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Multi-stage rift evolution of the SW Barents Sea from wide-angle seismic velocity modeling

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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 690 km-long profile is oriented NW-SE, coincident with the deep multichannel seismic reflection profile IKU-B acquired in 1984. The transect comprises 4157 shots from a 78 l. (4800 cu. in.), four-airgun source array. The shots were recorded by 28 GEOMAR ocean-bottom stations (26 four-component OBS and 2 single-component OBH) and 10 land stations deployed by the University of Copenhagen along the northern coast of Norway. Data quality is generally good, with clear signal offsets in excess of 200 km. We utilize first-arrival tomography, layer-based raytracing, and gravity modeling to constrain the velocity and density structure of the sediments, crust, and uppermost mantle in a complex tectonic regime. This is the first wide-angle seismic transect off northern Norway to extend continuously from continental craton, near the Russian border, to oceanic crust, at the interpreted COB. The profile images a wide range of crustal types and ages, including, from SE to NW: Proterozoic cratonic Baltica; Paleozoic orogenic Caledonides; generally westward-younging, Paleozoic to early Cenozoic basins; and transtensional rift structures and volcanics related to the Eocene breakup with Greenland. Our analyses indicate significant heterogeneity of the crystalline crust along the profile, with crystalline crustal thicknesses ranging from 45 km beneath the Varanger Peninsula to <10 km beneath the Bjørnøya Basin. Assuming an original, post-Caledonide crustal thickness of 45 km, the average stretching factor along the entire profile is 1.6, with 260 km of cumulative extension and an original length of 430 km. Associated, fault-bounded basins formed in the grabens and half-grabens of tilted crustal blocks during multiple, distinct rifting episodes. The main rift stages (Carboniferous, Late Jurassic-Early Cretaceous and Late Cretaceous-Paleogene) are closely related to the paleogeography and megasequences established with regional seismic mapping, which has revealed a westward migration and rotation of the main rift structures formed during the successive stages. We suggest that late Paleozoic rifting and post-orogenic collapse of the Caledonides restored an average continental crustal thickness of 35 km along the profile, followed by 150 km of Mesozoic to final breakup extension. This extension was limited to the northwesternmost 300 km of the profile, with a pre-extension length of 150 km and an average stretching factor of 2.0. Local stretching factors approach 3.5, where Bjørnøya Basin reaches a depth of 17 km. At such extreme basin depths, chemical compaction and metamorphism make sedimentary basin fill difficult to distinguish from original crystalline basement, thus the actual stretching factors may exceed our estimates.