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The crust and mantle lithosphere in the Barents Sea/Kara Sea region

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ABSTRACT

The focus of this study is the nature of a prominent, high-velocity (S-wave) anomaly in the upper mantle below the Barents Sea–Kara Sea region and its relation to the evolution of the sedimentary basins, in particular the Permo–Triassic East Barents Sea Basin. The high-velocity anomaly exhibits a thickness of 75–100 km below the central Barents Sea and thickens considerably below the East Barents Sea Basin (150 km). The thickest part of the high-velocity anomaly follows the outline of the East Barents Sea Basin which is bended around Pai-Khoi–Novaya Zemlya Fold Belt. Density modeling of the lithosphere along a 3200 km long transect from the Barents Sea to the West Siberian Basin was used to evaluate different models for the upper mantle structure. The best fit gravity model was achieved when either assuming a 1D, horizontally- layered mantle structure, or, a forward-modeled density structure using an average Proterozoic mantle composition. The first model requires a further, compensating excess mass below the (seismic) Moho in the East Barents Sea Basin region. The latter model exhibits a higher-density dome structure below the basin. Both models indicate probable old, continental lithosphere below the central part of the transect in eastern Barents Sea/Kara Sea region. Calculated temperatures of 400–1000 °C (60–200 km depth) further support this concept. Hence, the East Barents Sea Basin developed probably as an intra-continental basin within a non-extensional setting. Such basins exhibit generally crustal inhomogeneities which contributed considerably to their subsidence history. Likely structures below the East Barents Sea Basin are Pre-Permian rifts, accumulated melts derived by the Siberian mantle plume, and/or the Late Neoproterozoic Timanide Orogen.

1. Introduction

Recently, Levshin et al. (2007) published a 3D geophysical model (BARMOD) for the crust and upper mantle based on surface wave tomography in the greater Barents Sea region (Fig. 1). A striking observation was the strong positive S-wave velocity anomaly within the upper mantle below the Barents Sea, Novaya Zemlya, and the Kara Sea (Fig. 2). The anomaly is up to 4% higher than the surrounding, very fast upper mantle velocities in the Barents Sea region (Schweitzer and Kennett, 2007). The shape of the anomaly is flat below the western Barents Sea and thickens considerably to more than 120 km below the East Barents Sea Basin. It exhibits a gentle dip to the east and thins again below the Kara Sea region. The BARMOD model therefore validated the earlier and global model CUB1.0 (Shapiro and Ritzwoller, 2002). A look at the regional geology indicates that the high-velocity anomaly possibly follows known geological lineaments such as the Neoproterozoic Timanide Orogen (Gee and Pease, 2004), the Early–Middle Palaeozoic Caledonide Orogen (Roberts and Gee, 1985) or the Triassic–Jurassic Pai-Khoi–Novaya Zemlya Fold Belt (Zonenshain et al., 1990). Moreover, the thickest section of the high-velocity anomaly follows almost exactly the outline of the Permo–Triassic East Barents Sea Basin (Fig. 3, Johansen et al., 1993).

Immediately after emergence of the BARMOD results, geologists and geophysicists started a controversial discussion of the nature and the geodynamic history of the upper mantle anomaly. In this paper, we will carefully introduce the geophysical structure of the Barents Sea–Kara Sea lithosphere on the basis of the tomography model of Levshin et al. (2007). Density modeling of the upper mantle structure will help to evaluate models suggested for the high-velocity anomaly, such as the remnant of a subducted slab (Faleide et al., 2006; Levshin et al., 2007).

The striking match between the East Barents Sea Basin and the upper mantle velocity anomaly leads to assumption that both features are strongly connected. Regardless of the geodynamic history behind the upper mantle anomaly, the processes in the mantle lithosphere are obviously linked to the subsidence history of the East Barents Sea Basin in the upper, crustal lithosphere. The East Barents Sea Basin hosts major gas fields on the Arctic Shelf; here, the (Russian) Shtokman field is one of the largest findings worldwide. Basin formation is therefore also in focus of the petroleum industry. We extended our study region to the east across the West Siberian Basin (Vyssotski et al., 2006) to the Archean to Proterozoic Siberian Craton (Rosen et al., 1994) and the Siberian Traps (Fig. 1; Renne and Basu, 1991). Since we can not rule out an intra or pericratonic setting (Stephenson et al., 2006; Stille, 1958) for the eastern

