Contemporary stress orientation features in bedrock, Trøndelag, central Norway, and some regional implications

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Based on *in situ* rock stress measurements and contemporary stress orientation structures observed at diverse sites in Trøndelag, it can be shown that the Møre-Trøndelag Fault Complex marks an important structural divide separating crustal blocks with disparate, present-day stress fields. This supports earlier proposals reached by both field and numerical modelling studies; and, in one case, our data confirm published predictions that contrasting contemporary stress fields should, theoretically, characterise the footwall and hangingwall blocks of this major fault zone. The prevalent NW-SE horizontal compression recorded in coastal areas of central Norway northwest of the Møre-Trøndelag Fault Complex accords with borehole breakout and earthquake focal mechanism solution data acquired offshore, indicating that this pattern is likely to relate to a distributed ridge-push force arising from divergent spreading along the active axial ridge of the North Atlantic Ocean. Taken as a whole, the combination of *in situ* rock stress measurements and field observations of drillhole reverse-slip offsets and complementary axial fractures is seen to provide a reliable indicator of the contemporary stress patterns existing in exposed bedrock.

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Introduction

Recent research in the field of neotectonics in Norway has revealed growing evidence that the near-surface continental crust of this western part of the Baltic Shield is not as inherently stable as geologists had earlier believed. Observations of Late Quaternary faults, notably in northern parts of Norway and Sweden (Lagerbäck 1979, 1990, Olesen 1988, Olesen et al. 1992, Mörner 2004) but also in some southern areas (Anda et al. 2002), coupled with seismotectonic investigations, some scattered stress measurements and information gained from drilling through faults (Myrvang 1988, 1993, Bungum 1989, Bungum & Lindholm 1997, Roberts et al. 1997) have all indicated the importance of neotectonic crustal movements. For a review of this topic and an assessment of the reported evidence of neotectonics, with an extensive bibliography, the reader is referred to Olesen et al. (2004); and to the neotectonic map of Norway and adjacent areas compiled by Dehls et al. (2000).

As well as these larger-scale manifestations of crustal instability, studies of contemporary, small-scale thrust faulting and other structural features revealed by drillholes in artificial road-cuts or quarry faces have provided additional information on the current crustal-surface stress regime, notably in Finnmark, northern Norway (Roberts 1991, 2000, Pascal et al. in press). These indicators of neotectonic stress orientation can then be compared with direct determinations of *in situ* rock stress made at various locations. In Finnmark county, although such rock-stress measurements are comparatively few (Myrvang 1993), the drillhole data do conform reasonably well with the contemporary horizontal stress regime (Roberts 2000).

In this contribution we present data from structural features revealed by road-cut drillholes in parts of Trøndelag, central Norway, and compare the results and interpretations with *in situ* rock-stress measurements recorded in this region over the last 2-3 decades. In central and southern Norway as a whole, the rock stress database is more comprehensive than in northern areas, thus allowing for more rigorous comparison between observation and measurement.

Rock stress in general

In Scandinavia, the early investigations of Hast (1958), measuring *in situ* stress in bedrock, showed that horizontal stresses almost always exceeded the theoretical horizontal stress ascribed to overburden. Later measurements in many locations, also in Norway, have reproduced this same general trend and, indeed, the major principal stress is commonly horizontal (e.g., Stephansson et al. 1986). On the contrary, measured vertical stresses in most cases correspond fairly well with the theoretical stress calculated from the thickness of overburden, at least down to depths of c. 500 m. It has been found, too, that the horizontal stress field in most locations is essentially anisotropic, where one component dominates, i.e., the principal horizontal stress, S_{Hmax}. In practical tunnelling and underground excavation, high horizontal stresses normal to the tunnel axis have, in many cases, created severe technical problems. This high stress is concen-

