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Thermodynamic Modelling of Volatiles in Kimberlite Ascent and Eruption

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The unique aspect of kimberlite magmas is their potential for having high dissolved contents of primary volatiles (e.g., H_2O + CO_2 > 15 wt. %) coupled to a high ascent rate. The high ascent rates help couple the exsolved fluid to the magma as it rises to the point of eruption. During ascent the system evolves from a system featuring 30-40% suspended solids in a silicate melt to a system that is volumetrically dominated by the exsolved fluids (due to exsolution and expansion). The physical-chemical properties of kimberlite melt govern the transport and eruption behaviour of kimberlite magmas. For example, exsolution of a CO_2-H_2O fluid phase provides a logical and efficient means of reducing magma density and promoting the buoyancy critical for rapid ascent and eruption. The composition of the exsolved fluid depends on the total dissolved fluid content of the melt as well as the T-P ascent path. Under conditions of equilibrium degassing (e.g., closed system), the original dissolved fluid content limits the range of fluid compositions produced during ascent. Under perfect fractional degassing (open system), increments of equilibrium fluid are released and "fractionated". Such situations arise when 2-phase flow (melt and gas) develops and the gas phase decouples from the host magma. Separated two-phase flow is likely to develop in kimberlite and allows for highly transient fluid compositions beginning with fluids extremely enriched in CO_2, and ending with H_2O-dominated fluid. The physical properties and behaviour of the fluids during ascent are, thus, constantly changing in response to the evolving fluid composition.

Here we use computational models calibrated on experimental data for multicomponent melts (e.g., MELTS; Ghiorso & Sack 1995) saturated with a CO_2-H_2O fluid (e.g., Papale et al. 2006) to explore the physical-chemical properties of volatile-saturated kimberlite during ascent and eruption. The exsolved magmatic fluid is modelled as mixtures of CO_2 and H_2O. No speciation calculations were attempted. The thermodynamic properties of the fluids were retrieved using program REFPROP (Lemmon et al. 2007) that employs the GERG-2004 equation of state and mixing models (Kunz et al. 2007). We then compute how the properties (V, H, S) of the expanding fluid change as a function of ascent path. As the magma decompresses, the fluid phase increases in mass and volume, and the thermal consequences of adiabatic expansion begin to dominate. We have explored the isentropic and isenthalpic adiabatic expansion paths (e.g., Spera 1984; Mastin & Ghiorso 2003) for the ascending magma. The paths are based on "intrinsic" thermodynamic properties (Dodson, 1971) and do not include energy associated with motion or position in the gravitational field.

References

Dodson M 1971. Isenthalpic flow, Joule-Kelvin coefficients & mantle convection. Nature 234, 212.

Ghiorso MS & Sack RO 1995. Chemical mass transfer in magmatic processes. CMP 119, 197-212.

Kunz O et al. 2007. The GERG-2004 wide-range reference equation of state for natural gases. GERG Technical Monograph 15. Fortschritt Berichte VDI, Reihe 6, 557.

Lemmon EW et al. 2007. Fluid Thermodynamic & Transport Properties - REFPROP Version 8.0, NIST, Boulder.

Mastin LG & Ghiorso MS 2001. Adiabatic temperature changes of magma-gas mixtures during ascent and eruption. CMP 141: 307-321.

Papale P, Moretti R, Barbato D 2006. Chemical Geology 229, 78-95.

Spera, F.J. 1984. Carbon dioxide in petrogenesis. CMP, 88: 217-232.