverse-slip offset showed this to be 5.8 cm (in August 1989), with the hanging-wall having been displaced up-dip in the direction 116° – 120° . No mesoscopic slickenside lineation has been detected which could indubitably be taken to stem from this young movement. It can be noted that similar, thin but noticeable, cleavage-parallel, apparent fault surfaces have been



Fig. 2. The Friarfjord Formation phyllites showing the drillhole displaced along a marked planar discontinuity which is parallel to the penetrative, Caledonian, slaty cleavage. The sedimentary layering and lamination can just be seen, dipping at a steeper angle than the cleavage. Photo looking approximately northeast; grid-ref. MU 004229, Skogvika. The pencil is 15 cm in length.



Fig. 3. Close-up of the drillhole offset, looking ca. 45° up from the horizontal in an approximately northerly direction. Scale – eraser on pencil measures 2.3 cm.

observed in other road-cuts in Friarfjord Formation phyllites, but in these cases, although joints may be displaced, there are no drillhole 'markers' to constrain the timing of movement.

Discussion

Borehole offsets of the type described above have been reported from different parts of North America (e.g. Block et al. 1979; Schäfer 1979; Bell 1985), and not always in seismically active regions. Very recent faulting would be an expected ruptural response in zones of plate convergence or plate-bounding strike-slip characterised by frequent earthquake or other seismic activity. In this northern part of the Baltic Shield, seismicity is of a particularly low magnitude. Post-glacial faults are not uncommon, but no cases of contemporary faulting have hitherto been reported from northern Scandinavia.

In view of the isolated nature of the described offset phenomenon, it would be inappropriate at this stage to discuss at length the possible cause, or causes, of the movement. Geometrically, the feature represents a reverse- or thrust-fault, which has occurred along and reactivated a pre-existing Caledonian slaty cleavage in a strongly anisotropic lithology. The release of an approximately ESE-directed (ca. 118°) compressive stress is interesting, in that this is broadly coaxial with the Caledonian thrust vector in the LNC, a fact which is perhaps

coincidental rather than directly meaningful. Small reverse-faults similar to that described here but utilising Taconic slaty cleavages have been reported from North-east USA and Canada (Oliver et al. 1970).

Mechanisms such as frost-heaving, expansion ascribed to glacial unloading, and topographic load-induced release of stored elastic strain energy have all been appealed to in some cases of contemporary fault displacement (Lawson 1911; Oliver et al. 1970; Hatcher & Webb 1981); however, these are not considered relevant in the present case. Offsets ascribed to blasting operations can also be expected, but unlike the example described here from Skogvika these are generally gravity-controlled dip-slip displacements of comparatively small blocks or rock masses. Such features have been observed by the writer in road-cuts in other parts of Norway. In the present case it is, nevertheless, not inconceivable that the blasting may have initiated the release of stored strain energy in the rock mass. The mechanism of radial, static load-induced, shear movement from a topographic high (cf. Hatcher & Webb 1981) cannot be applicable here as the drillhole offset vector is normal to that which would be expected from such load-induced movement.

A more likely cause of the Skogvika thrust-fault offset can be sought in a consideration of the current regional stress field against a background of the known seismicity, or microseismicity, of northern Fennoscandia. Work on post-glacial faults in this region (Kujansuu 1964; Lagerbäck 1979, 1990; Olesen 1988; Bäckblom & Stanfors 1989) has revealed a major component of thrust-fault movement along ancient NE–SW trending structures. This has also been confirmed by studies on present-day and historic seismic activity, and in particular by detailed interdisciplinary studies of the type conducted in the Lansjärv area of northern Sweden (Bäckblom & Stanfors 1989). In this particular case, fault-plane solutions, in-situ stress measurements and structural studies (Bjarnason et al. 1989; Slunga 1989; Talbot et al. 1989) together present a current kinematic picture depicting a maximum horizontal compression (σ_1) trending ca. WNW–ESE (300° – 120°). Current stress pattern data in the northern Fennoscandian region, and in Finnmark in particular, are comparatively inadequate to allow more than generalisations to be made (Stephansson et al. 1986; Myrvang 1988; Stephansson 1988). The only existing map of global tectonic stress orientations (Zoback et al. 1989) shows a broadly NW–SE to WNW–ESE σ_1 in this region that is readily ascribed to ridge-push plate-tectonic forces (cf. Chase 1978; Olesen 1988; Talbot & Slunga 1989). Earthquake focal mechanism solution data from the Norwegian Sea and wellbore breakout analyses also support this broad NW–SE ridge-push compressive stress (Klein & Barr 1986; Bungum et al. 1991).