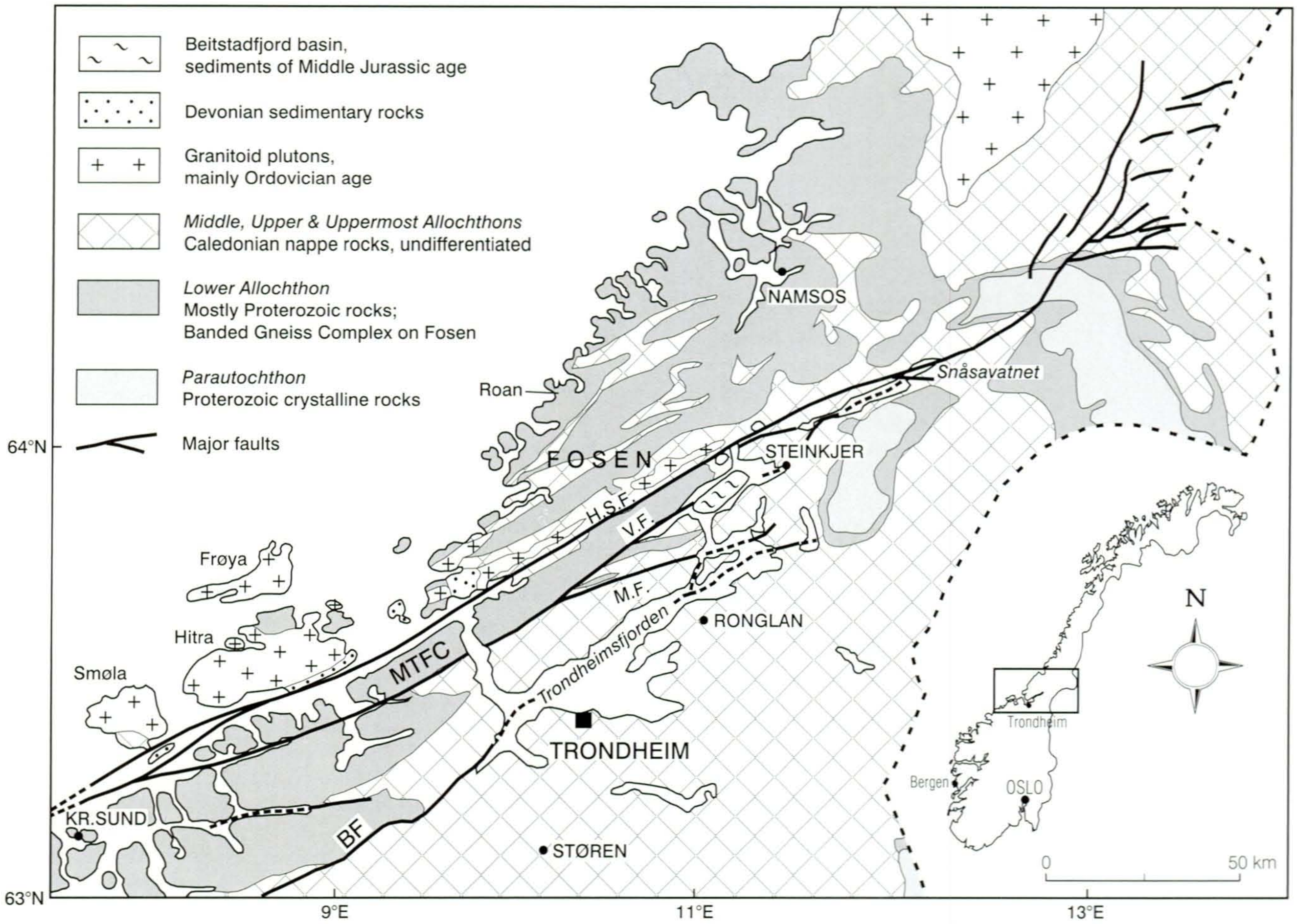

Fig. 1. Simplified geological map of the central Norway region. MTFC – Møre-Trøndelag Fault Complex; HSF – Hitra-Snåsa Fault; VF – Verran Fault; BF – Bæverdalen fault.

trated in the roof and floor areas of the tunnel, causing violent shear failure of the rock, a phenomenon known as spalling or rock burst. In several cases this has resulted in fatal accidents. This type of stress-related problem calls for comprehensive and expensive rock-support measures.

The same mechanism is also quite common in vertical petroleum wells offshore Norway, where high horizontal stresses will be concentrated in two, diametrically opposed points on the hole periphery, leading to violent failure, known in the petroleum industry as borehole breakouts.

In measuring *in situ* rock stresses, several techniques have been used in Norway over the years, including the use of both biaxial and triaxial gauges, and also the hydraulic fracturing, rock-stress measuring method (Myrvang 1993). Most measurements of stress magnitudes and horizontal stress vectors have been done by the Rock Mechanics Laboratory of the Norwegian University of Science and Technology, NTNU, in more than 200 locations, in mines, tunnels and boreholes. The data have been compiled in map form (e.g., Myrvang 1993, fig.2) which gives an immediate picture of the contemporary horizontal stress field operating in different parts of the country, and in which areas stress magnitudes are highest. Comparisons can then be made with the general bedrock geology and major fault patterns occurring in any one region, as has been done in the case of Finnmark county (Roberts 2000). In this contribution we consider neotectonic stress orientation indicators in relation to the current horizontal stress field in the Mid Norway region.

On a larger scale, inversion of earthquake focal mechanisms may be used to reveal the ratio between the principal stresses at depth, and thus provide information on the stress regime (Bungum & Lindholm 1997, Hicks et al. 2000).

Apart from stress measurements and focal mechanism studies, in many cases there may be surface phenomena present indicating high horizontal stresses (Myrvang 1998):

(i) Surface-parallel fractures known as exfoliation. These are extensional fractures caused by high horizontal compressive stresses. This is a near-surface phenomenon and exfoliation joints are rarely seen deeper than 20-30 m below the present-day surface. Exfoliation fracturing can be seen throughout Norway, particularly in competent Precambrian gneissic rocks, but it is also recorded in competent, multilayered younger rocks. In the Mid-Norway region, fine examples of exfoliation joints are exposed in the Roan district, which is also an area where reverse-slip displacements of drillholes have been recorded (see below, pp. 56-57).

(ii) Surface shear failure caused by high horizontal stresses acting at the bedrock surface. This can be seen on either a large or small scale, and surface spalling and exfoliation joints are commonly found in the same area and even in the same bedrock exposure.

Geological setting

Almost all the region considered here falls within the realm of the Caledonian fold belt, although there are evident differences in the character of the bedrock from area to area (Fig. 1). Western districts, for example, are dominated by Precambrian (Palaeoproterozoic) granitic gneisses, which were strongly reworked during the terminal Caledonian (Scandian) orogeny, whereas much of the inland region and areas north of Grong are underlain by nappes consisting mostly of Cambro-Silurian, metasedimentary and volcanic rocks with scattered intrusions of gabbro, diorite or granite (Sigmond et al. 1984, Nordgulen et al. 1993, Roberts & Stephens 2000). The youngest units are sedimentary rocks of Devonian age occurring on the southwestern Fosen Peninsula (Siedlecka 1975, Séranne 1992) and on several islands in this coastal district of central Norway (Siedlecka & Siedlecki 1972, Bøe & Sturt 1991).

A major feature of the geology of central Norway is the ENE-WSW-trending Møre-Trøndelag Fault Complex (MTFC) (Fig. 1). This composite, multiphase structure cuts through and displaces many of the Scandian nappes and thrust sheets, and has a history of movement and reactivation ranging from Devonian to Tertiary time (Grønlie & Roberts 1989, Grønlie & Torsvik 1989, Grønlie et al. 1991, Gabrielsen et al. 1999, Sherlock et al. 2004). Two major faults are recognised on land, the Snåsa-Hitra and Verran Faults, and an inferred third major structure, beneath Trondheimsfjord, is traceable to the southwest as the Bæverdalen fault (or lineament; Redfield et al. 2004). Lineament and fracture/fault patterns within and on either side of the MTFC show significant differences (Rindstad & Grønlie 1986, Grønlie et al. 1991, Gabrielsen et al. 2002), so much so that the MTFC has been considered as a fundamental crustal structure (Gabrielsen et al. 1999, Pascal & Gabrielsen 2001) that, on a seismic profile, can be traced down to depths of at least 15 km (Hurich 1996, Hurich & Roberts 1997). Gravimetric data also show the MTFC to be a major crustal structure with deep roots in the subsurface (Fichler et al. 1998, Skilbrei et al. 2002). Fission track studies have confirmed a type of upper-crustal, fault segmentation into elongate blocks (Grønlie et al. 1994, Redfield et al. 2004), with the inland areas showing evidence of Neogene uplift (Redfield et al. in press).

