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A global magma filter for ocean island basalt volcanoes

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Ocean-island basalts (OIBs) are considered messengers from the deep mantle, and therefore expected to have relatively primitive, Mg-rich compositions. However, a GEOROC [1] compilation of OIB bulk rock and glass data from the Atlantic, Pacific, and Indian oceans reveals many OIBs globally define a frequency distribution peak around only 5 wt.% MgO [2]. High MgO concentrations are rarely primary magmas, instead representing accumulation of mafic crystals (olivine and pyroxene phenocrysts), as modelled in the Canary Island of El Hierro (Spain). While initially surprising, the 5 wt.% MgO OIB data density peak suggests prevalent magma filtering during ascent through OIB plumbing systems, until an eruptible ‘sweet spot’ is reached.

Thermodynamic simulations with R-MELTS [3] indicate 50% crystallisation of OIB parental melt in the upper mantle fractionates the liquid down to 5 wt% MgO with reduced density, increased volatile content, and overall low viscosity, becoming positively buoyant relative to wall rocks and highly eruptible when reaching volatile saturation at depths around the crust-mantle boundary. Under these conditions, 5 wt% MgO OIB ‘sweet spot’ melts are propelled to the surface. Indeed, magma storage at the base of the crust in OIB systems with low magma flux can indicate an imminent eruption (e.g., 2021 La Palma eruption [4]). In frequently active OIB systems like Hawaii, higher magma flux allows sustaining additional shallow storage in the crust. Independent of flux, the proposed magma filter is consistent with petrography and chemistry of erupted products and suggests OIB volcanoes are dominated by low-MgO basaltic melts [1]. In other settings, global geochemical compilations can help assess the role of distinct volatile budgets and crustal architectures on magmatic filtering and eruption triggering mechanisms.

[1] GEOROC Database (Geochemistry of Rocks of the Oceans and Continents). [2] Ubide et al. 2022 Geology. [3] Gualda et al. 2012 J Petrol. [4] D’Auria et al. 2022 Sci Rep