

# Proceedings

## First meeting of the Tectonics and Structural Geology Studies Group of NGF on 'Fault tectonics of the Norwegian mainland, Svalbard and continental shelf'

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The aim of the Tectonics and Structural Geology Studies Group of NGF is to establish a forum for discussion of themes with relation to tectonics and structural geology, and to stimulate communication and co-operation between groups of academic institutions and industry working with this type of geological problems. The first meeting, which gathered eleven speakers, mirrored the broad activity within the field of fault tectonics going on in Norway today from Svalbard in the north to the Central North Sea in the south (Fig. 1).

The present report is an attempt to summarize the main points and conclusions given during the meeting. The report is mostly based upon abstracts submitted after the meeting, and in some cases upon the oral presentations. Accordingly, the present authors are responsible for the general conclusions and possible misunderstandings or inaccuracies in the text.

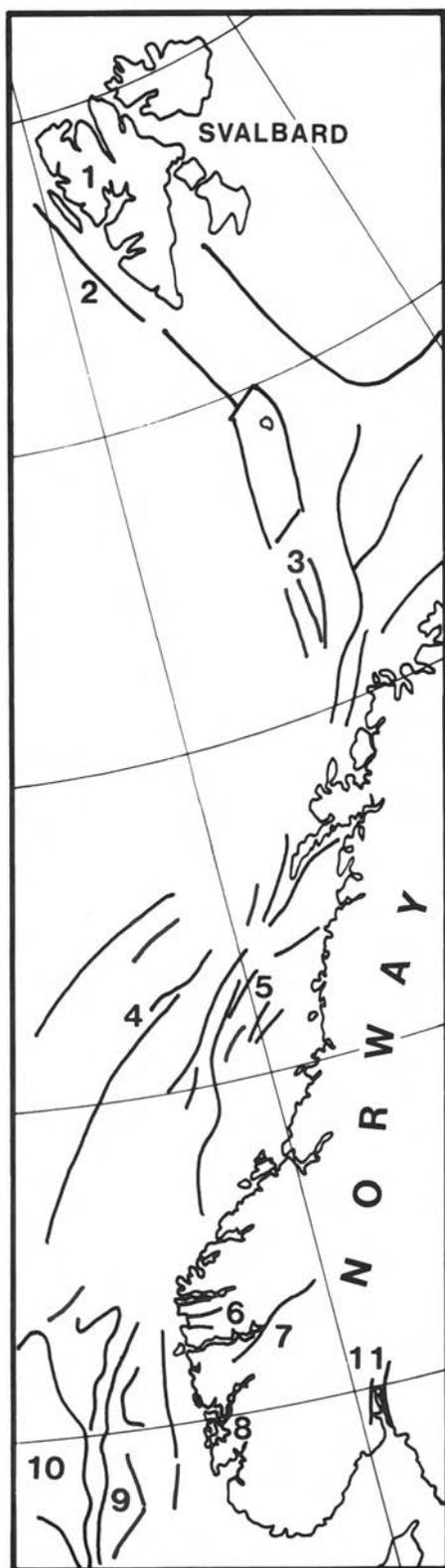
### *Faulting in the western Barents Sea and on Svalbard*

The fracture pattern of Svalbard (Y. Ohta) and the north western Barents Sea (A. M. Myhre & E. Sundvor) is dominated by the NNW-trending faults of the Hornsund Fault Zone and the sub-parallel fault trend on Svalbard. The latter is characterized by repeated activity, and has been associated with large-scale sinistral shear in Devonian as well as dextral shear in Paleocene times. On Svalbard, a system of conjugated faults trending NW-SE and NE-SW and longitudinal N-S faults reveal an E-W trending compressive stress situation. Many of these faults, devel-

oped during the Caledonian orogeny, were reactivated in Tertiary times (Ohta 1983). Lineaments in the Greenland Sea with trends parallel to the on-shore structures suggest that the initial separation of the Greenland and the Eurasian plates has been controlled by preexisting Caledonian fracture systems.

Multichannel seismic data from the area south of Svalbard indicate that the transition between oceanic and continental crust is situated close to the Hornsund Fault Zone (Myhre et al. 1982). The geometric outline of this fault zone varies considerably along strike from a single major fault with a throw in the order of 4 sec. (two-way reflection time) west of Hornsund to a more complicated, step-like fault system SW of Sørkapp. Midway between Sørkapp and Bjørnøya a horst-like structure is seen on the continental crust-side. According to the model presented, the Hornsund Fault Zone resulted from a two-stage tectonic history representing Early Paleocene shearing and Early Eocene drifting.