Contemporary stress features

During the course of fieldwork in this region over the last few years, in projects not involving neotectonics, the first author has recorded diverse examples of neotectonic stress orientation indicators in different types of bedrock. In the short descriptions that follow, only localities where several examples of the features can be seen, or where the evidence is indubitable, are taken into account. Isolated or less convincing examples that await future, detailed, systematic investigation are therefore not considered.

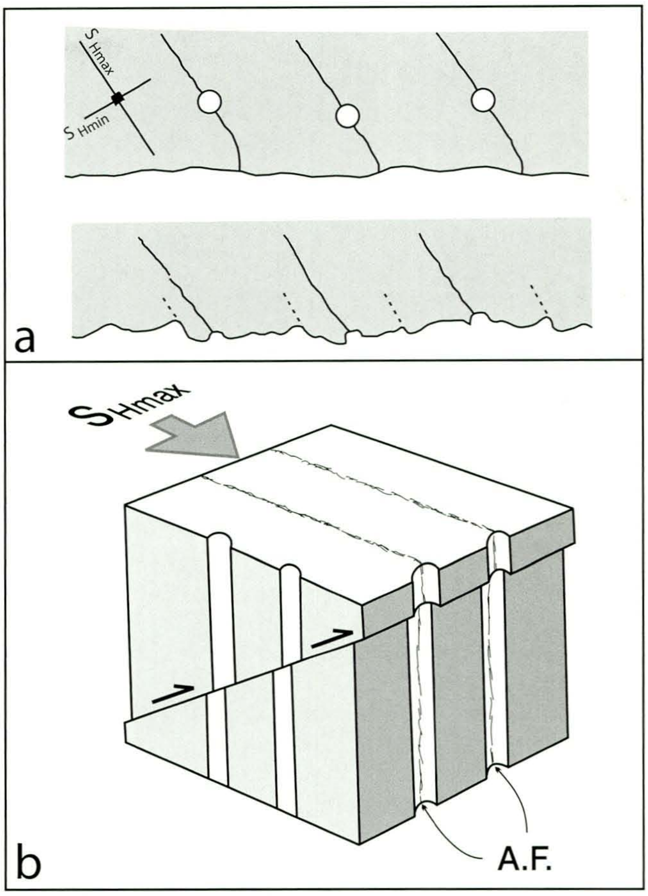

Fig. 2. (a) Inferred origin of axial fractures in the walls of vertical boreholes at the time of blasting. In the upper sketch (plan view of the rock body), gas pressure-induced fractures are generated parallel to SHmax. In the lower sketch, the same rock body is shown after blasting and removal of the rock mass. New joints (exposed breakage surfaces) are common parallel to the alignment of the axial fractures. Modified from Bell & Eisbacher 1996 and Roberts 2000).

(b) Simplified block diagram showing the coeval development of a reverse fault with offset drillholes and, on the orthogonal shaded wall, axial fractures (A.F.) in the concave drillholes. The extensional, axial fractures penetrate the rock body and lie within the plane of the maximum and intermediate stresses.

The structural features that are meaningful in the context of contemporary stress orientation are reverse-slip offsets of vertical to near-vertical drillholes (also called boreholes) in road-cuts, and axial fractures developed in the concave walls of many such drillholes (Fig. 2). Both these structures are regarded as stress-relief features that formed instantaneously at the time of road-cut blasting, essentially a sudden release of accumulated strain energy (Bell & Eisbacher 1996). The displacement vector of the offset records the direction of reverse slip along a minor fault or thrust surface and, in trend, is aligned parallel to S_{Hmax} or σ_1 (Fig. 2b). Axial fractures, on the other hand, are gas-pressure induced extensional fractures that propagated parallel to

S_{Hmax}, in the plane of σ_1 and the principal vertical stress, in most cases σ_3. An almost perfect example of such a fracture in a concave drillhole is shown in Fig. 3.

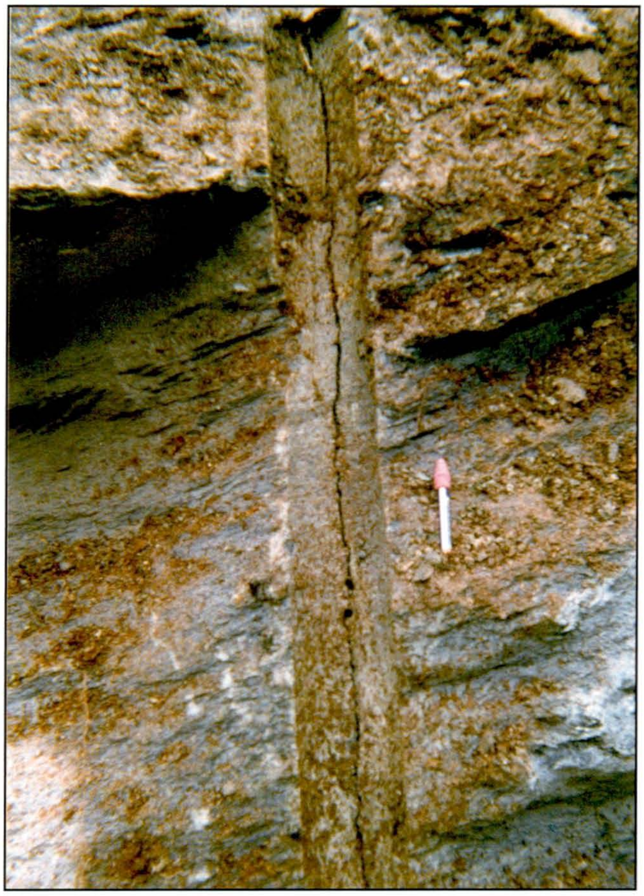

Fig. 3. A particularly well developed, continuous axial fracture in a drillhole penetrating mica schists. Locality along a new section of the E39 road, currently under construction, 1.5 km east of Børsa, southwest of Trondheim.

Reverse-slip offsets of drillholes

Two localities where clear, definitive examples of reverse-slip displacement of drillholes can be seen are near Roan, on the Fosen Peninsula, and along the E6 road close to Snåsavatnet (Fig. 1).

