Characteristics of olivine and diopside crystals in magma erupted at Stromboli during the 2003, 2007 and 2009 paroxysms: implications for magma ascent dynamics

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We present the results of morphological and compositional study on crystals associated with three paroxysmal explosions occurred at Stromboli in 2003, 2007 and 2009. Although with variable volume of emitted products, all the eruptions involved a deep-seated, volatile-rich, low-porphyricity magma (LP) ejected as pumice. Pumices are almost aphyric, highly vesicular and include portions of a shallow-derived, crystal-rich, moderately vesicular scoria (high porphirycity, HP magma type). We extracted about 1000 crystals (olivine and diopside) in the size interval between 1 and 0.125 mm. Three types of crystals are characterized by complex textures and compositions related to variable degrees of interaction between the LP and HP melts. The fourth type consists of transparent, light coloured crystals (light green for pyroxene), euhedral or sub-euhedral with some skeletal edges. They contains in some cases melt inclusions and are characterized by an homogeneous composition, and in some cases by a more evolved rims. Only this type of crystals is in equilibrium with the LP magma. The variable abundances of the different crystal types in the studied samples suggest the occurrence of different pre-eruption dynamics associated with the paroxysms at Stromboli. Real CSD was performed on olivine and diopside crystals in equilibrium with the LP magma. Results show that, during the 2003 event, crystallization occurred in a single step, while two different events of nucleation can be identified in the 2007 eruption. Equilibrium crystals are very rare in the 2009 paroxysm (the smallest of the three events considered) and they mainly occur as fine grained crystals (0.250-0.125 mm).

Results of this study are discussed in terms of crystallization – degassing processes, timing and modalities of magma ascent during paroxysms at Stromboli and possible relationships with signals recorded by the monitoring network.

Thermodynamics of almandine-spessartine garnet solid solutions

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The heat-capacity, C_p, behavior of a series of well characterized natural and synthetic almandine (Alm)-spessartine (Sps) garnets $[(Fe_xMn1_{-x})A1_2Si_3O_{12}]$, was measured between 3 and 300 K using relaxation calorimetry and between 282 and 764 K using DSC methods.

All garnets show a λ-type anomaly at low temperatures resulting from a paramagnetic-antiferromagnetic phase transition. The temperature of the magnetic transition for Alm-rich garnets lies between those of end-member Alm at 9.2 K and Sps at 6.2 K, but is shifted to lower values between 3.5 and 4.5 K for garnets with $X_{Sps} > 0.5$. The low-temperature C_p data yield calorimetric entropies at 298 K (S_{298}), from which the excess entropy of mixing (ΔS_{ex}) of the join was calculated. By applying the phonon dispersion model of Komada and Westrum (1997), the lattice heat capacity was calculated for each solid-solution member. This allowed a decomposition of S_{298} into its vibrational (S_{vib}) and magnetic (S_{mag}) contributions.

The C_p data show that $\Delta S_{ex} \approx 0$ at 298 K for the Alm-Sps binary and thus the entropic interaction parameter $W_S \approx 0$. An analysis of published Fe-Mn exchange experiments between garnet and ilmenite giving W_G, together with this W_S term, allows W_H to be calculated. The resulting value is in satisfactory agreement with that calculated from phonon line broadening in infrared spectra of Als-Sps garnets using the autocorrelation method. ΔH_{ex} is asymmetric with a maximum in Sps-rich compostions. ΔG_{ex} is also asymmetic with a maximum of ~0.7 kJ/mol at X_{Sps} ~0.60 for temperatures between 500 °C and 1000 °C.

Our new subregular activity model for Alm-Sps garnets yields temperatures for Mn-rich metamorphic assemblages that agree with those from Fe-Mg biotite-garnet thermometry.

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