Combined Rb-Sr and U-Th evidence for protracted pre-eruptive magma formation of rhyolites

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The dynamics of crustal magma reservoirs are controlled by chemical differentiation of the magma in response to numerous processes. It is generally considered that crystal-liquid separation is dominant. Fluid dynamic models increasingly envisage magma chambers as open, dynamic multicomponent systems subject to the interplay of melts and crystal mushes. Boundary-layer crystallization is thought to occur along the colder walls of a magma chamber where the positive buoyancy of residual interstitial melt causes ascent of differentiated liquids through the crystal mush and separation from the less evolved bulk magma volume. Low-density melts fractionated in such a way can accumulate near the top of a magma reservoir and reside there, if isolated from convection or prevented from crystallizing. Theoretical models often require parametric assumptions or simplifications, such that they essentially describe stationary processes and therefore lack viable predictions for the temporal evolution of magmatic systems. In contrast, analyses of radiogenic isotopes systems in young volcanic rocks provide an excellent means of quantifying timescales of magmatic processes.

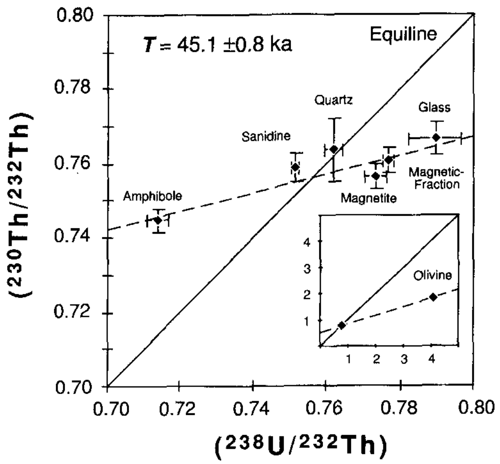

FIG. 1. Internal mineral isochron for high-silica rhyolites erupted at ~9 ka (Olkaria volcanic field, Kenya).

This abstract presents combined Rb-Sr and U-Th (TIMS) isotopic age constraints on rhyolite magma genesis from two contrasting silicic systems: (1) the Long Valley magmatic system in California (> 600 km^3) and (2) the comenditic Olkaria volcanic field in Kenya (< 3 km^3).

Results

Long Valley. High-silica rhyolites erupted at around 100 ka fall on Rb-Sr isochrons which define ages of 277?124 ka (glasses) and 297?78 ka (internal mineral isochron). Furthermore, low- and high-silica rhyolites indicate ^{230}Th-^{238}U ages of up to 150 kyr older than eruption.

Olkaria. The most evolved comendites (1 ka and 9 ka old) reveal Rb-Sr ages of 22 ± 5 ka and 50?14 ka. Linear glass-mineral arrays on an equiline diagram correspond to an age of 45 ± 0.8 ka.

Discussion

Combined Rb-Sr and U-Th isotopic age constraints from glasses and internal mineral isochrons confirm significant pre-eruptive magma storage times of rhyolitic magmas in large as well as small silicic systems. U-Th disequilibrium studies by TIMS clearly allow much better age resolution and help assess the crystallization histories of magmas and the temporal evolution of the system.

Previously, long magma chamber residence times (~300 kyr) of pre-caldera rhyolites from the Long Valley magmatic system (e.g. Davies *et al.*, 1993) caused discussion on the age significance of Rb-Sr isochrons and the feasibility of keeping near-solidus magma melted for such long periods (Sparks *et al.*, 1990). Other authors (e.g. Knesel and Davidson, 1997) advocated assimilation processes being responsible for large ^{87}Sr/^{86}Sr variations. Inevitably, careful evaluation of the genetic relationships of samples is required in order to avoid erroneous applications to whole-rock samples which may show indications of magma mixing. This requires verification of the age information by internal mineral isochrons and ideally by different isotope systems.

Post-caldera rhyolites from Long Valley record chemical evolution following caldera collapse (Heumann and Davies, 1997) indicating fractionation of high-silica melts from a bulk low-silica volume. Simple re-melting of pre-existing rhyolites does not appear to be a viable process to explain the various isochronous relationships in two independent isotopic systems. Apparently, evolved magmas can remain isolated from major convection in the reservoir for timescales of ~200 kyr, similar to pre-caldera magmas. Our Rb-Sr and U-Th data confirms the pre-eruptive U-Th model ages (~ 150 ka) obtained from ion-probe analyses of zircons on the youngest Long Valley rhyolites (Reid *et al.*, 1997).

At the Olkaria volcanic field in Kenya, Pb and Nd isotope signatures clearly preclude mixing between different magmas to produce glass Rb-Sr isochrons. Rb-Sr and U-Th mineral ages are within error and confirm with much higher precision pre-eruptive ages obtained in previous alpha-spectrometry studies (Black *et al.*, 1997). These data establish that magma differentiation and mineral crystallization occurred up to ~40 kyr prior to eruption in this small magma system.

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