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Complex Magma Chamber Dynamics at Stromboli During the 20th Century

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Stromboli is famous for its continuous activity over the last two millennia, 4-8 events per hour. The near continuous activity offers an ideal opportunity to study the rate and nature of magma chamber processes. During last century activity generally produced dark ash, bombs, lapilli scoriae and lavas that have a composition transitional between high-K calc-alkaline and shoshonitic basalts. Scoriae and lavas are highly porphyritic (HP) with olivine (4-8%), clinopyroxene (12-20%) and plagioclase (20-25%) in a glassy groundmass (Francalanci et al., 1999). Phenocrysts are up to 2.0cm long. Periodically more violent eruptions produce small amounts (<10%) of yellow highly vesiculated low porphyritic (LP) scoriae. Phenocrysts are rare (5%) and small, <1cm, comprising ol, cpx and rare plag. LP scoriae are less chemically evolved than HP scoriae (MgO > 7%). The distinct major, trace element and isotopic composition of the LP scoriae are key to understanding the recent magma dynamics of Stromboli. On the basis of relatively constant Sr contents of products last century, Francalanci et al. (1999) interpreted a change in Sr isotope from 1980 to the present day (0.70627-0.70616) to represent a change in magma input. Coupled with the lower Sr isotopic composition of LP scoriae (0.7061), the temporal variation in Sr isotope compositions constrains magma chamber size to 0.04 to 0.3km^3 and a magma residence time to 19 ±12yr (Francalanci et al., 1999). Gauthier & Condomines (1999) argued, on the basis of ^{210}Pb-^{226}Ra disequilibrium and assuming a steady state outgassing of ^{222}Rn, for a chamber size of 0.1±0.1km^3 with a residence time between 0.3 and 1.4 yr. Both residence time estimates are based on the assumption of thoroughly homogenised and mixed magmas. In an attempt to better quantify magma dynamics and residence times we present results from a detailed petrographic, and Sr isotope study of phenocryst phases from 4 scoriae formed since 1984 (3 HP one LP).

The majority of phenocrysts in the LP scoriae are homogeneous with the exception of 50-100mm rims (e.g., An core 75-84; An rim 88). Plagioclase contains between 20 and 30% glass inclusions. Approximately 10% of plagioclase grains have resorbed cores that have two compositions (An ~66 and ~89) surrounded by glass rich plagioclase. Phenocrysts of HP scoriae are notably less homogeneous. Complex resorbed cores are typical. Cpx cores contain ol and glass and can be of two or more compositions (CaO 19.7-23.0). The majority of grains comprise euhedral growth bands of more limited compositional variation (CaO 21.2-21.9). Plag have glass-rich resorbed cores that can be highly variable in composition (An 59-80) surrounded by a rim of euhedral growth bands (An 63-67). Polished thick sections were prepared and sampled in situ by LA-ICP-MS and computer-controlled microdrilling. The cores of cpx in HP scoriae have LREE contents that vary by an order of magnitude (La = 2.3-23 ppm). The banded rims are also heterogeneous (La = 7-17.5) with increasing La/Nd towards the rim. Plag also records marked trace element variation (Sr 50%). Sr isotope compositions are also heterogeneous. Rims of HP phases record a temporal variation becoming less radiogenic with eruption age (0.70630-0.70611). The rims of both cpx and plag in 1996 HP scoriae are ~0.7061 with cores being both more and less radiogenic (0.70605-0.70633). LP minerals are generally homogeneous 0.70608-0.70616. The rare resorbed cores, however, have two distinct compositions; 0.7061 and 0.7063. These trace element and isotopic data unambiguously establish that the temporal evolution of the magma chamber last century involves at least three components and imply that either magma supplied from depth is highly heterogeneous and/or that older igneous material is sampled. Importantly, however, the relative constant composition of mineral rims that are in isotopic equilibrium with host glass implies that the major volume of the phenocrysts grew from the host magma. The mineral growth rates in high-level basaltic systems are in the order of 10^{-9} to 10^{-11} cm/s (Cashman, 1991). This in turn implies that mineral rims grew within 100 years. The concentric mineral growth bands implies numerous episodes of magma replenishment during this time.

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