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Petrological, Textural, and Volatile Constraints on the Architecture of Mauna Loa's Magmatic System over 170 years (1852–2022)

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Mauna Loa's reawakening in 2022 highlighted the limited availability of petrological constraints characterizing the geometry and dynamics of pre-eruptive storage at this volcano. In particular, there has been relatively little prior work constraining pre-eruptive volatile budgets, mineral zoning, and textures. To address this, we examine olivine and orthopyroxene-hosted melt inclusions, their hosts, and matrix glasses from seven Mauna Loa eruptions spanning 170 years (1852–2022). We present the first extensive, multi-eruption melt inclusion dataset from Mauna Loa with direct Raman measurements of vapor bubble CO_2. Olivine- and orthopyroxene-hosted melt inclusions contain 0.3–0.5 wt% H_2O, and 0.01–0.08 wt% CO_2. Melt inclusion saturation pressures reveal that the dominant reservoir is located at ~2–5 km depth, consistent with fluid inclusion barometry and geophysical constraints. This depth has remained consistent over the past 170 years, although depth ranges vary by eruption. Even the high Mg# orthopyroxene phenocryst-hosted melt inclusions record saturation pressures of < 150 MPa (< 6 km depth), which is inconsistent with a deep sub-Moho origin proposed by previous studies relying on thermodynamic modelling.

The zoning and textures of melt inclusion crystal hosts provide additional constraints on the plumbing system to supplement melt inclusion barometry. Orthopyroxene exhibits varied zonation patterns, including oscillatory zoning recording injections of more primitive magma into the plumbing system, and sector zoning indicating rapid, kinetically controlled crystal growth. While faster Fe-Mg diffusion in olivine results in a simpler zoning record, reversely zoned olivine from 1852, 1868 and 1950 also record the injection of primitive melts at shallow levels. Many orthopyroxene are hosted within enigmatic glomerocrysts comprising of 3–35 grains. Electron backscatter diffraction (EBSD; Figure 1) reveals that touching crystals exhibit very weakly systematic crystallographic orientation relationships, perhaps due to rapid aggregation in a dynamic system (although an origin from reaction or nucleation cannot be excluded).

Overall, our data are consistent with a large, shallow (~2–5 km) pre-eruptive reservoir repeatedly recharged by primitive magma injections that homogenized prior to eruption. This chemical complexity is effectively recorded in melt inclusion compositions and mineral zoning (particularly orthopyroxene) but is obscured in glass and whole-rock analyses.

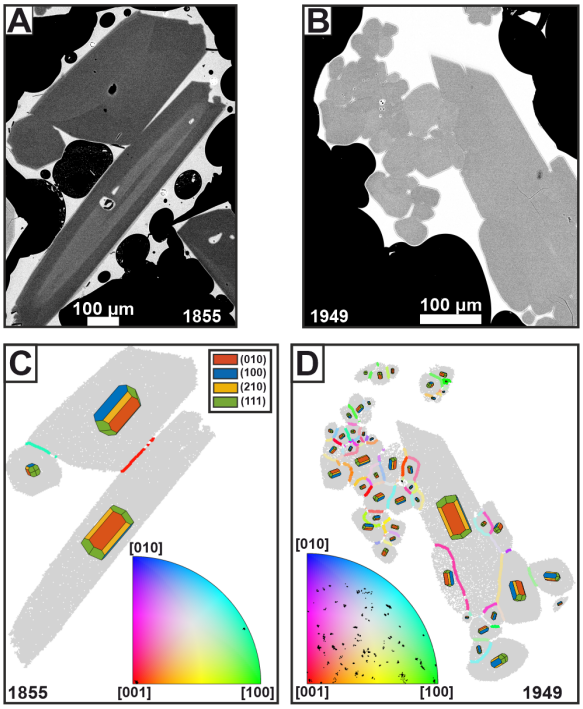


Figure 1: Back-scattered electron images (A-B) and electron backscatter diffraction maps (C-D) showing crystal orientation relationships between touching crystals in orthopyroxene glomerocrysts. The grain boundaries are colored by their misorientation axes using an inverse pole figure key (IPF, e.g. a boundary colored red has a misorientation axis about [001]). Schematic crystal shapes are also overlain to help visualize attachment faces. The black symbols on the inset IPF key show the misorientation axes across each boundary.