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Iron–zinc isotopic constraints on the source lithology of basalts from the Tristan-Gough-Walvis hotspot track (IODP Expeditions 391 and 397T)

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Plate subduction can transport diverse crustal materials into the mantle, contributing to mantle chemical and lithological heterogeneity. Such heterogeneity can be investigated via the chemical compositions of plume-derived ocean island basalts. Identifying the link between chemical and lithological heterogeneity in the plume source is important for our understanding of deep Earth recycling processes. The recently developed Fe and Zn isotope tracers may be useful for linking chemical heterogeneity in plume sources to distinct mantle lithologies, as their equilibrium fractionation can reflect variations in source mineralogy (e.g., olivine-rich versus olivine-poor lithologies) [1,2].

The Tristan-Gough mantle plume, currently located beneath the South Atlantic, is one of the longest-lived mantle plumes with a lifespan of ~135 Myr [3,4]. The partial melting of this plume has produced the ~3300 km long Tristan-Gough-Walvis (TGW) hotspot track. Previous studies have revealed that this mantle plume exhibits a heterogeneous chemical structure [3,5], but its lithological nature remains unconstrained. IODP Expeditions 391 and 397T recovered fresh basalts from six sites, spanning ~30Ma of plume activity along the TGW volcanic chain [4]. This provides an excellent opportunity to investigate the lithological evolution of the Tristan-Gough plume by analyzing Fe-Zn isotopes of recovered basalts. We measured Fe-Zn isotopes alongside major and trace elements of fresh basalts from five drill sites (U1575, U1576, U1577, U1578, U1585). The Fe-Zn isotope data exhibit significant variations, with $\delta^{57}Fe$ and $\delta^{66}Zn$ values ranging from 0.04‰ to 0.36‰ and 0.20‰ to 0.43‰, respectively. From the older Walvis Ridge (U1575, U1576, U1577) to the younger Guyot Province (U1578, U1585), there are clear temporal-isotopic variations for both isotope systems, characterized by increasing $\delta^{57}Fe$ and $\delta^{66}Zn$ values. Furthermore, Fe and Zn isotopes positively co-vary with one other, and with Nb/La and La/Yb values. These initial observations hold great promise for modeling and quantifying the lithological makeup of the Tristan-Gough mantle plume during its different evolutionary stages.

[1] Williams & Bizimis (2014), EPSL 404, 396-407; [2] Zhang et al. (2022), Nat. Commun. 13: 6085; [3] Hoernle et al. (2015), Nat. Commun. 6: 7799; [4] Sager et al. (2023), Proc. IODP, Exp.391; [5] Rohde et al. (2013), Geology 41, 335-338.