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Identifying the components of Milos island subvolcanic plumbing system (South Aegean Volcanic Arc, Greece): An amphibole perspective

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Over the last ~3 Ma, the volcanic complex of Milos Island has evolved from a shallow submarine into a subaerial edifice. It has erupted almost the entire range of calc-alkaline series compositions, but silicic units are volumetrically dominant (Fytikas et al., 1986; Stewart & McPhie, 2006). Although numerous studies have been published, data on the mineral record of the magmatic processes are absent. We examined amphiboles from 3 explosive and 4 effusive units, ranging from andesite to rhyolite, to gain insights into the structure and evolution of the plumbing system. Like many arc volcanoes worldwide, Milos products contain bimodal amphibole populations, often present within the same unit. Mg-hornblende (6.79-7.22 a.p.f.u. Si) forms macro-crysts (>600 μm; often partly decomposed) and crystal clots with plagioclase (An_{47-51}), orthopyroxene ($Wo_{1-2}En_{61-62}Fs_{37-38}$), and magnetite in the effusive units and phenocrysts (300-600 μm) in more evolved pumices. Mg-hastingsite occurs in effusive units as: (1) pristine micro-phenocrysts (<300 μm; 6.22-6.58 a.p.f.u. Si); (2) relics (6.22-6.46 a.p.f.u. Si) in the inner domains of pseudomorphs mostly replaced by coarse-grained orthopyroxene ($Wo_2En_{68}Fs_{30}$) rimmed by clinopyroxene ($Wo_{43}En_{47}Fs_{10}$), plagioclase (An_{47}), and magnetite; and (3) framework-forming crystals in quenched enclaves; and (4) the only amphibole (6.29-6.59 a.p.f.u. Si) phenocrysts in andesitic scoria.

Temperature (T) and pressure (P) conditions were calculated by applying hornblende-plagioclase (Holland and Blundy, 1994) and amphibole composition (Ridolfi and Renzulli, 2012) thermo-barometers. Amphibole compositions and calculated P-T conditions are in good agreement with experimentally grown amphiboles. Mg-hornblende compositions and their petrographic context are consistent with cold storage (780±24°C) in a near-solidus, upper crustal (1.7-2.8 kbar) silicic mush. This scenario is further supported by the rhyolitic (74±3.6 wt.% SiO_2) compositions of calculated melts in equilibrium with Mg-hornblende, in contrast with the less evolved bulk compositions of the host effusive units. Although the explosive eruptions likely originated from differentiated, crystal-poor melt pockets in the mush, the more common effusions of hybrid andesite-dacite magmas resulted from interaction between mafic recharge magma and the silicic

mush. This interaction is preserved in the disequilibrium textures affecting both Mg-hornblendes and Mg-hastingsites, coupled with the growth of high-T (960-885°C) post-recharge Mg-hastingsite. Most of the recharge magmas in Milos are effectively dispersed, trapped, and hybridized in the upper crust, although in rare cases magmas from a deeper crustal storage region (T~960-885°C;P~3.8-5.1 kbar) erupted after limited interaction with the upper crustal storage system.

The mineral chemistry reveals that a large, shallow, silicic reservoir has been the dominant component of the Pliocene plumbing system beneath Milos. Magma inputs from deeper crustal sources are preserved in enclaves and volumetrically minor explosive products. The plumbing system of Milos shares similarities with other Aegean arc volcanoes, where magmas experience storage, differentiation, and assimilation in different crustal levels, like Methana (Popa et al., 2020).

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