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Vp/Vs-ratios and anisotropy on the northern Jan Mayen Ridge, North Atlantic, determined from ocean bottom seismic data

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ABSTRACT

In order to gain insight into the lithology and crustal evolution of the northern Jan Mayen Ridge, North Atlantic, the horizontal components of an Ocean Bottom Seismometer (OBS) dataset were analyzed with regard to Vp/Vs-modeling and seismic anisotropy. The modeling suggests that the northernmost part of the ridge consists of Icelandic type oceanic crust, bordered to the north by anomalously thick oceanic crust formed at the Mohns spreading ridge. The modeled Vp/Vs-ratios suggest variations in gabbroic composition and present-day temperatures in the area. Anisotropy analysis reveals a fast S-wave component along the Jan Mayen Ridge. This pattern of anisotropy is most readily interpreted as dikes intruded along the ridge, suggesting that the magmatism can be related to the development of a leaky transform since Early Oligocene.

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1. Introduction

It is well established that the Jan Mayen Ridge, North Atlantic, at least partly represents a continental sliver rifted off East Greenland (e.g. Myhre et al., 1984; Gudlaugsson et al., 1988, Fig. 1). The western and eastern boundaries of the ridge have been described by Kodaira et al. (1997); Mjelde et al. (2008a) and Breivik et al. (2012). In 2006, an Ocean Bottom Seismic (OBS) survey was conducted along the northernmost part of the ridge, mainly aiming at identifying the northern termination of the continental ridge (Kandilarov et al., 2012, Fig. 2). By modeling the OBS vertical components, combined with gravity modeling, Kandilarov et al. (2012) divided the northernmost part of the ridge into three segments from south to north; continental crust, Icelandic type oceanic crust, and oceanic crust accreted within the Mohns Ridge system.

Modeling of OBS horizontal components have earlier successfully constrained crustal lithology further south on the ridge (Mjelde et al., 2007). The main aim with the present study is thus to obtain Vp/Vs-ratios from the modeling of the OBS horizontal component data acquired in 2006, building on the P-wave and density models described by Kandilarov et al. (2012), in order to test the hypothesis outlining the northernmost part of the ridge as an oceanic plateau. Furthermore, the horizontal components will be explored with regard to seismic anisotropy, which could provide insight into tectono-magmatic dynamics (e.g. Mjelde et al., 2003).

2. Tectonic setting

The continental rifting following the collapse of the Caledonian mountain range occurred during several rift episodes over a time span of about 350 myr, culminating with continental break-up between Norway and Greenland in the early Eocene (magnetic anomaly 24r, ~53 Ma, e.g. Talwani and Eldholm, 1977; Cande and Kent, 1995). Oceanic spreading lasted around 20 myr (until ~33 Ma, magnetic anomaly 13a) at the Reykjanes, Aegir and Mohns Ridges (Fig. 1). During this phase, spreading along the northern Mid-Atlantic Ridge was simultaneous with spreading in the Labrador sea (Talwani and Eldholm, 1977; Tessensohn and Piepjohn, 2000). Voluminous magmatic activity accompanied the separation of Norway and Greenland, leading to the formation of thicker oceanic crust. Thick igneous layers were also intruded as sills into

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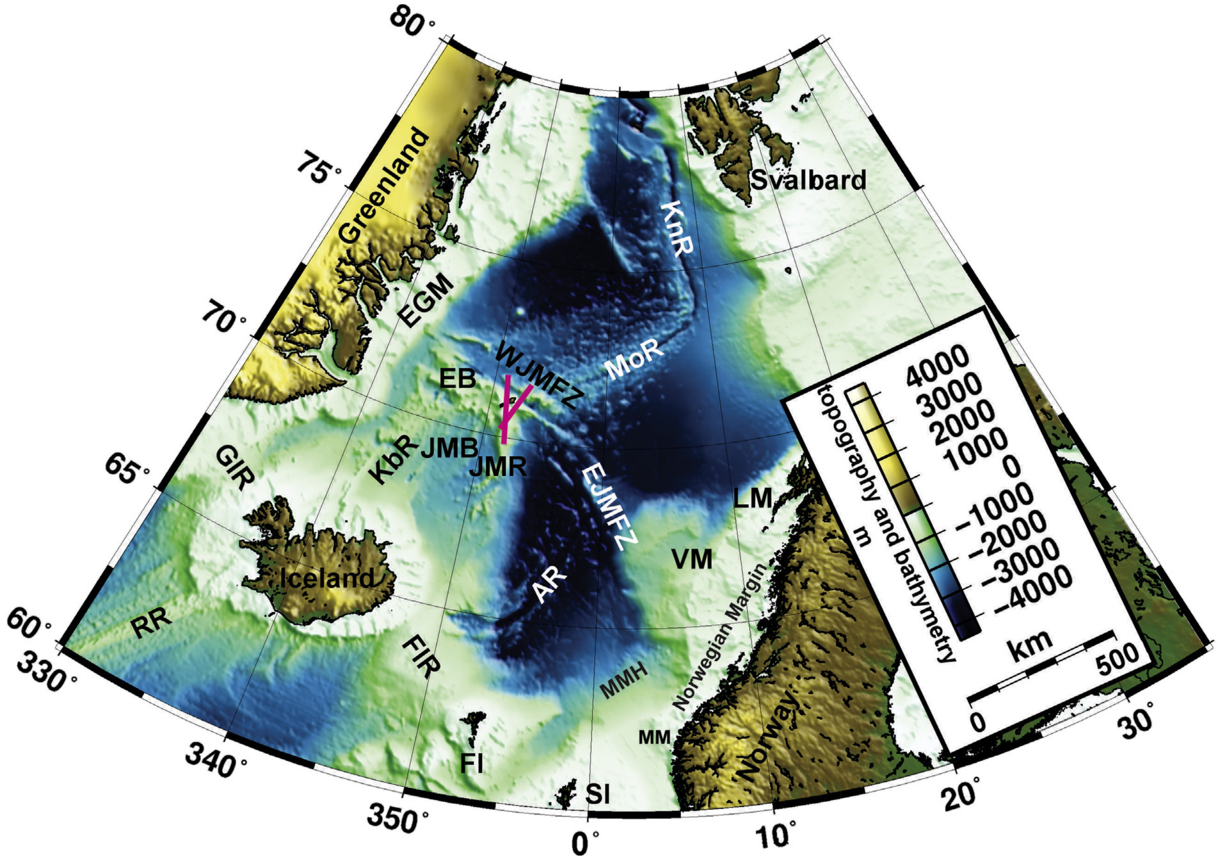

