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Stochastic velocity inversion of seismic reflection/refraction traveltime data for rift structure of the southwest Barents Sea

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ABSTRACT

We present results from an active-source, onshore–offshore seismic reflection/refraction transect acquired as part of the PETROBAR project (Petroleum-related studies of the Barents Sea region). The 700 km-long profile is oriented NW–SE, coincident with previously published multichannel seismic reflection profiles. We utilize layer-based raytracing in a Markov Chain Monte Carlo (MCMC) inversion to determine a probabilistic velocity model constraining the sedimentary rocks, crystalline crust, and uppermost mantle in a complex tectonic regime. The profile images a wide range of crustal types and ages, from Proterozoic craton to Paleozoic to early Cenozoic rift basins; and volcanics related to Eocene continental breakup with Greenland. Our analyses indicate a complex architecture of the crystalline crust along the profile, with crystalline crustal thicknesses ranging from 43 km beneath the Varanger Peninsula to 12 km beneath the Bjørnøya Basin. Assuming an original, post-Caledonide crustal thickness of 35 km in the offshore area, we calculate the cumulative thinning (β) factors along the entire profile. The average β factor along the profile is 1.7 ± 0.1, suggesting 211–243 km of extension, consistent with the amount of overlap derived from published plate reconstructions. Local β factors approach 3, where Bjørnøya Basin reaches a depth of more than 13 km. Volcanics, carbonates, salt, diagenesis and metamorphism make deep sedimentary basin fill difficult to distinguish from original, pre-rift crystalline crust, and thus actual stretching may in places exceed our estimates.

1. Introduction

Continental extension leading to breakup and subsequent oceanic accretion is a complex tectonic process. Variations in structure, duration, and episodicity are observed not only between different rifted margins globally, but also along strike and between conjugate margin pairs (e.g., Blaich et al., 2011; Crosby et al., 2008; Mjelde et al., 2008; Tsikalas et al., 2008). Lithospheric strength is the primary control on these variations, generally agreed upon to be a function of crust and mantle thicknesses and compositions, temperature, melting, and rate of extension (Buck, 1991; Ziegler and Cloetingh, 2004). Increasingly complex numerical modeling studies of rifting explore the relative influence and evolution of these parameters (Huismans et al., 2005; Lavier and Manatschal, 2006; Rosenbaum et al., 2008), but they continue to be debated. Observational constraint in as many locations and with as much detail as possible remains critical to evaluating and improving our understanding of geodynamic processes.

The western Barents Sea margin is predominantly a transform margin, where final breakup occurred during the early Cenozoic along the dextral transform De Geer Zone between northwest Eurasia and northeast Greenland, eventually evolving into the obliquely-spreading Knipovich Ridge (Engen et al., 2008; Faleide et al., 1993a). Prior to breakup, however, the long-term rifting between Norway and east Greenland that would eventually form the Norwegian–Greenland Sea continued along-strike hundreds of kilometers northeast into the Barents Sea region (Faleide et al., 1993a). Because the line of final breakup followed the transform zone instead of the rift axis, most of the rift-related structures remain on the Barents side, with no major rift basins observed at the transform-margin conjugate in northeast Greenland (Faleide et al., 2008). As such, these rift structures are highly asymmetric, with rifting progressively shifting from near-orthogonal extension to predominantly transform breakup.

