ON LARGE-SCALE TECTONIC STRUCTURES IN THE AGDER-ROGALAND REGION, SOUTHERN NORWAY

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It is proposed that the shape of the southern tip of Norway is controlled by a complex megatectonic Precambrian fold (synclinorium) with N–S axis and fold closures situated along the present coastline.

Lithologic units of metasediments, such as calc-silicate rocks (skarns) can be linked together by the proposed interpretation, and even isolated areas of granulite facies rocks stretching east–west may be tied up. It is suggested that an older fold belt (geosyncline) ran east–west, and was situated near the present coast of Agder-Rogaland in southern Norway.

Faulting connected to the older structures occurred in late- and post-Precambrian time, and facilitated the erosional work of the Pleistocene glaciers by accentuating the relief of the southernmost tip of Norway.

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During twelve years geological investigation in Vest- and Aust-Agder counties in the southernmost part of Norway, the structural evolution of the Precambrian migmatites was revealed to be extremely complex with several phases of folding, intrusion, and migmatization. However, discoveries of suitable lithologic marker horizons and detailed mapping of these, have shown that the macroscopic structures are large-scale isoclinal flow folds several times refolded and intruded (Falkum 1966a, b, 1969a).

Barth & Dons (1960) showed that the migmatitic rocks of the Agder-Rogaland region ran (striking) north–south. I agree that this is the general picture, but the migmatitic formations were found to close in large macroscopic folds. Thus, I am of the opinion that the formations run north–south for approximately 20 to 40 km, and then turn around in large fold closures, so that the real extension of the rock units is east–west.

However, it has not yet been possible to link together all the different gneisses and amphibolites in the entire area. Migmatitic rocks in particular look the same all over the world, so normally it is not possible to recognize the formations unless they have been 'walked out'. Nevertheless, the present results seem to indicate that the southernmost tip of Norway was folded into a large macroscopic structure.

Field relationships

Several observations can be summed up in order to substantiate this view:

The attitude of some of the most important macroscopic folds is nearly constant in areas of one to two thousand square kilometres, but varies over larger areas. In the Kristiansand area, the general foliation and axial surfaces of the larger isoclinal folds strike northeastwards with a moderate dip to the northwest (Fig. 1). On the contrary, in the Flekkefjord area, the general strike is north–south with a moderate dip to the east. Farther southeast the strike changes towards the northwest with the dip to the northeast. This configuration indicates a synform, but as this region is dominated by tight isoclinal folds, the structure must be a complex synclinorium or anticlinorium with outward fanning.

During the investigation in the Flekkefjord area (Falkum 1966b) five fold phases were revealed. It was observed that most fold closures are very complex with intense small-scale folding. Magnetic anomalies are often connected with these fold closures, and occasionally many magnetite pegmatites are found near the hinge zone.

The number and intensity of small-scale folds are frequently seen to be connected with fold closures. Approaching the coast one almost always finds an increasing number of small-scale folds. The coastline might consequently be the site of a number of fold closures.

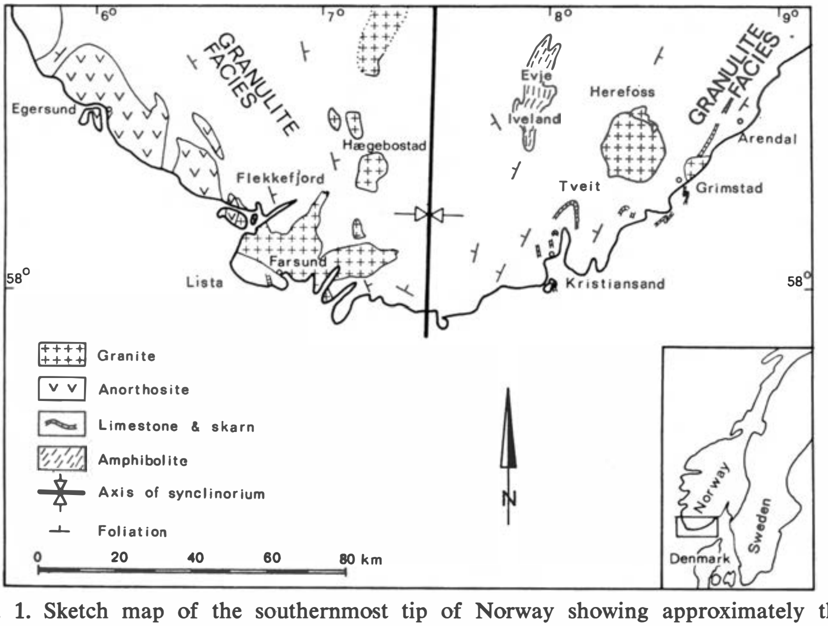

Fig. 1. Sketch map of the southernmost tip of Norway showing approximately the trace of the axial surface of the megastructure (synclinorium). The general dip of foliation indicates an outward fanning of the megastructure.

In most places where the fold closures are situated on land, they are found to be strongly eroded. Lakes and rivers frequently cover the hinge, thus hiding an important part of the fold. Thus, it may be predicted that fold closures near the coast should be strongly eroded into the present type of fjord landscape.

