Magmatic vapor plumes in active volcanoes: dynamics, discharge and disasters

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Magmatic gas mixtures released by crystallizing intrusives expand across permeability discontinuities from lithostatic to near-hydrostatic pressure within volcanic systems. In arc volcanoes they provide most of the heat energy that is widely dispersed as extensive geothermal systems or released directly through the surface as high temperature, high enthalpy fumaroles and extensive solfatara and as gas plumes.Modeling of their expansion to the surface and their interaction with groundwater to form magmatic vapor plumes is compromised by the difficulties of dealing with compressible fluids. Data from fossil plumes (for example, porphyry and high sulfidation copper-gold deposits) however provide evidence of their scale and internal structure that may then be used to constrain modeling (Henley and McNabb, 1978).

A general approach to analysis of the dynamics of magmatic vapor plumes is outlined here based on simple phase relations and Markov principles and shows that one of the principle controls on plume architecture is the ratio,Kp, of vertical to horizontal permeability (Hurwitz et al., 2003). In low Kp systems, phase separation to form envelopes on the margins of plumes is a consequence of the net decrease in enthalpy due to groundwater mixing and has implications for hydrothermal alteration and mineralisation, and the evolution of geothermal systems. Where Kp is large, high energy discharges are maintained. In addition to input power, their periodicity is related primarily to changes in fracture permeability due to mineral deposition and depletion of the source magmatic gas reservoir.

Understanding of the behavior of magmatic vapor plumes may contribute to the analysis of the history of volcanic systems and their energy flux. It may also provide a basis for forecasting and tracking Plinean eruptions and their linkage to major seismic events in tectonically-challenged crust.