Fig. 1. Map of the North Atlantic showing the two studied profiles (red lines) and the main topographic and bathymetric features: RR – Reykjanes Ridge, GIR – Greenland–Iceland Ridge, FIR – Faeroe-Iceland Ridge, FI – Faeroe Islands, SI – Shetland Islands, MM – Møre Margin, MMH – Møre Marginal High, AR – Aegir Ridge, JMR – Jan Mayen Ridge, JMB – Jan Mayen Basin, KbR – Kolbeinsey Ridge, EGM – East Greenland Margin, WJMFZ – West Jan Mayen Fracture Zone, EJMFZ – East Jan Mayen Fracture Zone, VM – Vøring Margin, LM – Lofoten Margin, MoR – Mohn Ridge, KnR – Knipovich Ridge. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the continental crust or extruded sub-aerially as flood basalts. This magmatism decreased significantly after 5–10 myrs of oceanic spreading (Eldholm et al., 1989; White and McKenzie, 1989; Mjelde et al., 2008a).

The second stage of the northern North Atlantic evolution started in the early Oligocene (~33 Ma) when the spreading in the Labrador Sea ceased and Greenland became attached to the North American plate (Torsvik et al., 2001). This was accompanied by a change in the relative plate motion between the European and North American plates from NNW—SSE to NW–SE. Spreading along the Aegir Ridge decreased gradually and the ridge became extinct at ~25 Ma (magnetic anomaly 6–7, Talwani and Eldholm, 1977; Tessensohn and Piepjohn, 2000; Mosar et al., 2002). The spreading along the Aegir Ridge was accompanied by simultaneous continental rifting on East Greenland from about 43.5 Ma until the Kolbeinsey spreading rift initiated at around 24 Ma (Mjelde et al., 2008a). Initially, the spreading along the northern Kolbeinsey Ridge was relatively slow and subject to modest volcanic activity. About 3 myr after the break-up the magmatic activity increased due to the influence of the Icelandic hot-spot, and thicker than normal oceanic crust has been generated since (Kodaira et al., 1997; Mjelde et al., 2007, 2008a).

The eastern side of the Jan Mayen micro-continent conjugate to the Møre segment on the Norwegian margin is a volcanic margin, while the western side of the micro-continent represents a non-volcanic margin (Gudlaugsson et al., 1988; Kodaira et al., 1998; Mjelde et al., 2007, 2008a; Breivik et al., 2012).

3. The P-wave models

Since the Vp/Vs-modeling presented in this paper is based on the P-wave models of Kandilarov et al. (2012), we will here summarize their findings, which divides the northern Jan Mayen Ridge into a southern continental segment, a middle segment with Icelandic affinities and a northern oceanic segment influenced by the Mohns Ridge (Figs. 3 and 4).

Continental crust, characterized by relatively low crustal P-wave velocities (5.75–6.85 km/h), is inferred along the southern parts of the two lines south of the Continent Ocean Boundary (COB), located near OBS 10 along Line 1 and near the mid-point between OBS 32 and 33 on Line 2. The COB is interpreted in the center of an about 20 km wide Continent Ocean Transition (COT). The continental crust is overlain by three pre-opening sedimentary sequences dated as pre-Cretaceous, Cretaceous, Paleocene/Early Eocene, respectively (Gudlaugsson et al., 1988). Two younger sequences of post-rifting Cenozoic sediments were deposited on top of the older sequences.

Oceanic crust related to accretion at the Mohns Ridge, consisting of layers 2, 3A and 3B, is present north of OBS 16 on Line 1 and OBS 28 on Line 2. The oceanic crust is characterized by anomalously large thickness and high P-wave velocities in layer 3B, which is indicative of elevated mantle temperatures. This finding explains the anomalously shallow bathymetry of the area. The oceanic accreted crust is overlain by a thin layer of Late Cenozoic marine sediments.

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