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Lithospheric strength and elastic thickness of the Barents Sea and Kara Sea region

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ABSTRACT

Interpretation of tomography data indicates that the Barents Sea region has an asymmetric lithospheric structure characterized by a thin and hot lithosphere in the west and a thick and cold lithosphere in the east. This suggests that the lithosphere is stronger in the east than in the west. This asymmetric lithosphere strength structure may have a strong control on the lithosphere response to tectonic and surface processes. In this paper, we present computed strength and effective elastic thickness maps of the lithosphere of the Barents Sea and Kara Sea region. Those are estimated using physical parameters from a 3D lithospheric model of the Barents Sea and Kara Sea region. The lithospheric strength is computed assuming a temperature-dependent ductile and brittle rheology for sediments, crust and mantle lithosphere. Results show that lithospheric strength and elastic thickness are mostly controlled by the lithosphere thickness. The model generally predicts much larger lithospheric strength and elastic thickness for the Proterozoic parts of the East Barents Sea and Kara Sea. Locally, the thickness and lithology of the continental crust disturb this general trend. At last, the gravitational potential energy (GPE) is computed. Our results show that the difference in GPE between the Barents Sea and the Mid-Atlantic Ridge provides a net horizontal force large enough to cause contraction in the western and central Barents Sea.

1. Introduction

The Barents Sea and Kara Sea region is located in the North European Arctic. The region is characterized by a west–east structural asymmetry (Fig. 1). The western Barents Sea is a shallow sedimentary platform crisscrossed by Late Paleozoic–Mesozoic narrow rift basins (Johansen et al., 1992; Gudlaugsson et al., 1998) whereas the eastern part is marked by a single wide and deep Late Paleozoic basin (Johansen et al., 1992).

Cenozoic deformation structures are widespread in the Barents Sea. The entire Barents Sea was uplifted and eroded during Neogene time. The western Barents Sea experienced more erosion than the eastern Barents Sea and Kara Sea (Dimakis et al., 1998; Henriksen et al., 2011; Sobolev, 2012). Seismic reflection data from the northeast Atlantic passive margins indicate that Mid-Miocene and older sediments (>16–18 Ma) are locally folded and form dome structures (Vågnes et al., 1998; Doré et al., 2008; Anell et al., 2009; Døssing et al., 2016). Such contractional structures are observed in sediment layers at the Vestbakken margin (Fig. 2a) located on the western margin of the Barents Sea (Faleide et al., 1988; Gabrielsen et al., 1997). Ridge push stress, generated by the difference in gravitational potential energy between elevated areas (the Knipovich Ridge and/or Iceland margin) and the western Barents Sea margin, has been proposed to explain these observations (Fejerskov et al., 2000; Doré et al., 2008). Magnetic isochron interpretation (Fig. 2b) indicates that the onset of the Knipovich spreading ridge predates the contraction of Mid-Miocene sedimentary strata (Faleide et al., 2010). To test the ridge push hypothesis, the net force provided by difference in gravitational potential energy between elevated areas and passive margins has to be compared with the lithosphere strength.

Uplift and contractional structures are the mechanical response of the lithosphere when it is exposed to external forces. The lithosphere mechanical response is in turn controlled by its yield strength, i.e. the amount of stress necessary to trigger anelastic deformation. Knowledge of the lithosphere yield strength structure is therefore an important element to understand the Cenozoic deformation in the Barents Sea region.

The purpose of the paper is to evaluate the present-day lithospheric yield strength and effective elastic thickness for the Barents Sea and Kara Sea region. We then use the modeled lithosphere strength to evaluate the potential of a ridge push mechanism to cause contraction in the Barents Sea region.

In this study we use an approach similar to Tesauro et al. (2012, 2013) to estimate present-day lithosphere yield strength and effective