To the south, the Hornsund Fault Zone terminates west of Bjørnøya (Fig. 1). Along its strike, separated from the Hornsund Fault Zone by the Bjørnøya Basin, another prominent tectonic feature is found - the Senja Ridge. Even this structural high, which was discussed by C. Roman in a model based on a dip-study, is believed to be associated with strike-slip movements. According to this model, the Senja Ridge resulted from a combination of NNW-SSE trending dextral and E-W trending sinistral strike-slip faults in Cretaceous times.



### Some tectonic features offshore Mid-Norway

The Vøring Plateau is divided into an outer and inner part by the Vøring Plateau Escarpment, which is a steep eastward sloping feature, running NNE-SSW and separating a basement high on the seaward side and a sedimentary basin on the landward side (*T. Hagevang*). By integration of gravity data and magnetic anomalies a tectonic model for the area was proposed. The basement-high consists of thickened (20 km) Icelandic type oceanic crust, emplaced above or close to sea-level in a period of abnormally high production of basalt in the earliest drifting phase. This resulted in volcanogenic deposits partly covering the rough topography of the earliest oceanic crust. A change to normal sea-floor spreading took place at anomaly 23 time, and can be related to an adjustment of the spreading axis (see also Hagevang et al. 1983).

The inner part of the plateau is believed to consist of thinned (16 km) continental crust. Accordingly, the escarpment coincides with the line of initial rifting, and the boundary between continental and oceanic crust.

The Kristiansund – Bodø Fault Complex (Gabrielsen et al. 1984) separates the Vøring Plateau from the Trøndelag Platform to the east. This fault complex (*R. H. Gabrielsen & C. Robinson*) is dominated by two regional fault trends, namely N-S in the southern and ENE-WSW in the northern parts, respectively. Until middle Jurassic times the area of the present Kristiansund – Bodø Fault Complex acted as a relatively stable basin with a few active normal growth faults. From this point in time, subsidence continued in the south, whereas the area to the north was affected by strike-slip movements resulting in compressional features in the Nordland Ridge area (see also Gabrielsen & Robinson 1984). After a period of erosion, the latter structures were reactivated during Late Cretaceous – Paleocene.

Fig. 1. Key map to contributions: 1) Svalbard (Ohta) 2) Hornsund Fault Zone (Myhre & Sundvor) 3) Senja Ridge (Roman) 4) Vøring Plateau Escarpment (Hagevang) 5) Kristiansund-Bodø Fault Complex (Gabrielsen & Robinson) 6) Sogn og Fjordane County (Bryhni) 7) Lærdal-Gjende Fault Zone (Koestler) 8) Sunnhordaland district (Naterstad) 9) Viking Graben border fault (Fagerland) 10) Northern North Sea, pseudotachylite (Norton et al.) 11) Oslo Rift (Larsen).

### *Some lineaments on-shore SW-Norway*

Regionally, E-W to ENE-WSW-trending structural elements are only found in a few, narrow zones on the Norwegian continental shelf. This is also the case for on-shore Norway. One of the areas where these trends are important is in Sogn and Fjordane, where the faults can be grouped into three categories (*I. Bryhni*):

1. NE-SW faults cutting the Jotun Nappe Complex. In the area between Lærdal and Gudvangen these have a vertical displacement in the order of several hundred metres down-to-the northwest. The dip is variable, but generally relatively low.
2. N-S faults or fracture systems which are most closely spaced on the coast and which are probably related to the formation of the Viking Graben offshore.
3. E-W faults (or faults striking approximately ESE-ENE and WNW-WSW) which often define the margins of the Devonian basins where they cut the entire sequence.

For the latter, a model of repeated strata by listric faulting may explain the great thicknesses of the Devonian sequence. This model is in accordance with the general steepening of the Devonian strata towards the basal fault.

The deformation within the Lærdal – Gjende Fault Zone in Jotunheimen (*A. G. Koestler*) has been estimated to have some relation to the faults of the Devonian Basins. This major NE-SW trending lineament cuts all tectonic units of the Jotun Nappe Complex, and presumably, the underlying basement unit. The normal fault zone, with a dip of 30–45° to NW, shows a displacement of at least two kilometres. This late Caledonian faulting may be correlated with post-orogenic isostasy of the Baltic shield and regional Devonian movements in the west coast area of Norway.