The borehole thrust-fault offset described here can thus be conveniently explained in terms of a release of accumulated strain energy in the framework of the contemporary, upper crustal, regional stress field, the slip vector directed, as it is, towards ca. 118° . While

the triggering mechanism can be assumed to have been seismic, there is little evidence of major, or even moderate, earthquake activity in this part of Finnmark (Bungum 1989; Bungum et al. 1991). Seismic monitoring in the Lansjärv area, however, over a 17-month period from 1987 to 1989 recorded over 90 earthquakes of magnitudes M_L 0.1–3.6 (Slunga 1989); and with a frequency of slightly more than one seismic event per week. Moreover, since a causal relationship between intraplate seismic events, plate motion and seismic energy release along the North Atlantic Ridge (Båth 1978) has now been fairly convincingly demonstrated (Meyer et al. 1988; Skordas et al. 1991), it is not inconceivable that seismically induced fault movements on the mm and cm scale may be more common than we have hitherto believed.

In Finnmark, the Holocene Stuoragurra Fault (SF), near Masi, trends NE–SW, dips southeast at ca. 30° and shows evidence of several metres of reverse-slip displacement (Olesen 1988). A linear belt of earthquake epicentres parallels the SF, situated some 30 km to the southeast of the fault zone; this suggests that the fault may still be intermittently active (Olesen 1988). The SF is part of the Mierujavri–Sværholt Fault Zone (Olesen et al. 1990, fig. 8), which extends northeastwards to northern Laksefjord and adjacent offshore areas. A parallel, NE–SW fault detected from displaced aeromagnetic anomalies is located in the basement in southern Laksefjord and may possibly extend, at depth, beneath the Lebesby–Skogvika area.

Accepting a seismic trigger for stress release and generation of the Skogvika thrust-fault offset, it is impossible to know if the full 5.8 cm displacement occurred in one event or if this has been incremental – perhaps with one principal initial offset followed by gradual or episodic aseismic slip or creep. Only future monitoring of the offset will allow us to determine if the displacement continues, and whether or not it is incremental.

Another aspect of this, and other field observations in the Friarfjord Formation is that there may be a far greater cumulative thrust, or simple shear, displacement than the 5.8 cm recorded by the fortuitous drillhole ‘strain marker’ reported here. One way of allowing future generations of geologists to monitor contemporary small-scale fault-slip would be to drill and expose new boreholes in existing road-cuts. Detailed observation of existing joints, in relation to potential slip surfaces, can also help in this little studied field of contemporary fault tectonics. A rather more sophisticated monitoring of active strains though not necessarily of specific faults, can perhaps be achieved by setting up a network of recording stations for Global Positioning Satellites (GPS). Such a network has already been established in parts of Sweden (Talbot 1991), and is being planned in Norway.

Conclusions

An offset drillhole in a road-cut in phyllites at Skogvika in eastern Laksefjord, Finnmark, denotes that there has

been a reverse-fault displacement of 5.8 cm, directed towards ca. 118°, at some time during the period from the early summer of 1986 to the late summer of 1989. The thrust-fault parallels the 40°-dipping, axial-surface slaty cleavage of Caledonian folds in the Friarfjord Formation of the Laksefjord Nappe Complex.

