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Evidence for mantle exhumation since the early evolution of the slow-spreading Gakkel Ridge, Arctic Ocean

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ABSTRACT

We study the basement configuration in the slow-spreading Eurasia Basin, Arctic Ocean. Two multichannel seismic (MCS) profiles, which we acquired during ice-free conditions with a 3600 m long streamer, image the transition from the North Barents Sea Margin into the southern Eurasia Basin. The seismic lines resolve the up to 5000 m thick sedimentary section, as well as the crustal architecture of the southern Eurasia Basin along 120 km and 170 km, respectively. The seismic data show large faulted and rotated basement blocks. Gravity modeling indicates a thin basement with a thickness of 1–3 km and a density of $2.8*10^3$ kg/m^3 between the base of the sediments and the top of the mantle, which indicates exhumed and serpentinized mantle. The Gakkel spreading ridge, located in northern prolongation of the seismic lines is characterized by an amagmatic or sparsely magmatic segment. From the structural similarity between the basement close to the ultra-slow spreading ridge and our study area, we conclude that the basement in the Eurasia Basin is predominantly formed by exhumed and serpentinized mantle, with magmatic additions. An initial strike-slip movement of the Lomonosov Ridge along the North Barents Sea Margin and subsequent near-orthogonal opening of the Nansen Basin is supposed to have brought mantle material to the surface, which was serpentinized during this process. Continuous spreading thinned the serpentinized mantle and subsequent normal faulting produced distinct basement blocks. We propose that mantle exhumation has likely been active since the opening of the Eurasia Basin.

1. Introduction

Our understanding of oceanic crust formation at slow to ultraslow-spreading ridges has seen dramatic changes in the past 20 years (Cannat et al., 2006; Cheadle and Grimes, 2010; Dick et al., 2003; Smith et al., 2008; Tucholke and Lin, 1994). Especially the fact that these regions are found to be magma-poor requires new concepts for oceanic crust formation. The process of ultraslow seafloor spreading is predominantly studied at the Southwest Indian Ridge (SWIR), which is easier accessible than the Gakkel Ridge in the high Arctic (Dick et al., 2006; Snow and Edmonds, 2007). At the SWIR it has been shown with seafloor mapping and dredging that exhumed mantle and magmatic rocks occur next to each other (Bronner et al., 2014; Cannat et al., 2006; Sauter et al., 2013). The volcanic rocks are described as a carapace on top of exhumed mantle (Sauter et al., 2013). Along a 300 km long segment of the Gakkel Ridge mantle peridotites, which experienced serpentinization are emplaced (Michael et al., 2003).

An important mode of seafloor spreading at slow to ultraslow-spreading ridges is oceanic detachment faulting and oceanic core complex (OCC) formation (summarized in e.g. Cheadle and Grimes, 2010). In this process, low-angle detachment faults generate large displacements, which accommodate tenth of kilometers of extension. The uplifted footwall blocks expose mafic and ultramafic rocks, which form OCCs (Smith et al., 2008). The top of these domal structures typically show corrugations that extent parallel to the direction of extension (Cheadle and Grimes, 2010) but they can also have a smooth surface (Sauter et al., 2013). Most studies so far focus on the present-day ultraslow spreading centers. Accordingly, little is known about the long-term evolution of these amagmatic segments.

Here, we image the oldest part of the Nansen Basin with multi-channel seismic data and a long streamer in ice-free conditions. Combined with gravity and magnetic modelling, we provide a conceivable model for the continent-ocean boundary and the formation and evolution of the basement in the Nansen Basin.

