Determination of crystal residence times and magma chamber volumes: Vesuvius 1944

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Zoned clinopyroxene phenocrysts from deposits of the 1944 eruption of Vesuvius show magnesium-rich cores with iron-rich, oscillatory-zoned rims. The compositional change is caused when magma moves from a chamber at 8km depth into a cooler magma chamber ~1km below the vent, which favours iron-rich growth. In Back-Scattered Electron (BSE) micrographs, a diffuse region caused by Fe-Mg interdiffusion between these two regions of the crystals is evident. By measuring the width of these diffuse interfaces, the residence time after interface formation (and hence decompression) of the crystals in the shallow Vesuvius magma chamber was calculated. Twenty-three phenocrysts gave residence times, ranging from zero to nineteen years. The exact form of the distribution of residence times is a function of chamber volume and supply rate of magma to that chamber. Since the volcano was in an open-conduit state in the decades prior to the eruption and the emitted volumes are known, the chamber volume for this eruption can be constrained to be between 9.0 x 10^7 and 1.5 x 10^8 cubic metres. The technique can be used to obtain volume estimates for magma chambers in open-conduit situations where eruption rates are known, and in other cases can give qualitative information about the chamber volume relative to arrival rates.

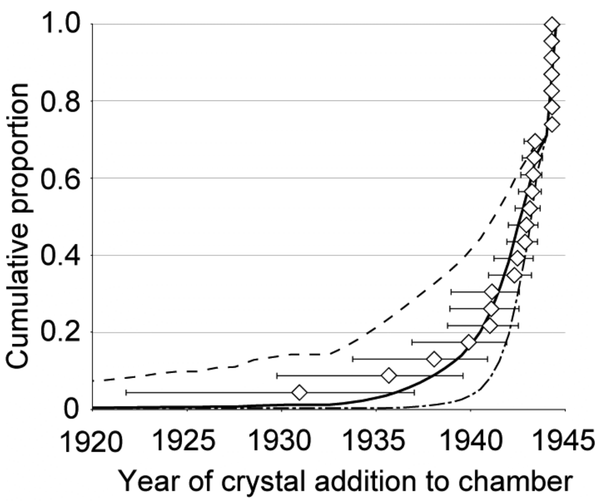

Figure 1. Residence times and associated error bars (diamonds) with curves representing population evolution in chambers of volume (from top left to bottom right) of 2 x 10^8 m^3, 1.0 x 10^8 m^3 and 3 x 10^7 m^3 respectively.

Rare gases suggest that the MORB source was made by OIB/EMORB melt extraction from the mantle

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Recent compilations of the ratios of rare gas abundances in ocean island basalts (OIB) and mid-ocean basalts (MORB) suggest that the MORB source has complementary ratios of He/Ne, He/Ar, He/Kr, and He/Xe to OIB basalts; OIB having less helium relative to the heavier rare gases (perhaps also a little less neon), while the MORB source has a relative surplus of helium. This evidence conflicts with mantle rare gas evolution models that invoke isolated, distinct, long-lived reservoirs as the sources of OIB/'enriched'-MORB (EMORB) and MORB. It also conflicts with the MORB source having a ~1Ga residence time for rare gases during which its radiogenic signature is formed by in-situ production of ^{4}He, ^{21}Ne, and ^{40}Ar. We review this rare-gas evidence as well as several other key Xe, He, and Ar constraints on the mantle evolution of the MORB and OIB/EMORB sources. Similar ^{136}Xe–^{129}Xe trends in OIB/EMORB, MORB, and cratonic diamonds indicate that nearly identical 'early radiogenic' and 'atmosphere-like' components control the Xe-isotope trends in MORB, OIB, EMORB, and the sources of these diamonds, while also indicating that the common MORB and OIB/EMORB Xe-isotope trend is inherited from ancient ^{244}Pu + ^{129}I decay. Correlated low $^{4}He/^{3}He$ and high $^{87}Sr/^{86}Sr$ ratios along the Iceland-plume-influenced-sections of the neighboring Reykjanes Ridge indicate that the helium abundance of the 'primitive' He-isotope component in the Iceland plume is greater, not less than the typical abundance of helium in the MORB-source, in conflict with the hypothesis that the 'primitive' OIB/EMORB-helium signal resides in depleted ancient residues to melt extraction that removed even more U and Th than He. The Iceland and Azores plumes and the Southern Mid-Atlantic-Ridge 'Shona-Discovery' EMORB-influenced ridge segments all demonstrate that the OIB/EMORB source contains at least one He-rich component less radiogenic and one more He-radiogenic than typical MORB. For heavier rare gases, the OIB/EMORB and MORB rare-gas trends indicate the presence of a significant 'atmosphere-like' rare-gas component. If actually an 'ocean-like' component arising from recycling of seawater-serpentinized subducting slabs, this could explain why the 'atmosphere-like' recycled signal is progressively more visible in the order Ne, Ar, Kr, Xe. These rare gas observations are all consistent with our previously proposed two-stage melting hypothesis in which the MORB source is the leftovers to OIB/EMORB-melt extraction from typical plum-pudding mantle that upwells in mantle plumes.