Roan: Along the road leading to Roan, south of Beskelandsfjorden, five separate examples of displaced drillholes have been recorded along a c. 150 m stretch of nearly continuous road-cut. The bedrock is a comparatively massive, quartz-monzonitic granulite gneiss of Palaeoproterozoic age. The road-cut here reaches up to 8 metres in height, and all the displaced boreholes measured occur in the lower accessible parts of the road-cut. The surfaces along which reverse slip has taken place all appear to be knife-sharp master joints (Fig. 4). Details of the separate displacements are as follows:-

(1) Offset of 3.5-4.0 cm towards 295° along a 008°/28° master joint (slip) surface.
(2) Offset of c. 2.5 cm towards 292° along a 026°/16° joint (slip) surface.
(3) Offset of 1.0-1.5 cm towards 288° along a 033°/25° joint (slip) surface.
(4) Offset of 1.5 cm towards 283° along a 038°/41° joint (slip) surface.
(5) Offset of c. 2.5 cm towards 268° along a 031°/22° joint (slip) surface.

As can be seen, the displacement vector of these separate thrust-faulted drillholes is reasonably consistent, averaging 285°. This would indicate that the S_{Hmax} in this particu-

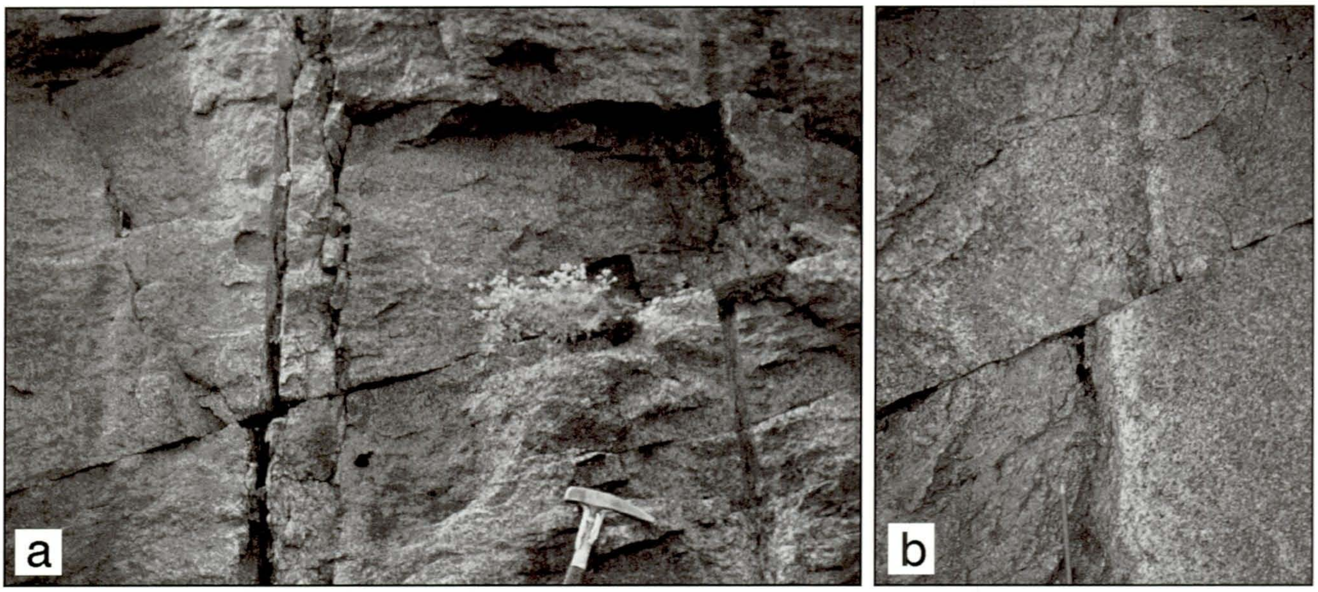

Fig. 4 (a) Reverse-slip offset of drillholes along an east-dipping joint in granulitic gneisses; from a road-cut south of Beskelandsfjorden, Roan, Fosen Peninsula, central Norway; looking south. (b) Close-up of a similar, reverse-slip displacement of a drillhole from the same locality, looking south. The reverse-slip motion in these areas is towards west-northwest.

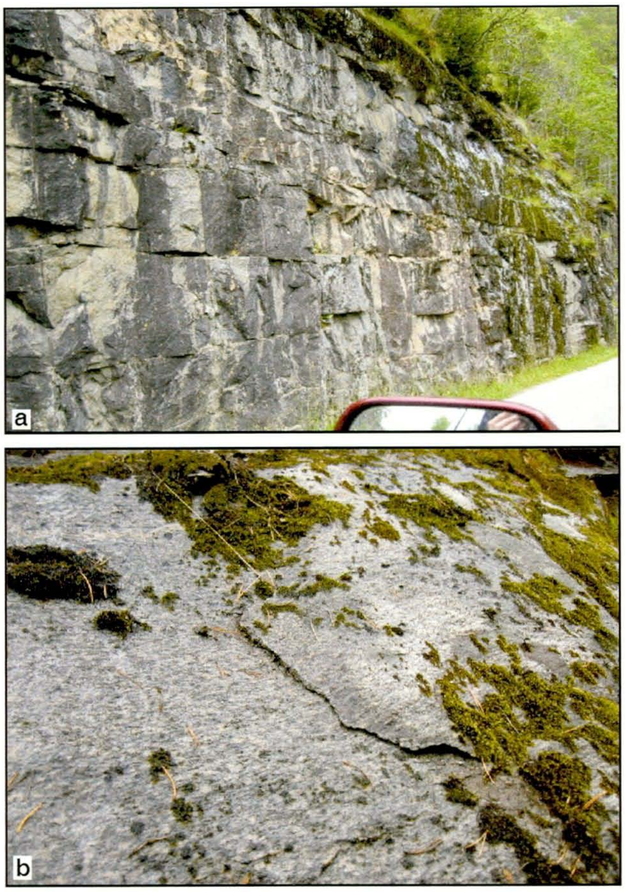

Fig. 5. (a) Surface-parallel, exfoliation fractures, indicative of high horizontal compressive stresses, are common in many areas. This example is from a road-cut close to Beskeland, c. 4 km northeast of Roan, Fosen Peninsula. (b) Small-scale surface spalling; from exposures close to Sumstad, 5 km northeast of Roan.

lar area trends c. WNW-ESE. Exfoliation jointing is also quite prominently developed in the Roan district (Fig. 5), a feature indicative of the current existence of high horizontal stresses in the surface and near-surface bedrock.

