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An experimental study of the fluid–melt partitioning of volatiles (H₂O, CO₂, S) during the degassing of ascending basalt

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We performed decompression experiments to constrain the fluid–melt partitioning of volatiles (H₂O, CO₂, S) in ascending basalt magmas associated with violent eruptions. Experiments were conducted in an internally heated pressure vessel under oxidizing conditions (fO₂: NNO+1.1) so that all sulphur occurs as sulfate (S⁶⁺) in the melt. Volatile-bearing (2.72 ± 0.02 wt% H₂O, 1291 ± 85 ppm CO₂, 1535 ± 369 ppm S) melts, prepared from Stromboli pumice, were synthesized at 1200°C and 200 MPa, decompressed between 150 and 25 MPa at constant rates of 39 and 78 kPa/s (or 1.5 and 3 m/s), and rapidly quenched. Run products were characterized both chemically (by IR spectroscopy and electron microprobe analysis) and texturally (by scanning electron microscopy), and then compared with Stromboli pumice products (glass inclusions, volcanic gases).

In H₂O-CO₂-S-bearing basaltic melts, bubbles start to nucleate heterogeneously on Fe sulfides for supersaturation pressures $\Delta P_{HeN} \leq 1$ MPa and to nucleate homogeneously for $\Delta P_{HoN} < 50$ MPa (ΔP_{HeN} and ΔP_{HoN} are the difference between the saturation pressure and the pressure at which heterogeneous and homogeneous bubble nucleation are observed, respectively). Bubble growth, coalescence and outgassing occur in addition to continuous bubble nucleation, which is sustained by the preservation of CO₂ supersaturated melts during decompression.

In addition to model the degassing behaviour of sulphur (and also of CO₂ and H₂O), our experiments aim to assist in the interpretation of geochemical observables. On the one hand, the volatile degassing trend recorded by Stromboli natural glasses (unsealed glass embayments) was closely experimentally simulated, with a coupled decrease of H₂O and S whereas CO₂ concentrations remain elevated. On the other hand, the experimental H₂O/CO₂ and CO₂/SO₂ fluid molar ratios, calculated by mass balance, both reproduced or closely approached the lower ranges of gas ratios measured at Stromboli for quiescent magma degassing and explosive activity. Compared to models that attribute a deep origin to CO₂-rich fluxes and high CO₂/SO₂ gas ratios, our experimental observations support a model of low pressure ($P_f \ll 25$ MPa) explosive degassing of CO₂-rich melts generated as a result of disequilibrium degassing to generate Strombolian paroxysms.