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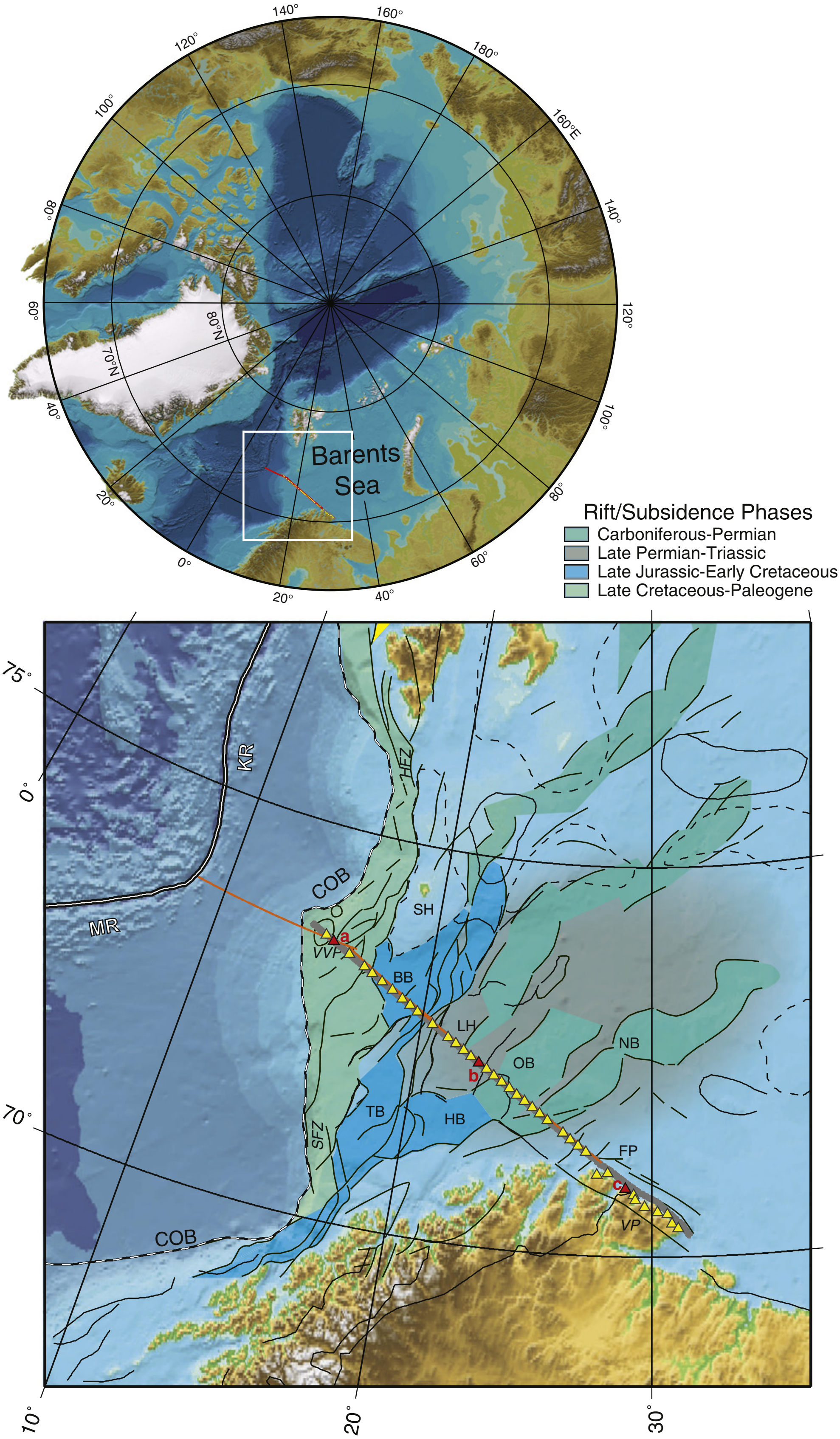

Fig. 1. Regional map of the Arctic (Jakobsson et al., 2008) with study area outlined in white (above) and basemap of the southwestern Barents Sea (below). Major faults shown as black lines (Faleide et al., 2008). Local highs shown as dashed black lines. Near-normal incidence seismic reflection profile (Fig. 2) shown as orange line. Wide-angle profile shots (gray line) and recording instruments (yellow triangles) also shown; labeled, red triangles correspond to record section examples shown in Fig. 3. MR: Mohns Ridge, KR: Knipovich Ridge, COB: continent–ocean boundary, HFZ: Hornsund Fault Zone, SFZ: Senja Fracture Zone, VVP: Vestbakken Volcanic Province, BB: Bjørnøya Basin, LH: Loppa High/Selis Ridge, SH: Stappen High, TB: Tromsø Basin, OB: Ottar Basin, HB: Hammerfest Basin, NB: Nordkapp Basin, FP: Finnmark Platform, VP: Varanger Peninsula.