Snåsavatnet: Along a relatively new stretch of the main E6 road on the northwest side of Snåsavatnet, near the farm Haugan, reverse-slip displacements of drillholes can be seen in a c. 5 m-high cutting on the north side of the road in Middle Ordovician Snåsa Limestone. The offsets, reaching up to 7.5 cm, occur along a prominent 10-13 cm-thick shear (fault) zone with a strike/dip of 204°/13° (Fig. 6); and the thrust direction is towards 105°. Within the narrow shear zone, which is composed of crushed and gouged limestone, there are internal shear bands dipping northwest at c. 20°. The slip vector here denotes a WNW-ESE trend for S_{Hmax}, as in the case of the observations from the Roan area.

Axial fractures

Millimetre-wide, near-vertical fractures along the axes of comparably oriented drillholes are of quite variable and irregular occurrence. Their presence is, in part, dependent on lithology and structure, but in view of their inferred origin they are more likely to be developed in areas where the horizontal stress field is strongly anisotropic. Another restriction is that they are only likely to be present in a reasonably high percentage of drillholes in road-cuts or quarry walls aligned normal to S_{Hmax}. For this reason, meaningful and regularly developed axial fractures do not usually occur along road-cuts showing displaced drillholes.

Although several long road-cuts have been examined in the Mid Norway region, only two have been found so far which display abundant and thus significant, axial fractures.

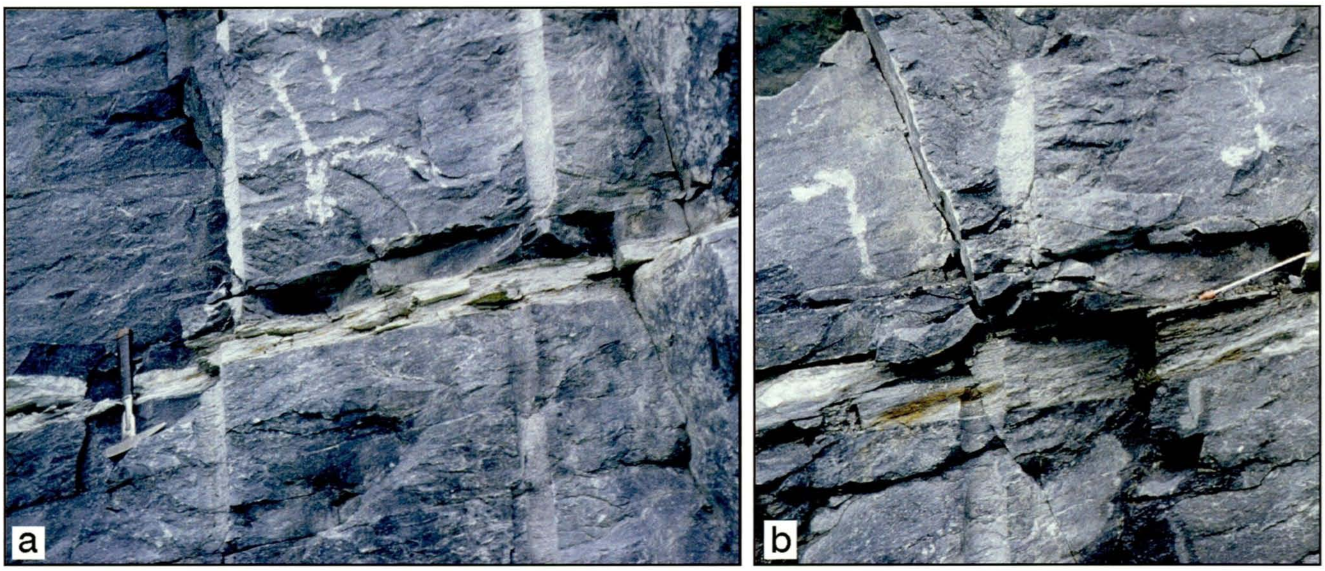

Fig. 6. (a) Reverse-slip offset of drillholes in the Snåsa Limestone; road-cut along the E6 near the secondary road to Nordaunen, north of Snåsavatnet; looking north. (b) Close-up of a displaced drillhole from the same locality showing the crushed and gouged limestone in the shear zone. The alignment of the pencil is parallel to the internal shear fabric in the crush zone (see text).

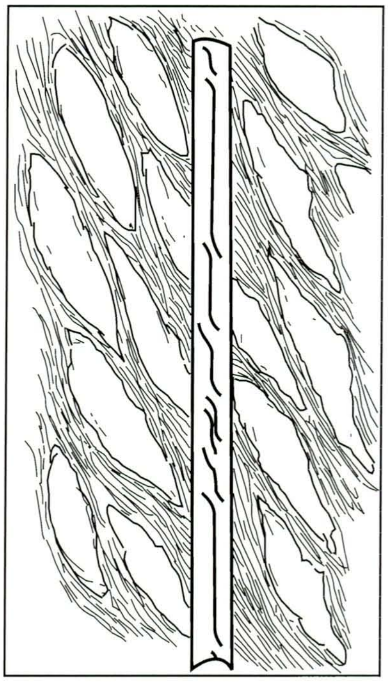

Fig. 7. Sketch of segmented axial fractures in a drillhole in deformed pillow lavas, near Haga Bridge, Støren, Sør-Trøndelag. Note that the terminations of the individual axial fracture segments are deflected into the trend of the foliation in the host-rock metalavas. Looking c. northeast. The sketch covers a 2 metre length of drillhole, but the drillhole diameter, actually 7 cm, is exaggerated in the figure.

Støren: A c. 400 m-long road-cut in Cambrian-Early Ordovician metabasalts (locally called greenstones) with pillow structures, is present just north of Haga Bridge on the east side of the E6 road, 3 km north of Støren (Fig. 1). Vertical or subvertical drillholes along this NW-SE-aligned, 6-10 m-high road-cut shows many examples of fairly continuous but irregularly developed axial fractures. Measurements were taken of the trends of axial fractures which exceeded c. 1 m in length, i.e., the fractures could be judged to be continuous through the greenstone host rock from one lava pillow to the next. In a few cases, the axial fractures were deflected at their extremities into a strong, inter-pillow schistosity (Fig. 7).

