

Time scales of metasomatism, differentiation and degassing at Volcán de Colima

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Volcán de Colima, Mexico (VDC) nearly continuous activity since 1998 provides a unique opportunity to assess the time scales characteristic of intermediate arc volcanoes. VDC andesites have $(^{238}\text{U}/^{230}\text{Th}) = 1$, but have significant excesses of ^{231}Pa and ^{226}Ra . These excesses, and relatively low Th contents, indicate that addition of Th-rich sediments in secular equilibrium to the mantle source cannot account for ^{238}U - ^{230}Th equilibrium, as generally advocated. In the VDC case, the U-series suggest that slab fluids carrying U were not added to the mantle wedge in the last 350 kyr and ^{226}Ra excesses are most likely mantle melting signals. ^{226}Ra and ^{231}Pa excesses indicate that the time scales of differentiation from primary mafic to dacitic melt (composition of the crystallizing melt) are short and < 1.6 kyr.

Most 1998-2010 magmas have $(^{210}\text{Pb}/^{226}\text{Ra}) = 1$, however small ^{210}Pb deficits are measured in few samples. This indicates that the magmas erupted at the onset of the eruptive phase (1998) degassed either more than 100 yr ago or within few months of eruption. Observed changes in petrology and the SO_2 flux measured prior to 1998 concur to suggest that significant degassing occurred within few months of eruption. Increasing maximum ^{210}Pb deficits with time are consistent with progressive degassing of a magma batch since 1998, but require several influxes of undegassed magmas and incomplete mixing between the magma batches. Influxes of undegassed magmas may cause the observed shifts in activity from Vulcanian to effusive.

Long residence (> 6 Ma) time of Paleoproterozoic seawater sulfate revealed by *in situ* and *ex situ* sulfur isotope measurements

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The 2.0 Ga Tulomozero Formation, Fennoscandian Shield, NW Russia, consists of shallow marine carbonates and silicilastics, dissolution breccias and widespread syndepositional marine evaporites, now mostly present as pseudomorphs after Ca-sulfates.

Ex situ measured carbonate-associated sulfate (CAS) and breccia-associated sulfate (BAS) throughout the entire formation ($\delta^{34}\text{S}_{\text{CAS}} = 10.9 \pm 2.7$ ‰, $\delta^{34}\text{S}_{\text{BAS}} = 9.0 \pm 1.1$ ‰) resemble the *in situ* SIMS sulfur isotope data from relics of sulfate evaporites in ubiquitous pseudomorphs after Ca-sulfates ($\delta^{34}\text{S}_{\text{anhydrite}} = 9.6 \pm 1.0$ ‰; $\delta^{34}\text{S}_{\text{barite}} = 11.0 \pm 3.1$ ‰).

The $\delta^{34}\text{S}$ record of the Tulomozero sulfates matches the sulfur isotopic composition of other broadly time equivalent evaporite successions [1, 2]. Furthermore, the homogeneity of the sulfate sulfur isotope record within the Tulomozero Formation together with an estimated minimum depositional time of the formation (based on average carbonate precipitation rates) suggests a residence time of seawater sulfate in the Mid-Proterozoic of at least 6.5 Ma.

Consequently, the apparent presence of Ca-sulfate evaporites and the homogeneity of sulfate sulfur isotope data from various lithologies support the existence of a sizeable seawater sulfate reservoir already in the Mid-Paleoproterozoic ocean.

[1] Schröder *et al.* (2008) *Terra Nova* **20**, 108–117. [2] Guo *et al.* (2009) *Geology* **37**, 399–402.