SIMS oxygen isotope analyses of white mica from the Larderello geothermal field reveal a complex magmatic – hydrothermal petrogenesis

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The Larderello geothermal field (LGF) in southern Tuscany is underlain by a series of shallow intrusions of isotopically and geochemically distinct two-mica granites belonging to the Miocene-Pleistocene Tuscan Magmatic Province (1). Muscovite is ubiquitous in the granites, the contact metamorphic aureole and the deep pre-Alpine metasedimentary units that constitute the lower reservoir of the LGF. Texturally and chemically distinct generations of muscovite record stages of magmatic crystallization, thermometamorphic/hydrothermal replacement and fluid/rock interaction (2,3).

Existing O isotope data of whole rock and mineral separates indicates that granite and contact metamorphic rocks have been gradually depleted in $^{18}$O ($\delta^{18}$O from 5-12‰ [4]). Although some secondary minerals, such as muscovite, proved highly retentive and retained their pre-alteration $\delta^{18}$O signature (8-10‰), biotite in the alteration zone can have $\delta^{18}$O values as low as 1.5‰ (3).

In-situ Secondary Ion Mass Spectrometry (SIMS) O isotope analysis of white mica is used to resolve the fluid/mineral interaction on microscale in the dynamic environment of the LGF. Data of white mica from granite, contact metamorphic micaschist and phyllite show a large and variable spectrum of $\delta^{18}$O values ranging from 14‰ to as low as 2‰. The highest $\delta^{18}$O data (≤14‰) are found in chemically homogeneous white mica from a phyllite sample, which are close to values from unaltered micaschist from the Northern Appeninnes (4). White mica from a contact metamorphic micaschist shows the largest spread of $\delta^{18}$O values, from 12‰ in homogeneous domains in larger grains to 2‰ in a more heterogeneous small grain. A granite and a high-temperature magmatic/hydrothermal vein contain white mica with a magmatic $\delta^{18}$O of ~9‰ and higher values of ~13‰ respectively. In both samples, white mica show a pronounced intra-grain $\delta^{18}$O variability of up to 5‰ either as core-rim zoning, or as $^{18}$O-depletion in Fe-Mg-enriched domains (~2.5 wt.% higher in Fe-Mg) that surround inclusions of chlorite.

The highest measured $\delta^{18}$O values from white mica in metasediments are either related to a pre-intrusive, syntectonic metamorphic overprint, or were caused by recrystallization from a more recent $^{18}$O-rich fluid, as proposed for other secondary minerals (2). Large homogeneous domains in the igneous white mica retained their magmatic $\delta^{18}$O values, whereas the selective $^{18}$O-depletion in the Fe-Mg-enriched, recrystallized domains results from hydrothermal alteration by meteoric water that also affected some metasedimentary white mica (2,4). The new SIMS $\delta^{18}$O data of white mica, therefore, reveal, for the first time, their multifaceted petrogenesis on a microscale, and may prove a valuable tool in further describing the fluid dynamics of complex magmatic-hydrothermal-metamorphic systems.

REFERENCES