The fault pattern of the Sunnhordland district (*J. Naterstad*) is, on the other hand, dominated by NNW-SSE to N-S striking fractures, i.e. parallel to the pronounced dyke system in the area (*Færseth et al. 1976*). The dykes are Carboniferous to Jurassic in age, but later movements on structures of this trend should be expected, and indeed, deep-seated earthquakes related to N-S faults have recently been recorded. The faults contain both ultramylonites and breccias, and extensive calcite and fluorite mineralization is reported. Also NE-SW trending faults, tradition-

ally associated with the late Caledonian formation of the so-called 'Faltungsgaben', influence the area.

However, faults of this trend off-set some elements of the NNW-SSE system, suggesting a late reactivation of the NE-SW system as well.

### *Faulting off-shore SW-Norway*

Traditionally, the continental shelf of Norway has been looked upon as an area dominated by tensional tectonics. However, an increasing amount of evidence in favour of fault systems with strike-slip components has been reported over the past few years. This type of faulting has been associated with late Cretaceous and Tertiary movements, and has previously been set in relation to the early opening of the North Atlantic. Evidence of older (Jurassic) shear movements has been reported.

The fault system along the SE margin of the Viking graben show evidence of reactivation in Palaeocene/Eocene (*N. Fagerland*). In some areas the reactivation phase is associated with flower structures and, in others, indicated by downwarping without off-set of the strata. Along some borderfaults tensional features are found, whereas compressional features are recorded along others. The geometry of the fault zone indicates a dextral movement along a near N-S trending shear zone (*Fagerland 1984*). This may be set in connection with the opening of the Norwegian – Greenland Sea, and a consequent rotation and/or tilting of the Shetland Platform situated ca. 40 km to the west. However, at present, no indications of similar type of faulting have been reported from the western part of the Viking Graben.

An occurrence of pseudotachylite was described from the middle Jurassic Tarbert Formation (*M. G. Norton, T. B. Andersen, H. Furnes & O. Malm*). Strong flow-banding and flow-folding in the glassy, siliceous veins indicate an origin due to frictional melting. Dating by the K/Ar method reveals an age of  $73 \pm 3$  Ma interpreted as the maximum age of the pseudotachylite. Faulting is the only likely source for the heating of this porous sandstone and temperatures of at least 1100°C are indicated by the composition of the melt.

The mechanism of activation of rifts was assessed by *Bjørn T. Larsen*, who showed that the Permian rifting in the Oslo Graben was not pre-

ceeded by doming. The depositional pattern of the Asker Group instead indicates that the early rift phase was associated with a gentle depression. On the other hand, later intrusion of sills indicates that compression prevailed from about 260 m.y. In a regional context, the Oslo Graben was considered a third order structure resulting from Hercynian transpressional movements.

### Conclusions

From the papers presented in the first meeting of the Tectonic and Structural Geology Studies group, two general conclusions can be drawn:

1. Indications of strike-slip movements seem to be more frequent as new data are gathered from the Norwegian continental shelf. There are indications that both the late Paleozoic, the Mesozoic and the Cenozoic movements were accompanied by strike-slip movements on a regional or semi-regional scale. Although this has been proposed by several authors in the North Sea (e.g. Ziegler 1981, Pegrum 1984, a, b), further indications of this type of strain should be sought farther north.
2. Several faults on-shore Norway indicate late Mesozoic (and even Cenozoic) movements. It is proposed that the influence of brittle, post-Caledonian deformation in Norway has been underestimated.

### List of contributions

- Yoshihide Ohta: Caledonian fracture system in Svalbard and its possible significance to the opening of northern Atlantic.
- Annik M. Myhre & Eirik Sundvor: The tectonic significance of the Hornsund Fault Zone, northwestern Barents Sea.
- Constantin Roman: A morphological study of the Senja Ridge and its regional tectonic framework.
- Terje Hagevang: Vøring Plateau Escarpment; geophysical signature and tectonic significance.
- Roy H. Gabrielsen & Charlotte Robinson: The Kristiansund – Bodø Fault Complex, off-shore mid-Norway.
- Inge Bryhni: Fault tectonics in Sogn og Fjordane county, western Norway.

- Andreas Koestler: The age of and structural features associated with the Lærdal-Gjende Fault Zone, Jotunheimen.
- M. G. Norton, T. B. Andersen, H. Furnes & O. Malm: Pseudotachylite in porous sandstone from the Northern North Sea.
- Johan Naterstad: Fault pattern of the Sunnhordland district, south-western Norway.
- Nils Fagerland: Tectonic analyses of the Viking Graben border fault.
- Bjørn T. Larsen: A tectonomagmatic model for the North Sea and the Oslo Rift in Upper Paleozoic time.

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