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Role of open system magmatic processes during crustal storage, evolution, and transport at Mount Etna: Insights from the Magma Chamber Simulator

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Mount Etna volcano, Sicily, Italy, has intermittently erupted alkaline-enriched products, yet the magmatic processes responsible for these geochemical shifts remain debated. The most recent enrichment, beginning after 1971, was accompanied by striking increases in eruption frequency, volume, and explosivity, emphasizing the need to understand the magmatic processes that influence potentially hazardous volcanic behavior. We used mass- and energy-constrained thermodynamic models to evaluate the magmatic processes that may have contributed to the geochemical differences between historic (1329–1970) and recent (1971–2013) lavas. Processes operating during crustal storage (crystallization, magma recharge/mixing, mush entrainment, crustal assimilation) were modeled using Magma Chamber Simulator [1,2], and changes during magma ascent were assessed using rhyolite-MELTS [3,4]. Results indicate that the geochemical shift may be primarily attributed to crustal assimilation of sedimentary host rock and to the recharge of a compositionally distinct magma into the post-1971 crustal system. The new recharge composition reflected a shift in mantle melting conditions, including a waning contribution from a pargasitic-bearing ultramafic source lithology, perhaps indicative of earlier phases of metasomatism associated with ancient subduction. Our findings reveal a coupled mantle-crust magmatic system in which changes at depth propagated upward, producing the observed geochemical and eruptive differences between pre- and post-1971 magmas. The protocol developed during this study offers an integrated approach for investigating source-to-surface magma genesis at other volcanoes located in complex geodynamic settings by directly comparing modeling results with whole-rock and mineral data.

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