Linking Composition, Temperature, and Buoyancy of the North Atlantic Large Igneous Province Mantle Source

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Recycled oceanic lithosphere, present in the mantle as pyroxenite, is recognized as a fundamental contributor to the chemical and isotopic heterogeneity observed in continental flood basalts (CFB) and large igneous provinces (LIPs). Yet, the geodynamic role fertile pyroxenite lithologies play in enhancing melt production in CFB/LIP provinces remains controversial because melt productivity also depends on the potential temperature (T_P) and upwelling rate of the mantle source. A prime example of these issues is provided by the Paleogene-Recent North Atlantic large igneous province (NAIP), which records the breakup of Pangea ~56 Ma and subsequent development of the North Atlantic Ocean basin. High T_P, active upwelling, and melting of pyroxenite lithologies have each been considered the primary mechanism for the region's high productivity. Here we present new modeling that links the thermodynamics of melting lithologically heterogeneous mantle with source buoyancy to assess the trade-offs between T_P, pyroxenite abundance, and upwelling rates in the NAIP. We show that solutions matching crustal thicknesses and isotopic compositions of NAIP basalts require a dominantly peridotitic source (<8% recycled oceanic crust) since the Paleogene. The presence of dense pyroxenite lithologies in the NAIP source offsets thermal buoyancy related to excess T_P, and limits active upwelling to a maximum of ~14 times the passive rate. The region's highest productivities require excess potential temperatures >150 °C. These results confirm the existence of a long-lived thermal anomaly in the NAIP, while also accounting for source heterogeneity required by the geochemistry. This analysis more broadly highlights that considering the effects of compositional buoyancy, in addition to those arising from elevated temperature, provides the additional constraint that enables one to relate the composition and volume of igneous crust to the underlying dynamics of upwelling and partial melting in all regions where lithologically heterogeneous mantle is involved.