^{210}Pb-^{226}Ra-^{230}Th disequilibria in very young Mid-Ocean Ridge Basalts

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We report the common occurrence of ^{210}Pb-^{226}Ra radioactive disequilibria in <20-year-old oceanic basalts. The 22-year ^{210}Pb half-life requires significant ^{210}Pb-^{226}Ra fractionation within the past half to full century. This study on deep sea floor volcanoes, where eruption histories are largely unknown, was possible because each of our samples was collected by manned submersible from well-characterized and known or presumed age recent sea floor eruptions. Normal Pacific Ocean MORB were analyzed from 3 sites spaning a range of erupted volume, spreading rate (moderate to superfast) and compositional variation (Rubin et al., 2001). Multiple samples were analyzed from each young flow and all contain ^{210}Pb deficits. (^{210}Pb-^{226}Ra)=1 in 2 older flows. By contrast, young Axial Seamount lavas display ^{210}Pb excesses and Loihi Seamount tholeiites contain slight deficits. The largest deficits occur in the most primitive basalts and (^{210}Pb/^{226}Ra) activity ratios correlate with (^{226}Ra/^{230}Th), MgO and compatible trace element ratios in manners that preclude magma differentiation or daughter isotope (^{222}Rn) degassing (e.g., Gauthier and Condomines, 1999) in crustal magma chambers as a primary cause of the ^{210}Pb deficits. Thus the disequilibria were likely present before magmas entered crustal magma bodies. Observed ^{210}Pb-^{226}Ra-^{230}Th disequilibria can be simulated with a common (analytically-solvable) instantaneous melting model (McKenzie, 1985) for a broad range of melting conditions and solid-melt partition coefficients, but the combined duration of subsequent melt transport and magma chamber residence must be on decadal timescales to preserve the observed disequilibria. Two important implications are that a major component of MORB magma transport at shallowest mantle and crustal levels is by rapid, presumably non-porous flow mechanisms and that crustal magma differentiation can occur in tens of years.

References

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Degassing and crystallization time-scales implied by ^{210}Po-^{210}Pb-^{226}Ra activities for lavas from Anatahan, Arenal, and Mount St. Helens

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Minerals and melts erupted from arc volcanoes are commonly marked by disequilibrium between ^{238}U-series nuclides with half-lives ranging from days to 75 ka. These data imply time-scales of crystallization, melting, and degassing occurring over multiple time frames stretching back as far as hundreds of millennia before eruption. This presentation will focus on the magmatic processes occurring within during the century leading up to eruption by reporting activities of ^{210}Po, ^{210}Pb, and ^{226}Ra in whole rocks, groundmasses, and plagioclase mineral separates. The volcanoes under investigation are Anatahan, Arenal, and Mount St. Helens, which have explosively to effusively erupted lavas ranging from basaltic andesite to dacite.

Basaltic andesites erupted from Arenal have relatively normal ^{210}Po degassing levels [((^{210}Pb)-(^{210}Po))/(^{210}Pb) x 100] of about 95%. In contrast, silicic andesites from Anatahan are 85% degassed of ^{210}Po, and 2004-2005 dacites from Mount St. Helens are variably degassed with values ranging to less than 40%. The low values for Mount St. Helens dacites can be explained by the principal degassing occurring during the 1980s as the magma rose to a relatively shallow storage site. An alternative explanation is that Po degassing efficiency changes with temperature and perhaps magma composition. Most lavas and tephras erupted from Arenal and Anatahan have near-equilibrium (^{210}Pb)/(^{226}Ra) ratios reflecting a time period of rise to the surface and degassing from magma reservoirs of less than about two years. Exceptions include Arenal lavas erupted in the early 1970s and mid-1990s, which had ^{210}Pb excesses of 100 % and 20 % respectively. The ^{210}Pb excess in the early 1970s lava resulted from ^{222}Rn fluxing associated with the arrival of recharge magma in the system. The excess in the 1990s may have resulted from a slowing of the magma velocity. Plagioclase from Arenal lavas have (^{210}Pb)/(^{226}Ra) ~ 2 disequilibrium, indicating that a significant proportion of the crystals grew within years or decades of eruption. Plagioclase erupted in November from Mount St. Helens have unusually high (^{210}Po)^{o} values, suggesting that at least a portion of these crystals also may be young.