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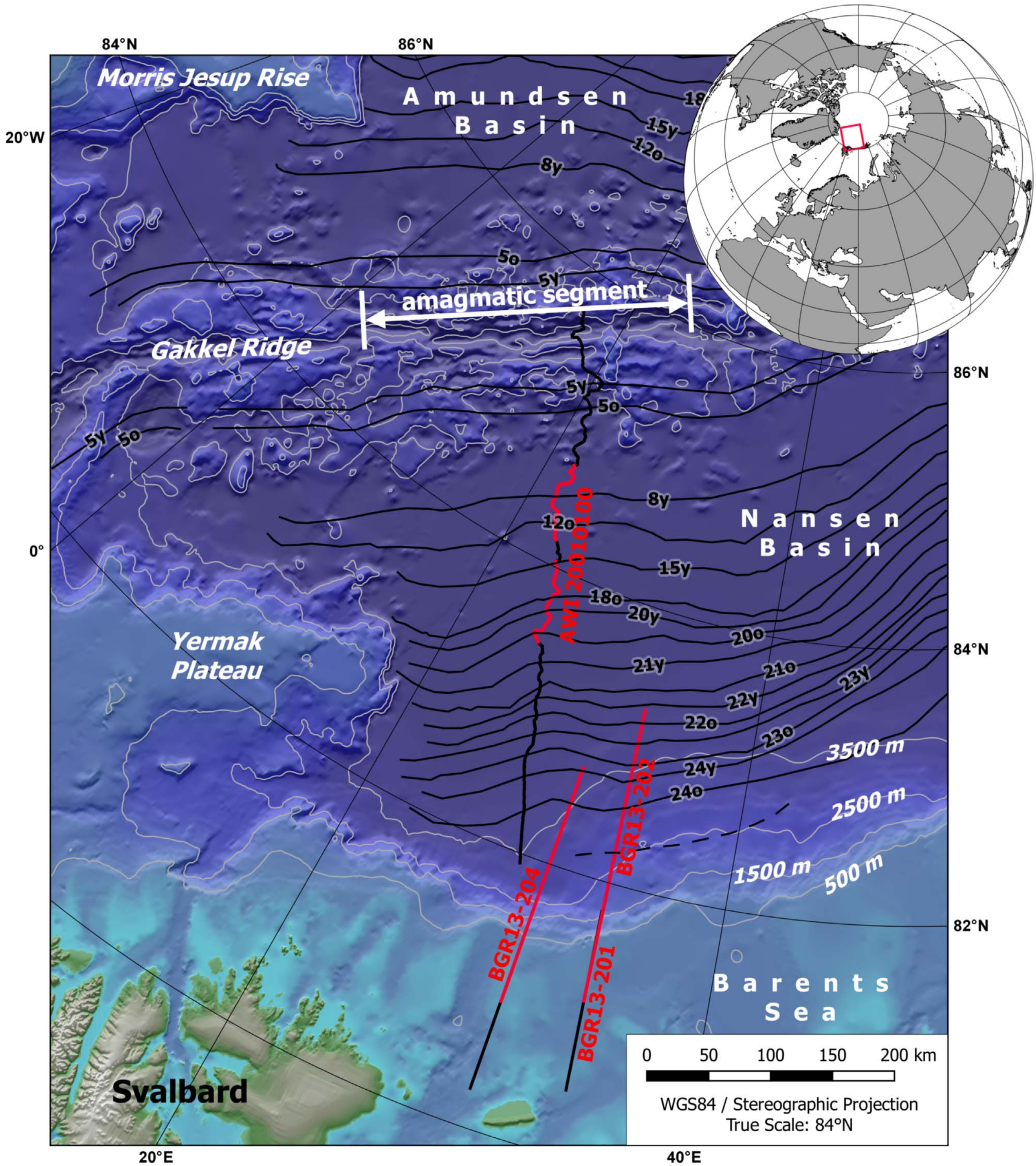

Fig. 1. Location of the study area in the Nansen Basin and on the North Barents Sea continental margin. Thick black lines indicate the seismic profiles discussed in the text and the red lines are the parts, which are shown in Figs. 2, 3 and 5. Thin black lines with annotations are the magnetic lineations from Brozena et al. (2003). Red rectangle in inset shows the map extent. Important structural features and locations are annotated. The extent of the amagmatic segment is taken from Schlindwein and Schmid (2016). Bathymetry is from the IBCAO dataset (Jakobsson et al., 2012). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2. Geological setting

The Eurasia Basin in the Arctic Ocean developed since 56–53 Ma, documented by magnetic anomalies starting from C24 (Engen et al., 2008; Vogt et al., 1979) and possibly C25 (Brozena et al., 2003; Døssing et al., 2013). The active seafloor spreading ridge, the Gakkel Ridge, separates the Eurasia Basin into a northern Amundsen and a southern Nansen Basin (Fig. 1). In the western Eurasia Basin seafloor spreading velocities at Gakkel Ridge decreased during basin evolution from ~27 mm/yr (C24–C20) to less than 20 mm/yr (i.e. ultraslow-spreading) after chron 20 (Glebovsky et al., 2006). The Lomonosov Ridge is a microcontinent which has been detached from the North Barents Sea and Kara Sea continental margin (e.g. Jokat et al., 1992; Minakov and Podladchikov, 2012) and forms the northern border of the Eurasia Basin. The conjugate margins of Lomonosov Ridge and the Barents Sea exhibit prominent steps or escarpments in bathymetry data. The role of strike-slip movements in the Lomonosov Ridge detachment process and initial basin formation is under discussion (e.g. Berglar