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Early Eocene evolution of the Vøring and Lofoten-Vesterålen passive volcanic margins in a conjugate setting

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The opening of the Norwegian-Greenland Sea during chron 24r, near the Paleocene-Eocene transition, was accompanied by massive, regional magmatism associated with the North Atlantic Large Igneous Province. Frequent eruptions resulted in thick lava sequences covering large areas along the continent-ocean transition at the present margin. We now use a greatly expanded magnetic, gravity and seismic database to re-examine the early opening history of the margin between Gleipne and Senja fracture zones, and its conjugate features off Greenland. This leads to: refinement of the pre-chron 22n magnetic anomaly pattern and the pre-chron 23n plate rotation stage pole; recognition of several, small-offset, early opening fracture zones; better confinement of the location and nature of the continent-ocean boundary; and documentation of the robust magnetic signature of breakup-related tectono-magmatic boundaries.

Our procedure for magnetic anomaly identification includes: 1) tracing of lineations based on anomaly character and amplitude, 2) locating areas of discontinuous lineations, changes in spatial separation, character and amplitude, 3) introducing short-lived, early-opening fracture zones, 4) evaluating the early opening rotation poles of Talwani and Eldholm (1977), and 5) adjusting conjugate lineations, and azimuth and location of fracture zones consistent with a modified opening-to-A23 stage pole. Several pre-A22 fracture zones that mainly interrupt the 24A-B sequence have been identified. We retain the Gleipne Fracture Zone and refine the Bivrost, Jennegga and Senja fracture zones of Hagevang et al. (1983), Olesen et al. (1997) and Faleide et al. (1993), respectively. Moreover, we introduce the Surt and Vesterålen fracture zones. These early Eocene features correspond to the four tectono-magmatic margin segments of Tsikalas et al. (2001) and Eldholm et al. (in press), i.e the Vøring, Lofoten, Vesterålen and Andøya segments. Although less data exist off Greenland, the aeromagnetic data provide a reasonable regional coverage of this mostly ice-covered margin. The well-developed pre-A22 lineations are readily interpretable except in the vicinity of the West Jan Mayen and Greenland fracture zones. The pre-A23 sequence trends obliquely with respect to the continental slope, loosing clarity and definition towards the south. The conjugate equivalents of all pre-A23 fracture zones off Norway have been inferred from the magnetic data.

The data also constrain the location and nature of the continent-ocean boundary. In particular, on the Vøring margin the continent-ocean boundary location coincides with the seaward gradient of a small, locally distinct, positive anomaly near the seaward termination of a base reflector below the inner part of seaward dipping reflector wedges. North of the Bivrost Fracture Zone, the anomaly gradient continues with decreased amplitude and coincides with structural lineaments bounding smaller and shallower seaward dipping reflector wedges near the foot of the slope. The continent-ocean boundary is placed along the seaward anomaly gradient between A24B and the structural lineaments and is, thus, restricted to a ~10-km-wide zone. Furthermore, we document the robust magnetic signature of both the Vøring and Greenland escarpments, as well as the landward termination of extensive breakup lavas on the Lofoten-Vesterålen segment.

The refined sea floor spreading anomalies and the fracture zones provide geometrical and azimuthal constraints for A23-to-opening plate reconstructions (Fig. 1). The reconstructions yield an unstable plate boundary, with several short-lived transforms, and require a pole of rotation which produces more northerly oriented flowlines than previously; i.e. azimuths of 165-168E. We calculate half-spreading rates of ~1.50 and ~2.38 cm yr^{-1} for the A22-23 and A23-24B periods, respectively. Thus, the initial spreading was by far the fastest in the history of the Norwegian-Greenland Sea. The new pre-A23 rotation poles have also other important implications. In particular, our well-constrained reconstructions both place the continent-ocean boundary on the Greenland shelf ~65-90 km off the coastline just north of West Jan Mayen Fracture Zone (Fig. 1), and they also account for the azimuthal differences between the conjugate Greenland and Senja fracture zones, providing a geometrical model in which the Greenland submarine ridge is a continental sliver.

