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Geophysical investigations of the area between the Mid-Atlantic Ridge and the Barents Sea: From water to the lithosphere-asthenosphere system

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Abstract

As a part of the large international panel "IPY Plate Tectonics and Polar Gateways" within the "4th International Polar Year" framework, extensive geophysical studies were performed in the area of southern Svalbard, between the Mid-Atlantic Ridge and the Barents Sea. Seismic investigations were performed along three refraction and wide-angle reflection seismic lines. Integrated with gravity data the seismic data were used to determine the structure of the oceanic crust, the transition between continent and ocean (COT), and the continental structures down to the lithosphere-asthenosphere system (LAB). We demonstrate how modeling of multiple water waves can be used to determine the sound velocity in oceanic water along a seismic refraction profile. Our 2D seismic and density models documents 4–9 km thick oceanic crust formed at the Knipovich Ridge, a distinct and narrow continent-ocean transition (COT), the Caledonian suture zone between Laurentia and Barentsia, and 30–35 km thick continental crust beneath the Barents Sea. The COT west of southern Spitsbergen expresses significant excess density (more than 0.1 g/cm^3 in average), which is characteristic for mafic/ultramafic and high-grade metamorphic rocks. The results of the gravity modeling show relatively weak correlation of the density with seismic velocity in the upper mantle, which suggests that the horizontal differences between oceanic and continental mantle are dominated by mineralogical changes, although a thermal effect is also present. The seismic velocity change with depth suggests lherzolite composition of the uppermost oceanic mantle, and dunite composition beneath the continental crust.

Keywords: Continent-ocean transition; Barents Sea; Seismic and gravity modeling; Lithosphere-asthenosphere system; Tectonic evolution

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1. Introduction

In the framework of the "4th International Polar Year" extensive geophysical studies were performed within the panel "Plate Tectonics and Polar Gateways" (Schweitzer et al., 2008). The international project "The Dynamic Continental Margin between the Mid-Atlantic-Ridge System (Mohns Ridge, Knipovich Ridge) and the Bear Island Region" was undertaken in the area of the southern Svalbard, mainly in order to study the crustal structure and evolution in the transition between continental and oceanic lithosphere (COT). The study was based on three refraction and wide-angle reflection seismic lines: Horsted'05, BIN-2008 and BIS-2008, acquired in August 2005, July 2008 and August 2008, respectively (Fig. 1). The project has four main goals: 1) study the processes causing the collapse of the Caledonian mountain range and subsequent continental basin formation, 2) investigate the continent-ocean-transition in a dominantly strike-slip environment, but containing segments of both trans-tension and trans-compression, 3) clarify the interplay between tectonic and magmatic processes during ultra-slow oceanic accretion, and 4) investigate whether the ocean bottom seismic method has oceanographic applications. The study area is unique, in the sense that all these four connected goals can be addressed within an area of limited geographical extent (*c*. 800 km by 500 km). The present paper reviews the results from the study of the three crustal profiles. The results of seismic studies and tectonic evolution of the North Atlantic Ocean was previously published in number of papers, e.g., Breivik et al. (1999), Doré (1991), Eldholm et al. (2002), Faleide et al. (1993, 1996, 2008), Gabrielsen et al. (1990), Ljones et al. (2004), Mjelde et al. (2003, 2008), Riis et al. (2008), Ritzmann et al. (2004), and Worsley (2008).

2. Tectonic setting of the study area

The crystalline basement structures of the western Barents Sea are to a large extent related to the collapse

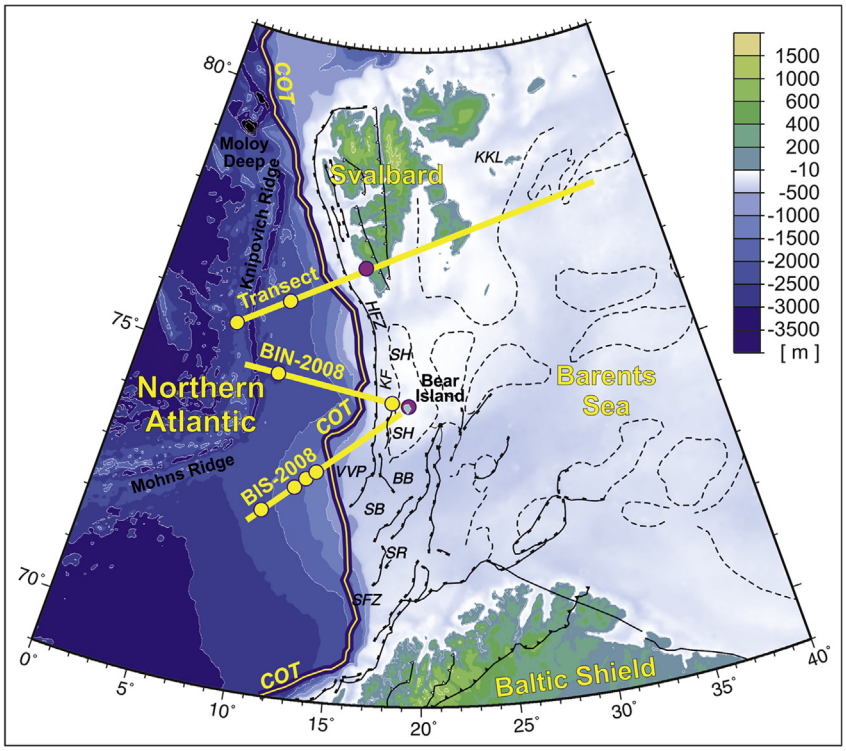

Fig. 1. Location map of the Transect, BIN-2008 and BIS-2008 seismic profiles on the background of topography/bathymetry map (Jakobsson et al., 2000) and simplified tectonic elements (Gabrielsen et al., 1990; Faleide et al., 2008) of the continental margin in the area of the Northern Atlantic (Norwegian-Greenland Sea). COT, continent-ocean transition (from interpretation of gravity data, Breivik et al., 1999); main fault zones and basins: BB, Bjørnøya Basin; BS, Barents Shelf; HFZ, Hornsund Fault Zone; KF, Knølegga Fault; KKL, Kong Karls Land; SH, Stappen High; SFZ, Senja Fracture Zone; SR, Senja Ridge; VVP, Vestbakken Volcanic Province. Big yellow and violet dots are locations of OBSs and land stations, respectively, for which examples of recordings are shown in Figs. 2 and 4.