Investigations on post-glacial faults in northern Fennoscandia, including Finnmark, comprising structural, in-situ stress, seismicity and fault-plane solution studies, have revealed a maximum horizontal compressive stress in the uppermost crust trending between NW–SE and WNW–ESE. The small thrust-fault at Skogvika can thus be explained as resulting from a release of accumulated strain energy, triggered perhaps by a seismic event or even initiated by the actual blasting of the road-cut. Future observation of the offset should show if any further movements occur and, if so, either by sudden, seismic increments or by slow aseismic creep. Observations elsewhere in road-cuts in Friarfjord Formation phyllites suggest that other cleavage-parallel thrusts may be present. Cumulative reverse-slip displacement within the phyllite formation may thus be a great deal more than the few centimetres recorded at Skogvika.

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References

- Bell, J. S. 1985: Offset boreholes in the Rocky Mountains of Alberta, Canada. *Geology* 13, 734–737.
- Bjarnason, B., Zellman, O. & Wikberg, P. 1989: Drilling and borehole description. In Bäckblom, G. & Stanfors, R. (eds.): Interdisciplinary study of post-glacial faulting in the Lansjärv area, northern Sweden 1986–1988. *Svensk Kärnbränslehantering Technical Report 89–31*, 7:1–7:14.
- Block, J. W., Clement, R. C., Lew, L. R. & de Boer, J. 1979: Recent thrust faulting in southeastern Connecticut. *Geology* 7, 79–82.
- Bungum, H. 1989: Earthquake occurrence and seismotectonics in Norway and surrounding areas. In Gregersen, S. & Basham, P. W. (eds.): *Earthquakes at North-Atlantic Passive Margins: Neotectonics and Post-glacial Rebound*, 501–519. Kluwer Academic Publishers, Dordrecht.
- Bungum, H., Alsaker, A., Kvamme, L. B. & Hansen, R. A. 1991: Seismicity and seismotectonics of Norway and nearby continental shelf areas. *Journal of Geophysical Research* 96, 2249–2265.
- Bäckblom, G. & Stanfors, R. 1989: Interdisciplinary study of post-glacial faulting in the Lansjärv area, northern Sweden 1986–1988. *Svensk Kärnbränslehantering Technical Report 89–13*.
- Båth, M. 1978: Energy and tectonics of Fennoscandian earthquakes. *Tectonophysics* 50, 9–17.
- Chase, C. 1978: Plate kinematics: the Americas, East Africa and the rest of the world. *Earth and Planetary Science Letters* 37, 355–368.
- Føyn, S. 1960: Tanafjord to Laksefjord. Guide to Excursion A3. *Norges geologiske undersøkelse* 212a, 45–54.
- Føyn, S. 1979: Foreløpig berggrunnskart Lebesby 1:100,000. *Norges geologiske undersøkelse*.
- Føyn, S., Chapman, T. J. & Roberts, D. 1983: Adamsfjord og Ul'lugai'sa. Beskrivelse til de berggrunnsgeologiske kart 2135 I og 2135 II–M 1:50,000. *Norges geologiske undersøkelse* 381, 78 pp.
- Hatcher, R. D. & Webb, F. 1981: Recent thrusting in the Appalachians. *Nature* 292, 389–390.
- Huseby, 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.
- Klein, R. J. & Barr, M. V. 1986: Regional state of stress in Western Europe. In Stephansson, O. (ed.): *Rock Stress and Rock Stress Measurements*, 33–44. Centek, Luleå, Sweden.
- Kujansuu, R. 1964: Nuorista sirroksista Lapissa. Summary: recent faults in Lapland. *Geology* 6, 30–36.
- Lagerbäck, R. 1979: Neotectonic structures in northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 100, 271–279.