Reconstructions to opening of potential field images show that the Bivrost Fracture Zone/Lineament, forming the transition between the Vøring and the Lofoten-Vesterålen margin segments, exhibits a history of structural inheritance and constitutes a primary tectono-magmatic boundary, greatly influencing the pre-, syn- and post-breakup margin development. A conceptual model is developed that may explain the along- and across-margin changes on either side of the transfer system. The model infers some rejuvenation of Late Jurassic-Early Cretaceous fault blocks during Late Cretaceous-Paleocene rifting and late Paleocene regional uplift of the rift system. We suggest breakup on the western flank of the Cretaceous Vøring Basin, and along a fault block just west of the Utrøst Ridge boundary fault north of the Bivrost Lineament. Thus, the Vøring and Greenland escarpments are not conjugate features, but rather two similar NE-SW trending features located on opposite margins on either side of the Bivrost Fracture Zone (Fig. 1). The escarpments reflect lavas that draped structurally controlled rift features which may have been also active for some period after breakup, possibly during the early Eocene. Moreover, it is likely that the newly formed thick oceanic, or Icelandic-type crust, experienced some syn-constructional faulting facilitating the build-up of the more than 6-km-thick seaward dipping wedges on the Vøring margin (Eldholm et al., 1995). Because the asthenospheric melts will preferentially move towards areas of accentuated crustal relief, or thinspots, the model is consistent with the across-margin asymmetry of the lower crustal body (Eldholm and Grue, 1994).

References

Eldholm, O. and Grue, K., 1994, North Atlantic volcanic margins: dimensions and production rates, *J. Geophys. Res.* **99**: 2955-2968.

Eldholm, O., Skogseid, J., Planke, S. and Gladczenko, T.P., 1995, Volcanic margin concepts, in E. Banda et al. (Eds), *Rifted Ocean-Continent Boundaries*, Kluwer Academic Publishers, pp. 1-16.

Eldholm, O., Tsikalas, F. and Faleide, J.I., in press. The continental margin off Norway 62-75EN: Palaeogene tectono-magmatic segmentation and sedimentation, in B. Bell and D. Jolley (eds), *The North Atlantic Igneous Province: stratigraphy, tectonics, volcanic and magmatic processes*, Geol. Soc. London, Special Publ..

Faleide, J.I., Vågnes, E. and Gudlaugsson, S.T., 1993, Late Mesozoic-Cenozoic evolution of the south-western Barents Sea in a regional rift-shear tectonic setting, *Marine and Petroleum Geology* **10**: 186-214.

Hagevang, T., Eldholm, O. and Aalstad, I., 1983, Pre-23 magnetic anomalies between Jan Mayen and Greenland-Senja fracture zones in the Norwegian Sea, *Mar. Geoph. Res.* **5**: 345-363.

Olesen, O., Torsvik, T.H., Tveten, E., Zwaan, K.B., Løseth, H. and Henningsen, T., 1997, Basement structure of the continental margin in the Lofoten-Lopphavet area, northern Norway: constraints from potential field data, on-land structural mapping and palaeomagnetic data, *Norsk Geologisk Tidsskrift* **77**: 15-30.

Talwani, M. and Eldholm, O., 1977, Evolution of the Norwegian-Greenland Sea, *Geol. Soc. Amer. Bull.* **88**: 969-999.

Tsikalas, F., Faleide, J.I. and Eldholm, O., 2001, Lateral variations in tectono-magmatic style along the Lofoten-Vesterålen volcanic margin off Norway, *Marine and Petroleum Geology* **18**: 807-832.

