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BaSIC: A Bayesian inversion model for basalt source investigation and characterization

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Though it is now generally agreed that the upper mantle is lithologically heterogeneous, few definitive models exist to quantify the mineralogical variability of the mantle source region of basalts. We present BaSIC (Basalt Source Investigation and Characterization), a Bayesian inversion method to constrain the source mineralogy of basalts based on ratios of selected first row transition elements and gallium. Using bulk rock geochemistry, the model takes the averages and standard deviations of six elemental ratios (Mn/Fe, Zn/Fe, Mn/Zn, Sc/Zn, Co/Fe, and Ga/Sc) for a given basalt suite and inverts for the most likely source mineral assemblages.

We apply BaSIC to a global suite of ocean island basalts (OIBs; [1]) and find considerable scatter in the mineralogies contributing to basalt production across the islands. We have identified two general groups in mineralogy space: OIBs with high mantle potential temperature (T_P), high $^3He/^4He$ ratios, and a lithosphere-asthenosphere boundary (LAB) at less than 40 km depth primarily plot with olivine and orthopyroxene dominated assemblages; while OIBs with moderate T_P, moderate $^3He/^4He$, and LAB depth of greater than 60 km plot with garnet and clinopyroxene rich assemblages.

When applied to basalts from the recent (2021-2024) eruptions on Iceland's Reykjanes Peninsula [2,3], BaSIC shows an increasing step away from an olivine-dominated source with each new round of eruption. Additionally, our model shows an apparent difference between lavas produced during these recent eruptions and older lavas from both the Reykjanes Peninsula and the Western Volcanic Zone, supporting studies that suggest the source of the recent eruptions contained more recycled material than much of the rest of Iceland [2,3].

[1] Harðardottir et al., 2025. Chemical Geology. doi: 10.1016/j.chemgeo.2024.122505. [2] Bindeman et al., 2022. Nat Comm. doi: 10.1038/s41467-022-31348-7; [3] Troll et al., 2024. Terra Nova. doi: 10.1111/ter.12733