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Orphan Basin crustal structure from a dense wide-angle seismic profile – layered modeling

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The Orphan Basin is a large, deep water basin to the east of Newfoundland and northwest of Flemish Cap, Canada. It contains a considerably wide series of rift basins that provides an excellent opportunity to study continental crustal deformations under varying degrees of extension. We present a 500-km-long P-wave velocity model across the complete rift system of the Orphan Basin, from Flemish Cap to the Bonavista Platform, using high-resolution refraction and wide-angle reflection data from 89 ocean-bottom seismometers (OBS). This layered model builds on a first-arrival traveltime tomography model (Watremez et al., this session) and is formed using additional constraints from a coincident multichannel seismic reflection profile, gravity data and borehole data from three wells. The layered model helps detail deep sediment and crustal variations across this wide region of extended continental crust.

The sedimentary section contains post-rift Tertiary (vp$\sim$1.7-3.5 km/s) and syn-rift Cretaceous and Jurassic (vp$\sim$4-5.4 km/s) layers within both the eastern and the western sub-basins, separated by three basement highs, suggesting that the two sub-basins may have opened during a single, extended rifting event. The crust is composed of three layers with vp of 5.4-6.1, 6.1-6.5 and 6.3-7.1 km/s of highly variable combined thicknesses, from 32 km beneath Flemish Cap and the Bonavista Platform to <10 km beneath both western and eastern sub-basins. The shape of the crustal thinning appears highly asymmetrical across the two sub-basins. Flemish Cap crust thins westward within the eastern sub-basin into a narrow zone (35 km) of hyperextended crust (<10 km thick) beneath an 8-km-deep sedimentary basin. In contrast, the Bonavista Platform crust thins eastward within the western sub-basin into a wider zone (116 km) of hyperextended crust. Separating the two rift basins is a central section with two distinctive zones of thicker (10-16 km) crust, where muted topography characterizes the eastern part and large basement highs in the western part, separated by the eastward dipping White Sail Fault cutting through the whole crust to the Moho. Higher velocities are, however, found within the lower crustal hanging wall relative to its footwall counterpart to its west. Since such structure cannot be explained by displacement along the fault alone, lateral ductile flow may be responsible for such depth-dependant stretching (DDS). Discrepancies between upper crustal thinning (γuc) and lower crustal thinning (γlc) are consistently observed, but only create a small deficit ($\sim$7% or 1.5 km) in the lower crust.

Reconstruction of the North Atlantic at M0 time suggests a complex connection between Rockall Trough and the West Orphan Basin, Porcupine Bank and the East Orphan Basin, and the Central Orphan High and Porcupine Bank. Unlike the Rockall and Porcupine Basins, no evidence for partial serpentinization of the upper mantle is observed beneath the E. Orphan trough. However, hyperextension (crustal thickness < 10 km) only occurs over a very narrow zone ($\sim$ 30 km wide) in the E. Orphan trough, which might have allowed the basement to have been covered by syn-rift sediment that inhibited the flow of water down the faults.