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High-Pressure Homogenisation of Melt Inclusions: Tracing Mantle-derived Carbon Across Geodynamic Settings

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The global carbon cycle of Earth's interior is regulated by the subduction of sediment-bearing lithosphere, which transports surface carbon into the mantle, and by mantle outgassing through mid-ocean ridges, mantle plumes, and subduction-zone volcanism. Quantifying the mantle carbon budget relies largely on measurements of CO_2 concentrations in melt inclusions (MI) trapped in early-crystallising olivine. However, these measurements are frequently affected by post-entrapment processes, including CO_2 exsolution into shrinkage bubbles. Conventional low-pressure homogenisation experiments suggest that up to ~90% of MI-hosted CO_2 partitions into a vapour bubble, and empirical back-calculation methods used to reconstruct primary concentrations from bubble volumes and assumptions about bubble composition introduce substantial uncertainties.

Here we present new results from high-pressure and high-temperature homogenisation experiments (0.8–2 GPa, 1350–1450 °C) using a Bristol-type end-loaded piston cylinder press and 0.5 inch diameter talc-pyrex assembly [1]. Experiments achieve complete re-homogenisation of olivine-hosted melt inclusions and restore their primary CO_2 contents. This approach allows recovery of original volatile concentrations across a wide range of geodynamic settings while avoiding artefacts inherent to empirical methods.

Plume-related lavas from Hawaii, Réunion, the Azores, the Canary Islands, and the Austral Islands yield primary CO_2 concentrations converging toward maximum values of ~4000–6000 ppm CO_2 across diverse plume environments, suggesting a consistent range of carbon enrichment in deep mantle plume sources. In contrast, classic subduction-related magmas from the Mariana arc show significantly lower values, with maxima around ~500 ppm CO_2. These results suggest that shallow slab dehydration alone cannot account for the elevated CO_2 contents characteristic of deep mantle reservoirs feeding plume magmatism.

Post-collisional magmas, derived from lithospheric domains metasomatized by previously subducted continental and oceanic crust, appear to represent a key reservoir of deeply recycled carbon. Results from Italian and Armenian high-K volcanic provinces reveal markedly elevated CO_2 concentrations, reaching up to ~12,000 ppm CO_2, highlighting the important role of recycled subducted material in generating mantle carbon heterogeneity.

Overall, these data demonstrate systematic variations in CO_2 concentrations with magma type and tectonic setting, providing new quantitative constraints on carbon storage, recycling, and transport within Earth's mantle.

[1] McDade, Wood, et al. (2002), *Min. Mag.* 66, 1021-1028.