Measurements recorded from separate, concave drillhole walls along this long road-cut show that the mean trend of these particular axial fractures is quite close to NE-SW (Fig. 8a). This would signify that S_{Hmax} is also aligned approximately NE-SW at this location — quite different from the situation at Roan and Snåsavatnet, but comparable with the *in situ* stress data recorded in this same area by Myrvang (1988, 1993).

Ronglan: A c. 500 m-long stretch of road-cut along the E6 just 1 km southwest of Ronglan (Fig. 1) also provides many good examples of axial fractures in drillholes (Fig. 9). The bedrock here is a multilayered succession of greywacke and phyllite of inferred Mid to Late Ordovician age. Measurements of the axial fractures show a fairly consistent WNW-ESE (290°) trend (Fig. 8b) indicating that S_{Hmax}, in this particular area, will also have approximately this same trend. The significance of this, in a regional context, will be discussed later.

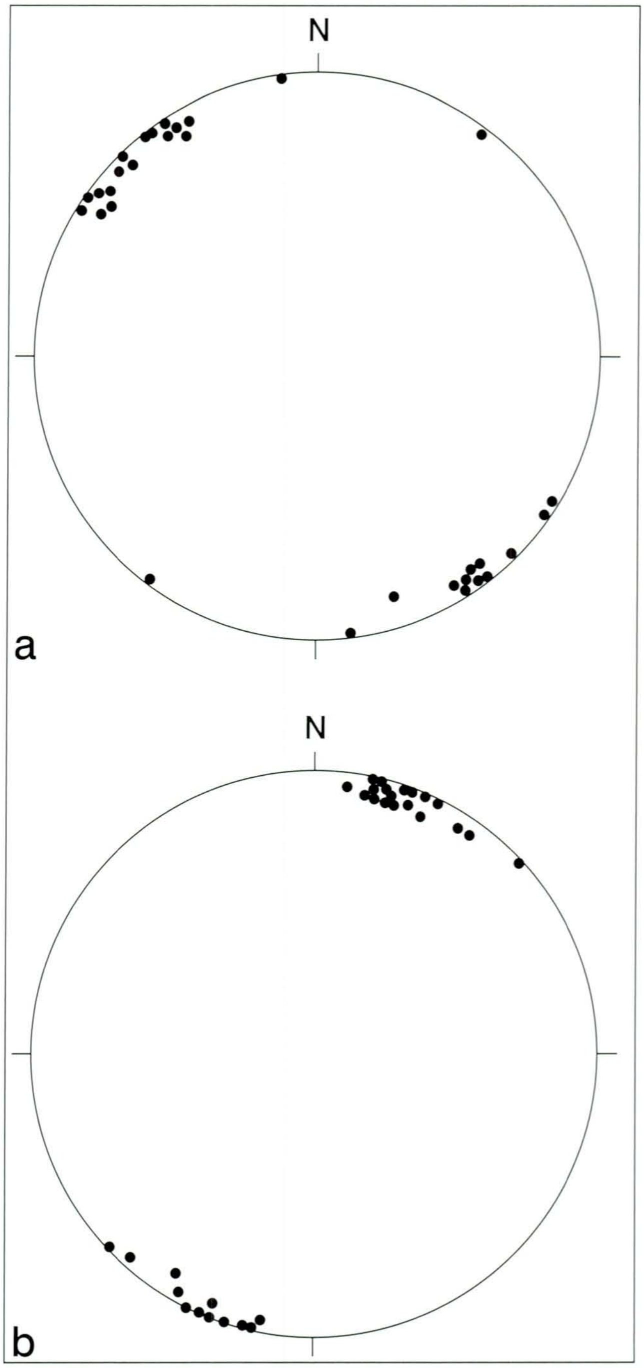

Fig. 8. Stereograms showing drillhole axial fracture data from (a) the Haga Bridge locality, Støren, and (b) the long E6 road-cut locality near Ronglan.

Other observations

Preliminary inspections of new road-cuts southwest of Trondheim and south of Støren have also revealed evidence of both drillhole offsets and axial fractures. About 5 km south of Støren, along the E6, one definite reverse-slip offset of c. 3 cm is directed toward SSW, a trend which is similar to that of S_{Hmax} at the Haga Bridge locality near Støren. Other, recently blasted road-cuts, 1.5 km east of Børsa along the new E39 road c. 20 km southwest of Trondheim, show sev-

Fig. 9. Photo of a drillhole showing a subvertical axial fracture with small kinks, E6 road-cut, near Ronglan; looking west-northwest.

eral axial fractures in drillholes (Fig. 2). These trend between NNE-SSW and NE-SW, an alignment which corresponds broadly with the trend of S_{Hmax} recorded near Støren.

It must be stressed that these observations are merely preliminary and sporadic. After completion of these new, major road constructions, a more systematic study of the road-cuts will be undertaken.

Discussion

One of the most striking features of this compilation of contemporary stress orientation structures and *in situ* rock-stress measurements is that the Møre-Trøndelag Fault Complex marks an important divide, separating major crustal blocks with apparently disparate stress fields. Both within and to the northwest of the MTFC, the principal horizontal stress trends between E-W and NW-SE, whereas inland, south of Trondheim, the trend of S_{Hmax} is close to NE-SW (Fig. 10). The axial fracture data from Ronglan might, at first sight, appear to provide an exception to this otherwise clear picture. However, satellite imagery clearly shows that this particular area has a lineament pattern which is comparable to that within the MTFC along the northwestern side of Trondheimsfjord (Rindstad & Grønlie 1986).