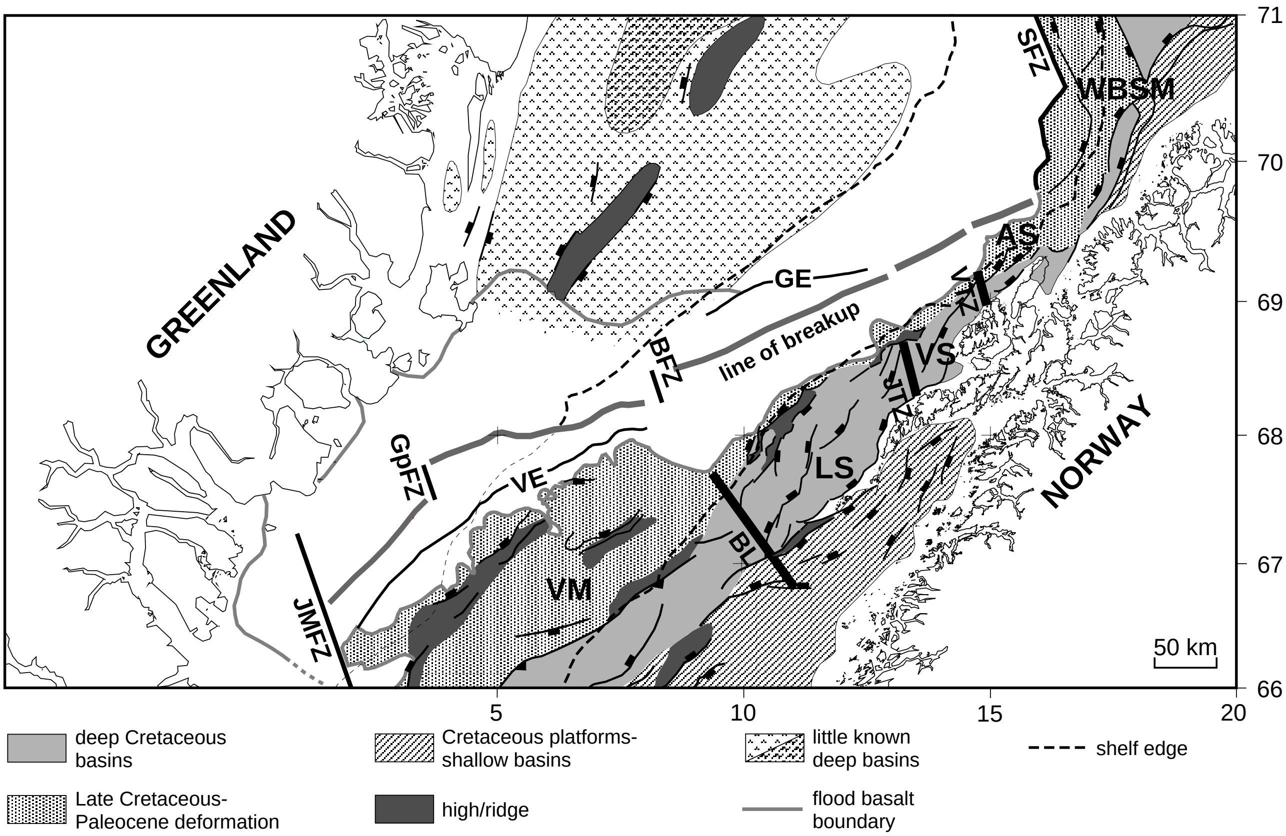

Fig. 1. Plate reconstruction to opening, ~55 Ma. VM, WBSM, Vøring and West Barents Sea margins, respectively; LS, VS, AS, Lofoten, Vesterålen, and Andøya margin segments, respectively; VE, GE, Vøring and Greenland escarpments, respectively; BL, JTZ, VTZ, Bivrost Lineament, and Jennegga and Vesterålen transfer zones, respectively; JMFZ, GpFZ, BFZ, SFZ, Jan Mayen, Gleipne, Bivrost, and Senja fracture zones, respectively.