- Lagerbäck, R. 1990: Late Quaternary faulting and paleoseismicity in northern Fennoscandia, with particular reference to the Lansjärv area, northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 112, 333–354.
- Lagerlund, E. 1977: Förutsättningar för moränstratigrafiska undersökningar på Kullen i Nordvästskåne – teoriutveckling och neotektonikk. Department of Quaternary Geology, University of Lund, Thesis 5, 1–106.
- Lawson, A. C. 1911: Post-glacial faults near Banning, Ontario. *Bulletin of the Seismological Society of America* 1, 159–166.
- Lundqvist, J. & Lagerbäck, R. 1976: The Pärvie Fault; a late-glacial fault in the Precambrian of Swedish Lapland. *Geologiska Föreningens i Stockholm Förhandlingar* 98, 45–51.
- Meyer, K., Olsson, R. & Scherman, S. 1988: Stress migration in the North Atlantic and intraplate seismicity in Scandinavia – a proposal. *Tectonophysics* 156, 175–178.
- Myrvang, A. 1988: Rock stress measurements in Norway: recent results and interpretations. Report, Workshop on Nordic Rock Stress Data. SINTEF, Trondheim, 10 October 1988. 5 pp.
- Olesen, O. 1988: The Stuuragurra Fault. Evidence of neotectonics in the Precambrian of Finnmark, northern Norway. *Norsk Geologisk Tidsskrift* 68, 107–118.
- Olesen, O., Roberts, D., Henkel, H., Lile, O. B. & Torsvik, T. H. 1990: Aeromagnetic and gravimetric interpretation of regional structures in the Caledonides of West Finnmark and North Troms, northern Norway. *Norges geologiske undersøkelse* 419, 1–24.
- Oliver, J., Johnson, T. & Dorman, J. 1970: Postglacial faulting and seismicity in New York and Quebec. *Canadian Journal of Earth Sciences* 7, 579–590.
- Schäfer, K. 1979: Recent thrusting in the Appalachians. *Nature* 280, 223–226.
- Skordas, E., Meyer, K., Olsson, R. & Kulhánek, O. 1991: Causality between interplate (North Atlantic) and intraplate (Fennoscandia) seismicities. *Tectonophysics* 185, 295–307.
- Slunga, R. 1989: Analysis of the earthquake mechanisms in the Norrbotten area. In Bäckblom, G. & Stanfors, R. (eds.): Interdisciplinary study of postglacial faulting in the Lansjärv area, northern Sweden 1986–1988. *Svensk Kärnbränslehantering Technical Report 89–31*, 5:1–5:14.
- Stephansson, O. 1988: Ridge push and glacial rebound as rock stress generators in Fennoscandia. *Bulletin of the Geological Institutions of the University of Uppsala* 14, 39–48.
- Stephansson, O., Särkkä, P. & Myrvang, A. 1986: State of stress in Fennoscandia. In Stephansson, O. (ed.): *Rock Stress and Rock Stress Measurements*, 21–32. Centek, Luleå, Sweden.
- Talbot, C. J. 1991: GPS networks to measure active strains in Sweden. *Geologiska Föreningens i Stockholm Förhandlingar*, in press.
- Talbot, C. J., Munier, R. & Riad, L. 1989: Reactivation of Proterozoic shear zones. In Bäckblom, G. & Stanfors, R. (eds.): Interdisciplinary study of postglacial faulting in the Lansjärv area, northern Sweden 1986–1988. *Svensk Kärnbränslehantering Technical Report 89–31*, 4:1–4:17.
- Talbot, C. J. & Slunga, R. 1989: Patterns of active shear in Fennoscandia. In Gregersen, S. & Basham, P. W. (eds.): *Earthquakes at North Atlantic Passive Margins: Neotectonics and Postglacial Rebound*, 441–466. Kluwer Academic Publishers, Dordrecht.
- Zoback, M. L. et al. (29 co-authors) 1989: Global patterns of tectonic stress. *Nature* 341, 291–298.