As noted earlier, gravimetric, seismic and apatite fission-track data have all indicated that the MTFC is a fundamental, deep-seated, crustal structure. Even the elongate blocks or slivers of crust within the fault complex have now yielded

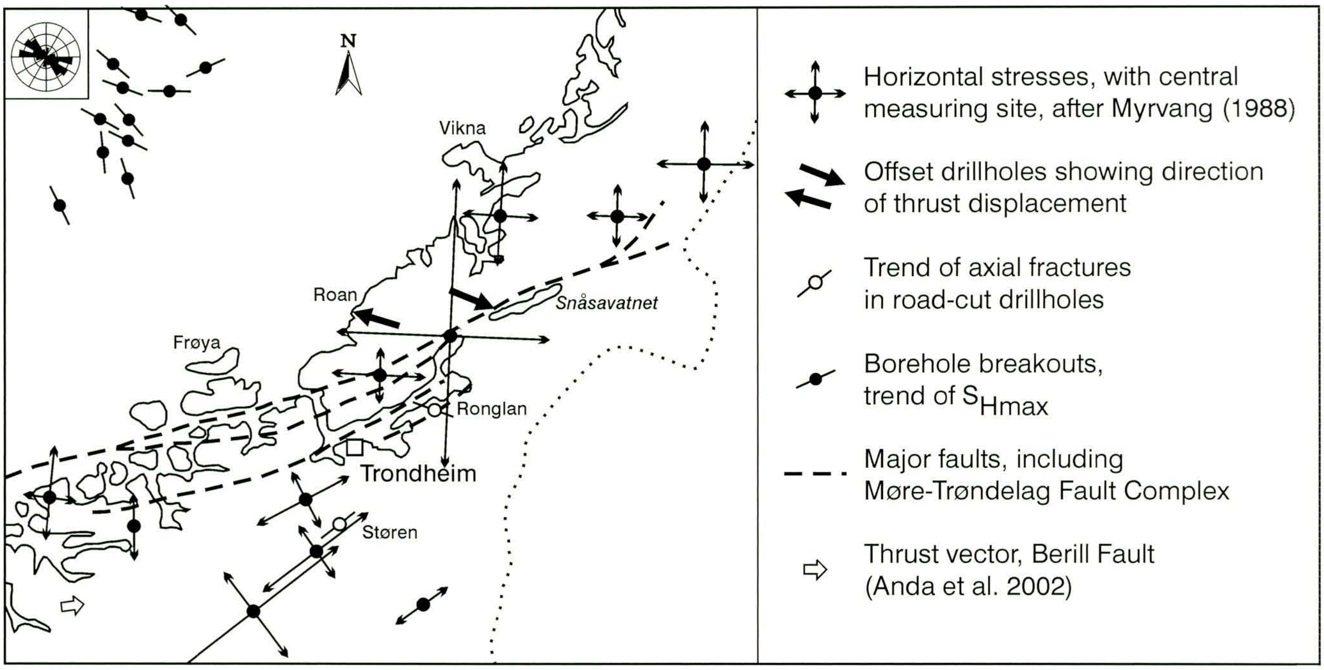

Fig. 10. Outline map showing the diverse rock-stress orientation data from central Norway and the Trøndelag Platform. The small rose diagram (inset, top left) is from Hicks et al. (2000, p. 243) and depicts the trends of maximum horizontal compressive stress as derived from earthquake focal mechanism solutions in the area of offshore Mid Norway (period 1980-1999).

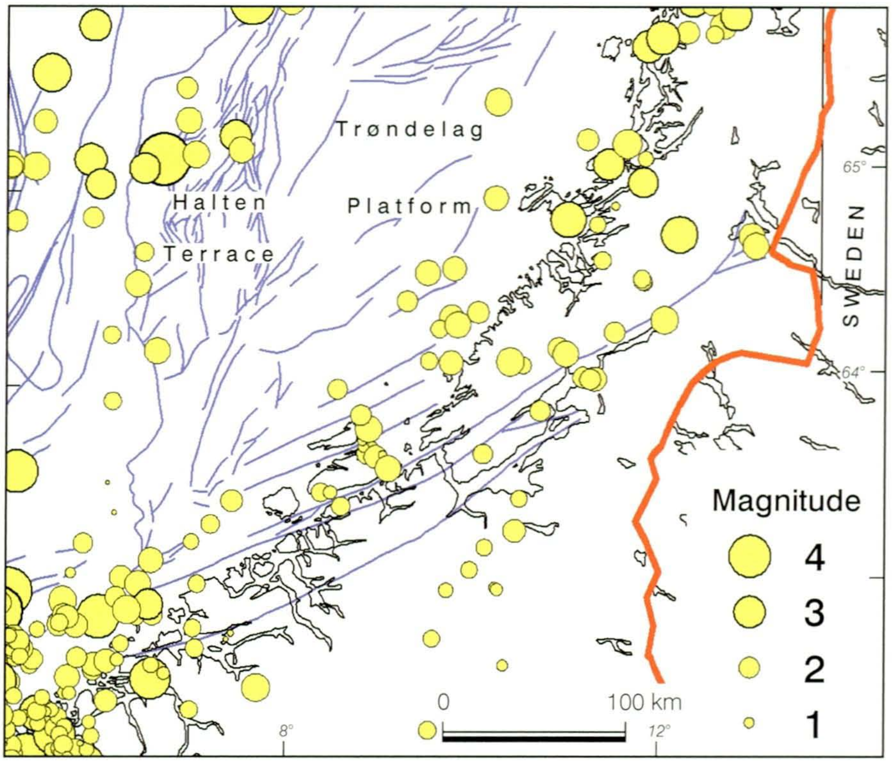

Fig. 11. Seismicity of central Norway, and the Trøndelag Platform and Halten Terrace, including the eastern margin of the overlapping Møre and Vøring Basins in the far west; based on Byrkjeland et al. (2000). The compilation takes in all events recorded since 1880. It should be noted, however, that some of the lowest magnitude events on land could possibly represent blasting from road or tunnel constructions. The major faults (continuous lines) are mostly taken from Blystad et al. (1995, Plate 1). For geographic locations onshore, see Fig. 1.

evidence of differences in exhumation histories; and the inland, footwall block, southeast of the Bæverdalen fault, experienced its latest major uplift, by up to 2 km, in Neogene time between 40 and 20 Ma ago (Redfield et al. in press). Based on numerical modelling of Cenozoic stress patterns offshore Mid Norway, Pascal & Gabrielsen (2001) proposed that the MTFC was a mechanically weak, composite fracture zone with an inherently high potential for having influenced both regional and local stress fields from Devonian time to the present day. Despite this, and notwithstanding its multiple reactivation history, the MTFC, onshore at least, is devoid of any significant, recent or contemporary, seismic activity (Hicks et al. 2000), i.e., over the last two decades. Looking back over the last century or more, however, there is a definite concentration of events above magnitude 2.0 in a crude linear zone trending c. NE-SW along and adjacent to the Møre-Trøndelag Fault Complex (Byrkjeland et al. 2000, Plate 2). There is also a weak NE-SW trending alignment of events passing through Støren. A version of this compilation of seismological data, based on Byrkjeland et al. (2000, Plate 2 and chapter on data sources, pp. 6224-5), is shown here as Fig. 11.

