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MAJOR FAULT SYSTEMS ON THE NORWEGIAN CONTINENTAL SHELF

by R. Muir Wood

ELOCS Report 1-4
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by

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1. INTRODUCTION

In the course of studies of the offshore geology of the Norwegian continental shelf it was found that there were certain important faults or fault-zones that showed a long history of displacement through into the Tertiary and even potentially the Quaternary. It was therefore considered useful to assess these major fault-zones independently.

In choosing those faults that should be given special attention it has been necessary to exercise some judgement. The faults and fault-zones considered here are generally major structures, more than 100 km in length, although often comprising two or more independent segments, and sometimes resembling more a fracture zone than a simple fault. Their main characteristic is large amounts of displacment and/or multiple reactivation through long periods of geological history. These faults form a primary category of structures that have remained as zones of weakness in the continental crust, through major shifts in the tectonic regime. The majority of them show evidence for displacements through into the Neogene and sometimes into the Quaternary. Such structures can be contrasted with a secondary category comprising the majority of the faults found within the Norwegian continental shelf which are less than 100 km in length, predominantly normal faults formed during the major phases of Mesozoic rifting.

Knowledge of these offshore fault-systems has been gained almost entirely from the available coverage of seismic reflection profiles. As high angle planar faults do not themselves form prominent reflectors, the existence of the fault can only be indicated by the disposition of the adjacent reflectors. Very often it may be difficult to retrieve the exact nature of the underlying basement fault-system, whether a single continuous fracture of a series of en-echelon fault fragments. The more complex and more frequently reactivated the fault-system, the more difficult it becomes to interpret an unambiguous fault history.

Along a number of these major fault systems the nature of the sedimentary deformation commonly presents evidence of non-simple displacements, sometimes involving possible strike-slip or reverse movements. Where ambiguities of interpretation are present the most effective course is to provide illustrations of the raw seismic reflection data in order that the complexities can be viewed.

Within the Norwegian continental shelf the following faults have been considered:

a) The projected westerly continuation of the Tornquist Zone
b) The West Viking Graben Fault Zone
c) The Øygarden Fault Zone
d) The Jan Mayen Fracture Zone
e) The Møre - Trøndelag Fault Zone
f) The Kristiansund - Bodø Fault Complex
g) The Inner Vøring Plateau Escarpment
h) The Senja Fracture Zone & Hornsund Fault Zone

2. THE WESTERN CONTINUATION OF THE TORNQUIST ZONE

2.1 Extent of the fault system

The Tornquist Zone (TZ), or Fennoscandian Border Zone, is a very important continental fracture zone, passing towards the NW from southern Poland. The 20-150 km wide band of faults, marks the southern border of the Fennoscandian and East European cratons. The Tornquist Zone lineaments are considered to be at least 1,000 Ma (Watson, 1976) and even possibly as old as 2500 Ma (Strømberg, 1976).

Pegrum (1984) has proposed that the Tornquist Zone can be followed across northern Jutland into the North Sea, at least as far as the southern end of the Viking Graben. While towards the south-east the course of the border zone is defined by the exposed pre-Mesozoic basement terrains, it is the analogies with the Mesozoic tectonic development on which Pegrum bases his extrapolation.

2.2 Characteristics of the Tornquist Zone

From Poland through Skåne and onto Jutland the deep narrow basins that developed parallel with the zone in the Jurassic and Early Cretaceous, suffered pronounced late Cretaceous inversions. To the north-west of Jutland, faults of the Tornquist trend can be followed offshore, the most prominent being the Fjerritslev Fault, which bounds the Fjerritslev Trough. The Ferritslev Fault passes towards the west into a complex zone of WNW and NW oriented faults which can be traced around the southern margin of the Stavanger Platform. Further to the west both the Sele High and the Utsira High are terminated to the south by WNW oriented structures. Pegrum argues that this zone of faults marks the boundary between the platform areas to the north and the deep Fiskebank Basin, the major downwarp of the Norwegian - Danish Basin. However it appears that the influence of the Tornquist Zone on Mesozoic structures is waning towards the north-west.

Within the Norwegian sector the Farsund Basin, to the north of the Fjerritslev Fault, marks the western end of the Fjerritslev Basin, the last narrow and deep basin along the zone. A branch of the Tornquist Zone, appears to pass towards the north-west across the Stavanger Platform onto the Stord Basin. Pegrum has claimed that the southern end of the Egersund Basin marks a renewal of WNW influence on basin formation, though this is less pronounced than the other Tornquist Basins to the southeast.

A major component of Pegrum's claims for a continuation of the Tornquist Zone as far as the southern end of the Viking Graben concerns the existence of Upper Cretaceous, Early Tertiary inversions along this zone. However similar age inversions to those found along the south-west margin of the Stavanger Platform also occur beneath the NW-SE Lindesnes Ridge (Gowers and Saebøe, 1985), 200 km further south. A N-S oriented inversion found in block 15/9 (Sleipner Gamma Reservoir) is primarily a response to mid-Tertiary compression, and lies at the furthermost continuation of Pegrum's projected Tornquist Zone. Other N-S inversions are found further to the north around the southern margin of the Viking Graben, off Pegrum's projected Tornquist Zone. Therefore inversions do not characterize his claimed projection. There is no real evidence, as he proposes, that a single narrow NW-SE zone has suffered dextral transpression through the late Cretaceous and early Tertiary. (The N-S to NW-SE orientation of inversions rather suggests sinistral displacement.)

2.3 Decay of the Tornquist Zone

The pattern of NW-SE faults from the Central and Danish Grabens appears more diffuse than found further towards the south-east, into the Kattegat, Baltic and Poland. Therefore while faults of this trend do appear to define some relatively important tectonic boundaries through the southern Norwegian sector of the North Sea basin, Pegrum's fault system appears no more significant than other NW-SE faults in the same region. Instead of emphasizing the continuity of the Tornquist Zone into the North Sea it is more realistic to note the remarkable way in which the strong deformation found through the Kattegat dies out towards the north-west, as the broad axis of deformation narrows to the single Fjerritslev Fault, which itself passes into a series of disconnected fault segments further to the northwest.

3. WEST VIKING GRABEN BOUNDARY FAULT

3.1 Extent of the fault system

While the majority of the major normal faults found across the northern North Sea basin, dip towards the east, the most westerly zone of such faulting, marking the western boundary of the Viking Graben, is a major complex of westerly dipping fault-zones. The WVGBF system marks the eastern boundary of the Shetland Platform from 58°30' where NW-SE fault-trends of the Central Graben become dominant, and NNW-SSE from 60°, up to about 61°30' where northern North Sea fault trends are interrupted by the eastern marginal faults of the Faeroe-Shetland Basin. Where the two WVGBF trends meet at around 60° there is a promontory of the Shetland Platform, identified by Donato and Tully (1982) from its gravitational signature, as the location of an important buried Caledonian granite intrusion.

3.2 Early Tertiary reactivation

The pattern of WVGBF displacement through the Mesozoic was generally associated with the regional rifting seen throughout the northern North Sea, but in the early Tertiary there was a unique and major renewal of normal faulting along the whole WVGBF. Within the complex of faulting this renewed activity generally took place to the west of the earlier fault system. Two periods of faulting, identified with two episodes of rifting have been found from the Palaeocene (Morton, 1982). The first involving normal faulting along two en echelon NNE-SSW southern segments of the fault system, with up to 500 m of Palaeocene sediments accumulating on the hanging wall. This was closely followed by normal faulting along the NNW-SSE oriented northern fault segment by up to 800 m. This faulting was associated with the Palaeocene uplift of the Shetland Platform. The normal faulting on