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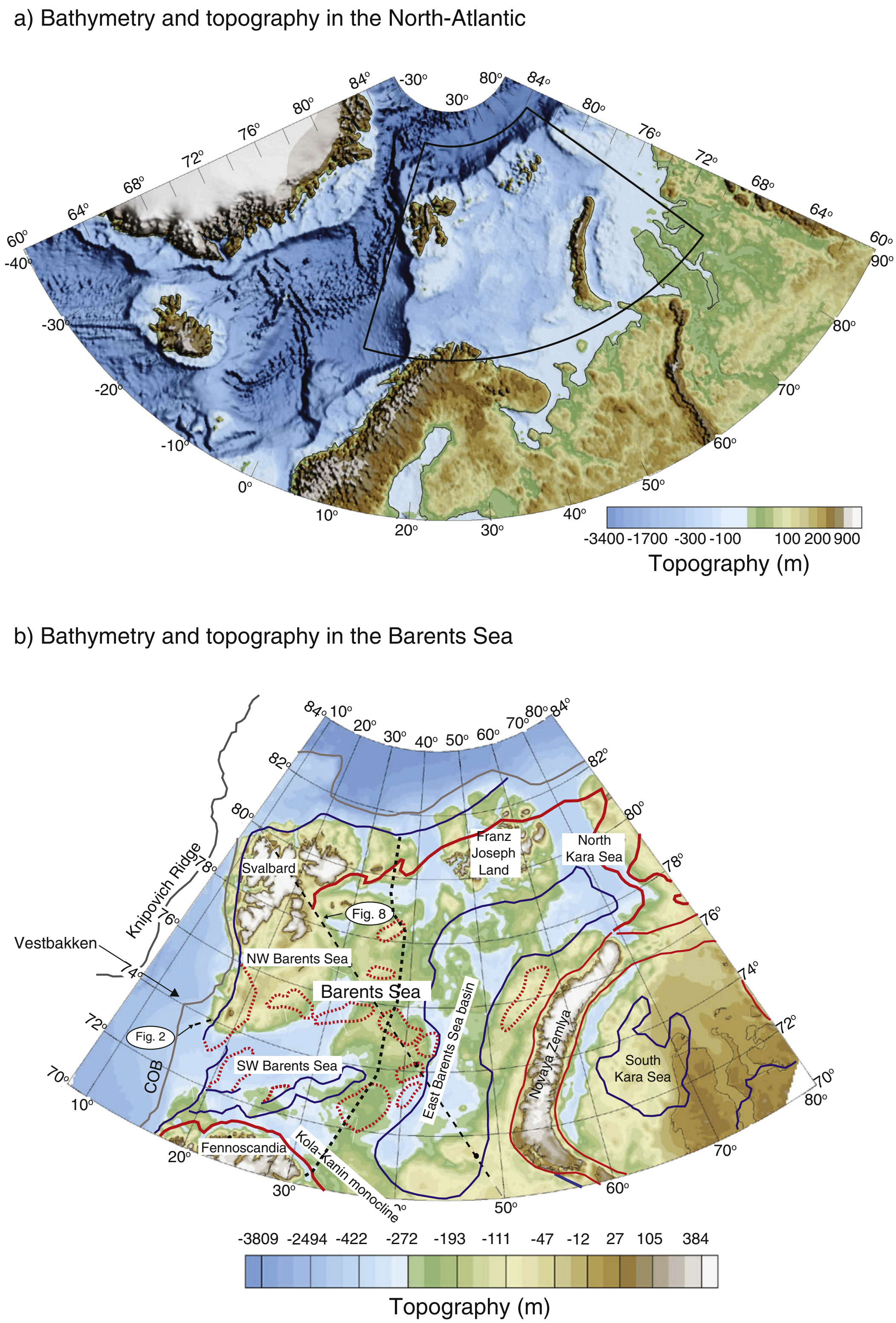

Fig. 1. Bathymetry–topography map of a) the North-Atlantic region (top) and b) the Barents Sea and Kara Sea region. Main structural features are represented, basins (blue) and highs (red). The locations of transects (dashed lines) crossing the Vestbakken margin (see Fig. 2) and the Barents Sea from NW to SE (see Fig. 8) are shown. The political border between Norway (West) and Russia (East) is shown (dotted line). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

elastic thickness maps. The strength is computed assuming brittle and temperature-dependent ductile rheology for the crust and mantle lithosphere. The present-day thermal field is steady-state. Effective elastic thickness map is computed using the modeled lithosphere strength envelope (Burov and Diament, 1995).

In the following, we first summarize the geology of the Barents Sea and Kara Sea region. Second, we describe the rheological modeling approach. The computation of yield strength is based on a 3D lithosphere-scale structural model (Klitzke et al., 2015) and thermal model of the region, consistent with seismic, gravity and tomography

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