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Preferential southward Tristan Plume flow during early rifting of the South Atlantic: Causes and consequences

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Rifted margins often exhibit sharp transitions between 'volcanic/SDR' and 'magma poor' characteristics, which Reston and Morgan (2004) proposed to reflect sharp transitions between rifting regions underlain by hotter recently plume-fed material and regions underlain by cooler normal mantle. The South Atlantic presents an enigma for the conventional plume-head scenario for the creation of volcanic rifted margins because its associated post-rift Tristan da Cunha hotspot track lies near the northern limit of mapped SDRs along the Brazilian and Angolan coasts instead of being located towards the center of the plume-influenced region. Here we use 3-D spherical global models with an embedded high-resolution subregion to study the potential mantle flow associated with the first 25 Ma of rifting evolution in the South Atlantic. Our focus is to search for model conditions that can satisfy observations on the post-rift location of the Tristan plume/hotspot while also generating preferential plume flow southwards of the Tristan plume. The models include initial lithosphere/craton structure based on de Wit et al. (2008) and the default global plate motion history in GPlates. Buoyancy forces are only non-zero within the 4200 km (NS) x 1800 km (EW) x 300 km (deep) high-resolution sub-region, elsewhere mantle flow is only influenced by surface plate-motion constraints. The model contains a single 'hot Tristan Plume' within the high-resolution region. This plume is assumed to have a temperature anomaly of 150C with respect to background mantle, and a volume flux ranging from 5-20 km^3/yr. Models typically develop rapid southwards migration of plume material from the Tristan Plume, with much higher sub-rift temperatures in the rifting regions underlain by plume material. Southward migration reaches it southernmost limit prior to the onset of faster rifting; once opening rates increase to >3 cm/yr the region of plume 'influence' along the proto-ridge becomes significantly more restricted. Preferential southward flow appears to be due to a combination of increased rift velocities in the South and the presence in the North of thicker São Francisco and conjugate Congo cratonic roots during early rifting. Regions of plume-influenced rifting are found to have significant early uplift and melting in comparison to 'non-volcanic' rifting sectors. We propose this mechanism is the cause for the observed asymmetric distribution of early-rifting-related SDRs along the South Atlantic margins.