So far the hypothesis of a larger structure around the southernmost coast of Norway has only been supported by structural evidence. As the area consists of high-grade migmatites, it is difficult to find marker horizons which may be identified from place to place, unless the formations are rather continuously followed. However, there are a few exceptions, one of these being a thin marble horizon enclosed in a calc-silicate (skarn or cipolin) zone of restricted thickness. This rock unit is the most important marker horizon which could be used to elaborate the map pattern of the huge Tveit antiform structure northeast of Kristiansand (Falkum 1966a). These calc-silicate rocks consist of garnet, diopside, scapolite, and sphene as the most important minerals. The Tveit marble disappears as garnet-diopside boudins in the migmatitic gneisses on the islands immediately to the southwest of Kristiansand. During the fieldwork this summer (1971), a similar calc-silicate rock was discovered on the Lista plain, southwest of Farsund. If this is the same calc-silicate rock horizon as the above-mentioned Tveit marble, it must be concluded that one or possibly several large-fold closures exist in this region.

It is of course a possibility that the two calc-silicate units are different, but this is not probable judging from the similarity of the sequence of the country rocks between the Kristiansand and the Flekkefjord areas.

By postulating the existence of this megatectonic structure, some other features of the rock distribution in southern Norway can be explained.

The anorthosite region in Agder-Rogaland with granulite facies rocks was discovered by Esmark (1823), and since then Bugge (1943) has discovered that a semi-circular area around Arendal was built up of granulite facies rocks called arendalites. Furthermore, there are several smaller areas along the coast and in the interior of Aust-Agder which consist of granulite facies rocks (Touret 1968).

By means of a megatectonic fold structure the different granulite facies areas can be fitted together into one large zone (Fig. 1). This zone of granulite facies rocks could eventually have been the core of the orogenic belt, or even part of an older belt, with the younger rocks to the north, as indicate the structural relationship.

To the west and southwest of the arendalites there are some igneous intrusions such as the Herefoss and the Grimstad granites. A north–south running zone of intrusions revealed by myself and some students in the Hægebostad area, is situated due north of the large Farsund pluton.

Again, these two zones of intrusions can be linked together as a marginal feature of the granulite facies rocks.

Both structural and lithological observations can therefore be used in order to tie up the different formations of the Agder–Rogaland region around the southernmost coastline. The next question is, Which type of structure is this supposed to be?

Previously it was mentioned that this was most probably a complex fold structure, but in order to discuss this problem it is necessary to compare the fold style of the macrostructures.

In the Agder-Rogaland region five macrophases deformed the rocks into complicated folds, and it would seem relevant to review the fold style of some of the different folds (Falkum 1966b). In many areas strongly subjected to the last two deformations, the characteristic style of folding is a kind of synclinorium. Normally, however, only the synforms can be traced around the fold hinges, while the antiforms are completely sheared out and found as straight belts with a rather constantly striking foliation.

Furthermore, it is typical that many of the old folds preserved contain rocks of granulite facies, while areas, which have undergone the younger deformations, tend to contain amphibolite facies rocks.

In southwest Agder the older folds, which are large-scale isoclinal flow folds, are best preserved in the southern part of the Flekkefjord area, and farther north they are obliterated by younger deformations. The same seems to apply to the Arendal area, as patches of granulite facies rocks are found farther north (Touret 1968).

Discussion and conclusion

Both structural and lithological evidence have been presented in order to demonstrate the possibility of a large megastructure in the southernmost part of Norway. The present termination of southern Norway into the Skagerrak is largely believed to be due to erosion of the fold closures of this megastructure combined with erosion along a NE–SW fault system (the 'Great Breccia' and the Fedafjord fault). Most likely, the megastructure is an outward fanning synclinorium, although it is difficult to decide whether the steeply folded area curves upwards or downwards.

The erosion of fold closures is probably facilitated by the numerous small faults and joints observed in hinge zones. Most of these faults exhibit little or no displacement at all. Nevertheless, most fold closures are deeply eroded.

As O. Holtedahl (1950, 1964) pointed out, the southeast Norwegian trench could be the result of a fault zone, partly parallel to the 'Great Breccia' zone, running from the Oslo graben to Kristiansand. Recently H. Holtedahl & Sellevoll (1970) failed to demonstrate large-scale faulting along the Skagerrak coast. This is in accordance with the present hypotheses, as the coastline may be partly due to selective erosion of fold closures where there may be many small-scale faults in the hinge zones.

A possible consequence of the proposed megastructure is that the Precambrian orogenic belt might have been running east–west with a core of granulite facies rocks. These rocks could be polyorogenic and belong to an even older orogen, situated in the southernmost part of the region in question.

The age of such an older orogenic belt could be Svecofennian, since the last main diastrophism with regional metamorphism in the Agder-Rogaland region is of Sveconorwegian age (1,000–1,100 m.y.). The north–south trend of the megastructure indicates that it belongs to this orogeny. The granulite facies rocks and the anorthosites are subjected to deformation and anatexis during this diastrophism, so earlier trends are changed. These rocks are cross-cut by several acid intrusions which are apparently undeformed. One of the largest granite plutons in Vest-Agder is the so-called farsundite (Farsund pluton) which cross-cuts all the metamorphic structures around it (late- or postkinematic). Pasteels, Michot & Lavreau (1970) published some zircon ages, which are close to 1,000 m.y. for the emplacement of the farsundite. This means that the megastructure must be older than 1,000 m.y. Although the absolute age of the synclinorium is uncertain, it most probably belongs to the Sveconorwegian orogeny (or Dalslandian in Sweden), which normally has a north–south trend.

The proposal of a megatectonic structure in southern Norway is a preliminary contribution to the discussion of the large-scale tectonic structures in the Agder-Rogaland region, and new data will probably show that the megastructure is more complicated than supposed at present. Considering that some granulite facies areas are found farther eastwards on the Swedish coast at Varberg, one might be tempted to draw the proposed structure farther eastwards, but as this is beyond the scope of the present paper, the question will be left open.

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