Submerged and tilted coastal features off Troms, northern Norway: a reply

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In their comment, Fjalstad & Møller (pp. 241–244 in this issue) point out important correlation problems between former sea levels on land and the shelf areas off Troms. This reply gives additional seismostratigraphical evidence for an age younger than the Weichselian glacial maximum of the last major erosional events on the shallow banks off Troms. Reasons for not finding a simple linear correlation between former sea levels on mainland Norway and on the continental shelf are also discussed further based on differences in bedrock geology and deformational history. In our opinion the questions about formation and age of the possible submerged coastal features off Troms cannot be resolved without new investigations on the shelf.

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In a comment to our paper (Rokoengen & Dekko 1993) dealing with the possible submerged coastal features off Troms, northern Norway, Fjalstad & Møller (pp. 241–244) present new datings from the adjacent land areas (mainly Andøya) and discuss the correlation between land and sea. It is encouraging that our paper has initiated new interest for the offshore features, since very little has been done concerning the submerged strandlines on the shelf off Troms since our first approach (Dekko & Rokoengen 1980).

The comment is mainly concerned about the youngest possible age mentioned. A number of questions are connected with the levels in general, however, and our interpretation probably represents an oversimplification. As stressed in our paper, the available data make the interpretation rather uncertain.

Regarding formation and age, Fjalstad and Møller make two main statements:

(1) Most likely, the assumed submerged levels off Troms are polycyclic, having formed during the Cenozoic, contemporaneously with the formation of the strandflat in the coastal zone.
(2) The gradients of 2.3 and 2.0 m/km, respectively, and the youngest possible age (13–11 ka BP), are not consistent with the emerged radiocarbon-dated shorelines, gradients about 1.0 m/km, from the same time period on the adjacent island Andøya in northern Vesterålen. The mapped submerged shorelines on the shelf are situated 50–70 m below the emerged Andøya shorelines and are therefore older.

The first point mostly follows our own considerations about the levelling of the bank areas. The possible connection with the Norwegian strandflat (Holtedahl 1993 with older references) has been indicated (Rokoengen & Dekko 1993, p. 204) and we believe that the bank areas have been levelled several times during the Cenozoic and for most of the time have been rather smooth features.

Most important for this discussion, however, is only *the last major erosional event*, which we definitely believe is younger than the strandflat. Our main argument is the seismostratigraphy found in the bank areas. As mentioned very briefly in our paper, the strata exposed by the Malangsgrunnen and Nordvestbanken Levels are composed of material of quite different age and origin. The areas where sedimentary bedrock comes close to the surface may certainly have gone through several cycles of erosion. But we also find younger deposits of glacial and marine origin. On the landward side of the banks seismically layered sediments may be recognized and are interpreted to represent sand and gravel deposited as coastal units (Dekko & Rokoengen 1993, Fig. 6, II and Fig. 11, I).

Fig. 1 illustrates the conditions on the outer part of Malangsgrunnen. There the seismic stratigraphy shows great similarity to the deposits off Mid-Norway, with possible till tongues and other indications of glacial deposition (Fig. 1).

The existence of ancient shore bars on the outer part of Malangsgrunnen was suggested by Holtedahl (1940) and Andersen (1986). The sparker data (Fig. 1) seem to support this interpretation. The level of the shore bars or barrier islands fits the Nordvestbanken Level (B in Fig. 1).

We thus believe that the last erosion described by us and informally named the Malangsgrunnen and the Nordvestbanken Levels is younger than the strandflat and probably also younger than the last glaciation on the

