

A Reply. The Relation of Joint Patterns to the Formation of Fjords in Western Norway

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Roberts provides an interesting alternative interpretation of joint patterns and their relation to fjord orientations in the Solund and Buelandet-Værlandet regions (Nilsen 1973). The problem is certainly a fascinating one and has not been directly treated since N.-H. Kolderup's studies of forty years ago (Kolderup 1931, 1934a, 1934b). One of the purposes of my paper, and also in part of Roberts' comments, is to pose the problem again and suggest some relations that may stimulate additional research on the problem and publication of offshore geophysical data.

Roberts' interpretation of the three major joint sets in the area is interesting but I believe unsupported by the data. A major northeast-plunging anticline that has an irregularly striking axial trace dominates the structure of the area; despite its variations in strike, and the unknown structural relations between the Buelandet-Værlandet district in the north to the Solund district in the south, the north-south-trending joint set dominates the entire area. If this joint set were Svalbardian in age, one would expect it to follow the known Svalbardian structures more closely rather than retain a consistent geographic orientation parallel to the regional coastline. To the north, the Devonian districts of Kvamshesten, Håsteinen, and Hornelen have east-west structural trends cross-cut by a dominant north-south joint set, if I remember correctly from brief visits to the areas, which is expressed by abundant north-south-trending 'fissure' fjords. These observations still indicate to me a post-Svalbardian origin of the north-south-trending joint set.

Roberts infers that the dominant structural trends in southern Norway as a whole are NE-SW and NW-SE, and that they may have been initiated during the Precambrian. This may be true, although I should certainly like to see more data to support this conclusion. Nevertheless, in the Sognefjorden-Nordfjord area, the dominant trends are N-S and E-W, as shown both by Holte-dahl & Dons (1960) and Kildal (1970). The terms 'fissure' and 'strike' fjords seem acceptable for this area, although they may not be suitable for others. To reject these terms and the analysis of this area because they do not reflect general conditions in Norway is unnecessary, particularly inasmuch as analyses

of joint patterns from other areas are generally not available and because comparison with Precambrian structures is difficult at best.

The latter half of Roberts' comments present some of his ideas, based primarily on the work of others, on the tectonic evolution of western Norway. Interesting though they are, they should stand the test of full publication with supportive documentation. I agree with him that glaciers may have eroded the Norwegian Channel and that its location may have been controlled by older structural features. However, I remain unconvinced that it is as old as he believes. The present seismic activity in the Channel and its north-south trend along the west coast, parallel to the hinge line of the Tertiary oblique uplift of Scandinavia, suggest to me that it is primarily a Tertiary feature; any relation to Precambrian features is undocumented. The Tertiary oblique uplift of Scandinavia, the opening of the Norwegian Sea, and post-glacial uplift were very important structural events on the west coast (Torske 1972, Talwani & Eldholm 1972) and must have left a tectonic overprint on earlier structural features; in fact, as the last important tectonic events to occur, they must have strongly affected jointing along the west coast. There is no valid reason why these joints should reflect older events that occurred under different stress conditions.

It is clear that solution of the problem demands a great deal of additional work and that neither Roberts nor I have provided a solution yet. The present data are limited in three respects:

Joint orientation data are available for only a small area of the west coast of Norway. To make valid conclusions, for more data covering a much larger area are needed, including the southern and northwestern coasts of Norway. It is possible that the joint patterns of the Solund and Buelandet-Værlandet areas are anomalous and not characteristic of either the Devonian areas or of the coastal area in general; nevertheless, the area was the basis for conclusions drawn by Kolderup in his earlier papers and for the paper discussed here.

Data are needed on the morphology and geology of the Norwegian Channel and adjacent offshore areas. The age and tectonic framework of the Channel are critical to the interpretation of both the development of the fjords and the Mesozoic-Cenozoic tectonic history of Norway. The publication and interpretation of offshore geological studies and marine geophysical surveys, including seismic profiles and gravity and magnetic anomaly maps, are essential to solving the problem.

Detailed structural geologic maps of western Norway are needed in order to be able to clearly distinguish structures, including joints, that have been generated by Precambrian, Caledonian, Svalbardian, and younger tectonic events. I attempted to distinguish joint patterns in rocks of different ages in the Solund and Buelandet-Værlandet districts, but was not able to cover a large enough area to make the data very meaningful. However, this work should be extended and at larger scales where possible.

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