Coastal areas of central Norway, on the other hand, have clearly been more active in terms of catalogued seismic events (Byrkjeland et al. 2000, Hicks et al. 2000), and this is reflected in diverse surface phenomena. In one area c. 30 km northeast of Roan (Fig. 1), for example, a curious orthogonal mosaic of pebble-like aggregates of sand in multilayered Quaternary sediments (Bargel et al. 1994) has been interpreted as liquefaction features arising from earthquake activity during late-Weichselian crustal uplift. Some 200 km farther southwest, the area of coastal Møre is one of the most seismically active regions of mainland Norway (Dehls et al. 2000, Hicks et al. 2000) (Fig. 11). This area also records the highest concentration of large-scale rock slides and allied rock-slope failures in Norway (Blikra et al. 2002, in press), features that have been directly related to increased earthquake activity in historic times. The post-glacial Berill Fault (Fig. 10) (Anda et al. 2002) also occurs in this same region. Summing up, even though Mid Norway as a whole is, in relative terms, a seismically 'quiet' region today, it is noteworthy that recorded activity above magnitude 1.0 diminishes rapidly southeast of the Bæverdalen fault and its extension into Trondheimsfjord (Byrkjeland et al. 2000, Dehls et al. 2000, Hicks et al. 2000). The inner part of Trøndelag is thus one of the most seismically stable parts of the present-day Baltic Shield.

The present-day stress orientation data onshore in Trøndelag and Nord-Møre, and in particular the prevalent NW-SE to WNW-ESE trend of S_{Hmax} along and to the northwest of the MTFC, is also reflected in borehole breakout and earthquake focal mechanism data (Fig. 10) from the offshore areas as far west as the margin to the Vøring Basin (Bungum et al. 1991, Gregersen 1992, Gölke & Brudy 1996, Byrkjeland et al. 2000, Hicks et al. 2000). There are also substantial seismic-reflection and well data from the Trøndelag Platform, Halten Terrace and shelf margin pointing to the presence of widespread compressional structures from Eocene to the present day (Doré & Lundin 1996, Langaker 1998, Vågnes et al. 1998). These structures, including reverse faults inverting earlier normal faults, and continuously growing elongate domal structures, indicate the existence of a NW-SE-oriented compressional stress field along this Mid-Norwegian margin (Fig. 10), with an extrapolated maximum bulk shortening of c.3% (Vågnes et al. 1998).

Numerical modelling of stress patterns in the Mid Norway region, both offshore and onshore, from the Tertiary to the present day has also defined a fundamental NW-SE-trending, maximum horizontal stress (Gölke & Coblentz 1996, Gölke et al. 1996, Pascal & Gabrielsen 2001). One of the models also predicts that contrasting, contemporary stress patterns should, indeed, exist in the footwall and hangingwall blocks of the MTFC (Pascal & Gabrielsen 2001). However, the precise trends and magnitudes, and degree of anisotropy of the horizontal stresses in the inland block are difficult to model, since the stress field is very sensitive to local effects such as, for example, topographic forces, which augment extensional stresses and cause stress axis rotations. An explanation for the NE-SW orientation of S_{Hmax} in the Støren district, for example, may be sought in a combination of stress axis deflections, influence of topography, and distance from the mechanically weak MTFC, but far more stress data are required from this inland region before we can say anything definitive.

In general terms, the prevailing NW-SE compression documented in both the offshore and the outer onshore domains is considered by a large proportion of the geoscience community as relating to a distributed ridge push force arising from mid-Atlantic sea-floor spreading (e.g., Stein et al. 1989, Müller et al. 1992, Fejerskov & Lindholm 2000, Lindholm et al. 2000). This coincides very well with the pattern seen on the World Stress Map, where stress data from both shallow depths and middle to lower crustal levels from all over the world have been compiled (Zobeck et al. 1989, Reinecker et al. 2004). The data that we have acquired on-land, in Trøndelag, i.e., contemporary horizontal stress orientations and evidence for WNW-ESE-trending, thrust-fault displacements of roadside drillholes, support this general compressional model.

With regard to the general stress situation, the mechanically weak nature of the MTFC, and the paradox of comparatively insignificant contemporary earthquake activity along this megastructure, it is not improbable that an expected accumulation of stresses may result in an earthquake of moderate magnitude in this region at some stage in the future. On the other hand, slip partitioning along the innumerable faults within the MTFC system may be such that seismic energy would possibly be widely dissipated, thus precluding the generation of sudden, major earthquakes within this zone.

Conclusions

Based on *in situ* rock-stress measurements and contemporary stress orientation structures at diverse localities in Trøndelag, it can be shown that the Møre-Trøndelag Fault Complex marks an important structural line separating crustal blocks with disparate, current stress fields. This supports earlier proposals reached by both field and numerical modelling studies, though in these cases pertaining mostly to earlier periods of geological time. In one case, however, our data confirm predictions (Pascal & Gabrielsen 2001) that contrasting contemporary stress regimes should, theoretically, characterise the footwall and hangingwall blocks of the MTFC.

Given this current situation, it is therefore not inconceivable that an earthquake of moderate magnitude may occur along the MTFC, on land, at some future date – effectively marking a release of the stresses that have been accumulating during the last few decades of relative inactivity.

The prevalent NW-SE horizontal compression recorded in the near-coastal areas of Trøndelag accords with data acquired offshore, including earthquake focal mechanism solutions derived from deeper crustal levels, indicating that this pattern is likely to relate to a distributed ridge-push force arising from divergent spreading along the axial ridge of the North Atlantic Ocean.

Taken as a whole, the combination of *in situ* rock stress measurements and field observations of drillhole reverse-slip offsets and complementary axial fractures is seen to provide a reliable indicator of the contemporary stress patterns existing in exposed bedrock.

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