Effects of rapid crystallization on ^{226}Ra-^{230}Th ages

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^{226}Ra-^{230}Th disequilibria can be used to constrain ages of crystal growth that occurred within the past few hundreds of years to ~10 ka, but accurate ^{226}Ra-^{230}Th ages must account for initial Ra incorporated into crystals during growth[1]. Using Ba as a proxy for Ra, elastic-strain partitioning models can be used to predict the magnitude of fractionation which, in many cases studied to date, appears to account for the observed patterns of data[1-2]. However, Ra concentrations measured in plagioclase from the 1996 N. Gorda Ridge eruption and the 1982 addition to the 1980-86 Mt. St. Helens dacite dome are higher than would be predicted relative to Ba. These observations cannot be explained by aging of crystals, because decay of ^{226}Ra would decrease Ra concentrations compared to Ba, and could potentially indicate that elastic-strain models do not fully account for trace-element behavior in natural systems.

We suggest that this pattern of data is the result of rapid crystal growth during the final stages of magma ascent, which has been documented in the case of plagioclase microlites in the Mt. St. Helens dome[3]. Such rapid growth could lead to entrapment of surface enrichments of slowly-diffusing elements[4] and could decrease the relative fractionation of highly incompatible elements like Ra and Ba. For plagioclase in the 1982 dacite, effective D_{Ra}/D_{Ba} is >0.6 (compared to values of 0.15-0.2 calculated from the elastic-strain model). Assuming that plagioclase and glass in the Gorda Ridge sample are related, effective D_{Ra}/D_{Ba} must lie between 0.3 and 0.6. Rapid plagioclase growth at St. Helens has been attributed to degassing, but because a similar increase in effective D_{Ra}/D_{Ba} is seen in the Gorda Ridge sample despite differences in bulk composition, rapid crystal growth may be a more general phenomenon. If mineral separates in other samples include a fraction of rapidly-grown crystals, then ages calculated from ^{226}Ra-^{230}Th disequilibria by assuming that partitioning models accurately predict D_{Ra}/D_{Ba} would underestimate the average crystallization age.

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Do we need a primitive mantle reservoir? An updated assessment.

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The question of whether a primitive reservoir exists within the mantle addresses a continuing enigma. The PETDB database of global MORB allows a new estimate of the composition of the upper mantle, and forms the basis of an updated assessment of where we stand on this issue.

Based on trace elements and isotope ratios of oceanic basalts, excepting volatile elements, there is little evidence for a primitive mantle component in MORB and OIB sources. Its absence is intuitively consistent with recycling of oceanic lithosphere into the lower mantle and whole mantle convection. On the other hand, a primitive mantle reservoir is supported by the presence of primordial helium and neon in some OIB, and appears to be required by most depleted mantle-continental crust mass balances. However, the presence of primordial noble gas does not require the existence of a primitive "reservoir", rather it requires that some mantle has never been degassed. Convection in the lower mantle would likely mix primitive mantle with previously depleted mantle, creating a depleted reservoir containing primordial noble gasses. Indeed, a primordial noble gas signal is strongest in OIB whose mantle sources also show Nd-Sr-Hf isotope ratios reflecting long-term depletion.

Our average MORB estimate indicates that the average upper mantle is isotopically more "enriched" than most previous estimates ($\varepsilon_{Nd}\approx 8.7$). Mass balance requires that the higher the ε_{Nd} of the upper mantle, the lower the ε_{Nd} required for the lower mantle to balance the continental crust. That is, a more isotopically enriched upper mantle implies an isotopically more depleted lower mantle. We addressed the question, what conditions would eliminate the need for a primitive mantle reservoir, using Loihi as a target composition for " average lower mantle".

How difficult is it to mix away a primitive mantle reservoir? As shown by mass balances over the past 25 years, estimates of continental crust element abundances combined with reasonable estimates of its isotope ratios requires large amounts of primitive mantle. For example, recent estimates of continental crust Nd abundances combined with a mean age of 2.25 Ga raises the average lower mantle Nd isotope ratio to be only 0.8-1.7 ε_{Nd} units above the bulk Earth. A lower mantle without a primitive reservoir requires that there is an amount of continent-like Nd in the mantle equal to or greater than the amount in the continental crust. If this can be accommodated in continental lithosphere and EM-type OIB sources, we can dispense with the need for a primitive reservoir.