Radiometric constraints on timescales of degassing and crystallization for lavas from arcs, ridges, rifts, and ocean islands

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The relative activities of short-lived radionuclides (e.g. 210Pb T1/2 =22.6 y and 210Po T1/2 = 138 d) in lavas are revealing contrasts in late-stage magmatic processes for different tectonic settings. Most basalts erupted from ocean islands and continental rifts have (210Pb/226Ra) < 1. Although 210Pb deficits in some of these lavas have been attributed to magma genesis or differentiation, most are caused by degassing of 222Rn in a CO2-dominated vapor phase as magmas decompress over periods of years to decades (e.g. Turner et al., 2012, G-cubed). Some small volume trachytes and phonolites can have (210Pb/226Ra) >1 as a result of removal of 226Ra during rapid fractionation of amphibole and K-feldspar (e.g. Reagan et al., 2008, GCA). Lavas ejected from a large and growing phonolite magma body at Erebus have 210Pb-226Ra equilibrium (Sims et al., 2013, J.Pet). Although arc lavas can have significant excesses or deficits of 210Pb, they more commonly have (210Pb/226Ra) within 10 percent of equilibrium. These near equilibrium values illustrate that water-rich arc magmas tend to degas for short periods of time, causing crystallization, higher viscosities, and magma stagnation. Excesses of 210Pb in arc magmas are commonly associated with magma intersection, and likely result from 222Rn transfer in a vapor phase from larger volumes of intruding magmas into smaller volumes of previously stagnated magmas, a process that can lead to their defrosting. Deficits of 210Pb in some arc magmas show that these magmas did not stagnate either due to latent heat inhibiting crystallization or to a more CO2-enriched volatile content. The lavas erupted in 2004-2008 from Mount St. Helens had progressively greater 210Pb deficits with time, illustrating that the entire magma body lost what little gas it had for the entire eruption. Mid-ocean ridge basalts have 210Pb deficits and excesses like arc lavas. Small 210Pb deficits have been attributed to melting and rapid melt migration to the surface (Rubin et al. 2005, Nature). However, the 210Pb excesses found in some MORB illustrate that gas loss and accumulation also play a role in their genesis (Waters et al., submitted, EPSL). Most subaerially erupted lavas from all settings degas more than 90 percent of their 210Po before eruption, providing a way to detect juvenile versus older ejecta. Exceptions to this rule include rare lavas erupted from Mount St. Helens between 2004 and 2008 that ceased open-system degassing weeks to months before eruption due to their extreme viscosity and low overall volatile contents.