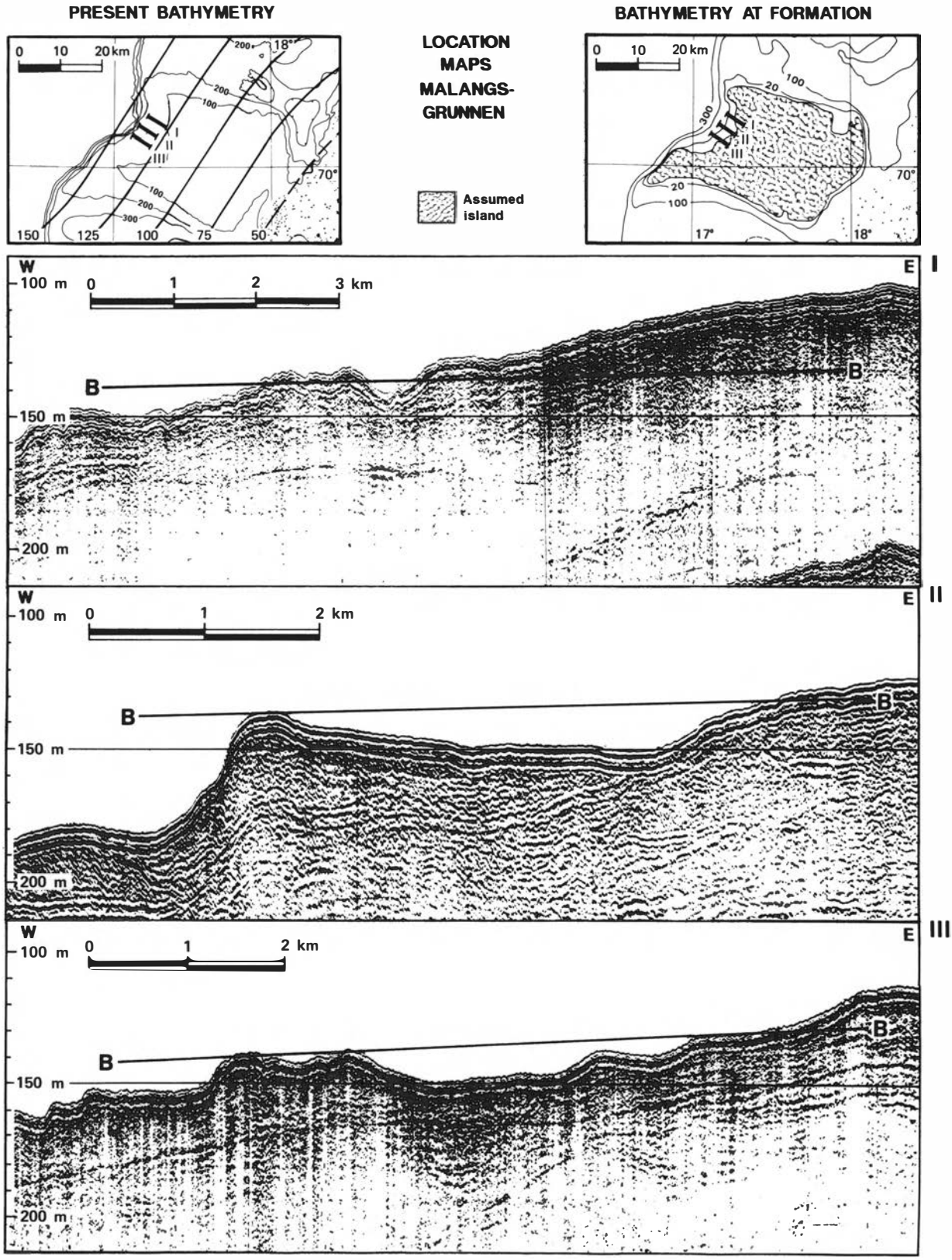

Fig. 1. Selected IKU sparker profile sections showing possible shore bars and glacial features in the deeper layers on the outer part of Malangsgrunnen. B = The Nordvestbanken Level.

bank areas, even if the banks off Troms are certainly polycyclic features.

Concerning Fjalstad and Møller's second statement, about the possible young age of the levels, Rokoengen & Dekko (1993) wrote: *The correlation with land is difficult. Based on the gradients and assuming the same deformational history, the levels should be older than all the levels mapped on land* (Conclusions 6).

We are thus well aware that it is quite heretical even to indicate possible young ages of the coastal features on the shelf. There are, however, several reasons why we feel it would be wrong not to mention the possibility. Especially as the apparent discrepancies may hide the answers to some of the really challenging unsolved problems in correlating land and sea.

It is always satisfying to find a simple linear correlation between for instance the strandlines on the shelf and on land. To evaluate this question we must go further into the deeper geological structures than in our original paper, where we concentrated on the surface features. The last decades of petroleum exploration have greatly increased the geological knowledge about the Norwegian shelf areas, as summarized in several recent maps and reports (Dalland et al. 1988; Brekke et al. 1992; Sigmond 1992; Vorren et al. 1992 and many others). The differences in bedrock geology and deformational history from mainland Norway are striking. A major feature is the normal fault complex off northern Norway (Brekke et al. 1992). Off Troms, the thickness of Cretaceous sediments west of this fault complex may reach several kilometres. It is in our opinion difficult to find convincing arguments supporting that the land and shelf areas off Norway, with previously very different tectonic history, after (or during) the glaciations should suddenly take on the same deformational pattern. More detailed investigations in the future will probably also reveal a more complex subsidence history on the shelf with more regional and local variations and differences than the simple linear model presented by us for the Troms area. We therefore think that it may give wrong results to correlate levels over too large distances and across major geological features, possibly still seismically active. The existence of large normal faults and fault zones in the outer part of Andfjorden is one reason for not extending the isobases across the deep feature of Andfjorden that also must have been a very important drainage path during several glaciations.

Another reason for mentioning the possibilities for young ages of coastal features on the shelf is related to our previous experience from the northern North Sea (Dekko & Rokoengen 1978). When we then suggested possible submerged postglacial coastal features deeper than 120 m below present sea level, very few if any (except Mørner 1980), believed it was possible. We feel, however, that the further investigations in that area, including detailed high resolution seismic profiling, surface sampling and drilling, have proved the existence of the 11–13 ka old, deeply submerged features (Rokoengen et al. 1982; Rise & Rokoengen 1984; Rise et al. 1984; Skinner et al. 1986).

Finally, this correlation problem between strandlines on land and "too deep" coastal features on the adjoining continental shelf is not just a local phenomenon occurring off northern Norway. Similar problems are encountered in the Celtic and Irish seas and also on the shelves off New England, off western Canada and off Scotland. This was one of the main items discussed at the conference of the European Science Foundation: Glacial–interglacial sea-level changes in four dimension: Continental shelf evidence of sea levels over the last 20 ka (R. Wingfield, chairman, pers. comm.)

About the other aim of Fjalstad & Møller, to present available radiocarbon dates (13–11 ka BP) of raised shorelines from land areas in northern Vesterålen and western Troms, we compliment the authors for their work. The postglacial deformational history on land in northern Norway has now become even better documented.

Regarding the deformational history of the offshore areas, we believe that the answers can only be found on the shelf itself – hopefully our paper and the later discussion can stir the interest of new, more detailed investigations as outlined in the conclusions of our original paper.

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