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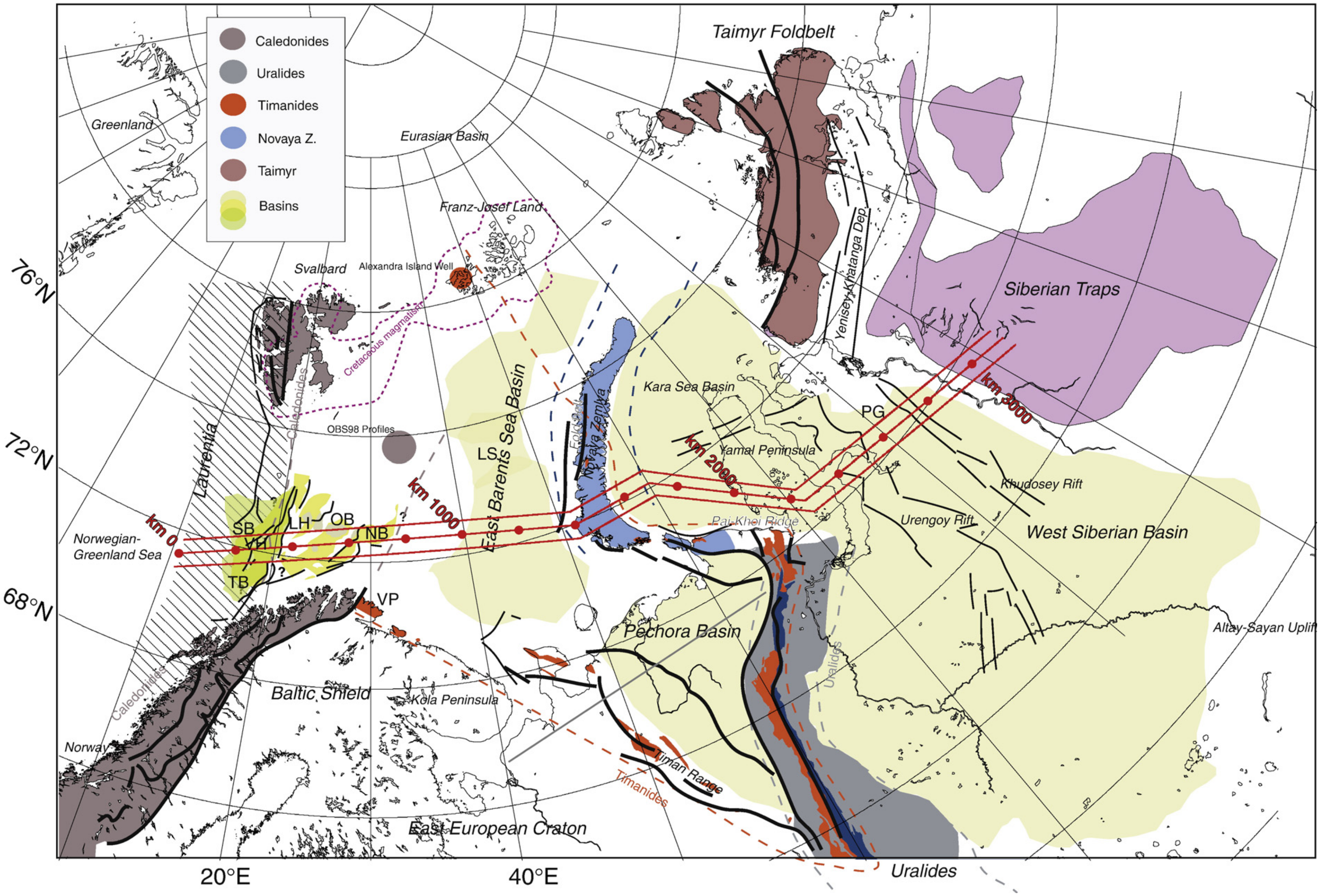

Fig. 1. Study area. Map showing the main geological elements in the study area. Principle convergent zones and sedimentary basins are color-coded. Caledonian basement in the central Barents Sea is suggested from wide-angle seismic studies (Breivik et al., 2002; 'OBS98 Profiles'). The red line covered by dots shows the location of the 2D transect discussed in this paper. The red lines to the north and south of it indicate a 50 km wide corridor around this transect. LH, Loppa High; LS, Ludlov Saddle; NB, Norkapp Basin; NGS, Norwegian-Greenland Sea; OB, Ottar Basin; PG, Pur-Gedan Basin; SB, Sørvestsnaget Basin; TB, Tromsø Basin; VH, Veslemøy High; VP Varanger Pensinsula.