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SPECIAL COLLECTION: DYNAMICS OF MAGMATIC PROCESSES

Geochemical and radiogenic isotope probes of Ischia volcano, Southern Italy: Constraints on magma chamber dynamics and residence time

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Abstract

The active volcano of Ischia, an island off-shore the city of Naples, Southern Italy, has a discontinuous volcanic activity characterized by caldera-forming paroxysmal eruptions, lava flows, and lava domes, and thus offers the opportunity to study the complexity of magma storage, differentiation, and extraction mechanisms in a long-lived magma reservoir. The overall geochemical composition of erupted magmas varies from shoshonite to latite and trachyte/trachyphonolite. Their Sr and Nd, isotope composition variation is typical of subduction-related magmas, akin to other potassic magmas of the Neapolitan District, and there is a complete overlap of radiogenic isotope composition among shoshonite, latite, and trachyte/trachyphonolite. The lack of systematic radiogenic isotope covariation during differentiation suggests that the radiogenic isotope variability could be a signature of each magma pulse that subsequently evolved in a closed-system environment. Erupted magmas record a recurrent evolutionary process consisting of two-step fractional crystallization along similar liquid lines of descent for each magma pulse, suggesting near steady-state magma chamber conditions with balanced alternating periods of replenishment, differentiation, and eruption. The dominant role of fractionating feldspars determines a significant depletion of Sr (<10 ppm) coupled with high Rb/Sr (>200) in the residual trachyte magma.

Several more-evolved trachytes have anomalous radiogenic $^{87}Sr/^{86}Sr_i$ (>0.707) coupled with high $^{87}Rb/^{86}Sr$ (>50), all other geochemical and isotopic characteristics being similar to normal $^{87}Sr/^{86}Sr_i$ trachytes at the same degree of evolution. This radiogenic Sr isotope signature is not consistent with assimilation of crustal material and demands for a time-related in-growth of ^{87}Sr during storage within the magma chamber. Rb-Sr isochrons on separated mineral-groundmass pairs provide robust constraints on a prolonged pre-eruptive history ranging from a few tens to hundreds of thousands of years at relatively low temperature (~750 °C). Remarkably, also normal trachytes with high $^{87}Rb/^{86}Sr$ (>200) yield a magma residence time from some 4 to 27 kyr, implying that the long-lived history of Ischia magmas is not limited to the anomalous $^{87}Sr/^{86}Sr_i$ trachytes. This long-lived history could be a characteristic feature of the magma chamber reservoir of this active volcano, which other volcanic products (i.e., shoshonite and latite) cannot disclose due to their lower Rb/Sr (i.e., low ^{87}Sr in-growth rate) and higher magma storage temperature (>900 °C) (i.e., rapid Sr isotope homogenization via diffusion).

The magma chamber dynamics of the active volcano of Ischia, probed on the basis of geochemical and radiogenic isotope tools, is consistent with recent models of complex magma chamber reservoirs made up of multiple discrete melt pockets, isolated by largely crystalline mush portions, maintained in a steady-state thermal flux regime with no mass exchange, and with reactivation shortly before eruption.

Keywords: Ischia volcano, radiogenic isotopes, geochemistry, magma chamber dynamics, magma residence time