Some parameters for volcanic conduit eruption models

Requested by Volcanology Workshop, provided by Youxue Zhang

Bulk H_2O diffusivity in rhyolitic melt:

$$D = 10^{-12} X \exp(m)\{1 + \exp[56 + m + X(-34.1 + \frac{44620}{T} + \frac{57.3P}{T}) - \sqrt{X}(0.091 + \frac{4.77 \times 10^6}{T^2})]\}$$

where m = -20.79 -5030/T -1.4P/T, P in is MPa, T is in K, X is the mole fraction of total H_2O on a single oxygen basis, and D is in m^2/s. The experimental data are for Mono Crater rhyolite. The reference is Zhang and Behrens (2000). To calculate X from wt% of total H_2O (W), use the following fomula for rhyolite:

$$X = \frac{W/18.015}{W/18.015 + (100 - W)/32.49}.$$

H_2O solubility in rhyolitic melt:

$$W = \sqrt{P}(0.4874 - \frac{608}{T} + \frac{489530}{T^2}) + P(-0.06062 + \frac{135.6}{T} - \frac{69200}{T^2}) + P^{3/2}(0.00253 - \frac{4.154}{T} + \frac{1509}{T^2}),$$

where P is in MPa, T is in K, and W is total H_2O solubility in wt%. That is, when W = 1, it means that there is 1 wt% total H_2O. The model is applicable to Mono Crater rhyolite. For reference, "the equation is reparameterized and simplified from the solubility model of Zhang (1999) by Youxue Zhang." A new paper by Liu et al. will be submitted soon and there will be a new solubility model. When the time comes, I will provide an updated equation and reference.

Bulk H_2O diffusivity in basaltic melt:

$D = W \cdot \exp(-10.88\text{-}15200/T)$,

where T is in K, D is in m^2/s, and W is wt% of total H_2O (if there is 1 wt% total H_2O, then W =1). The reference should be as follows: "The equation is reparameterized from Zhang and Stolper (1991)". The experimental data only cover the range of 0.2 to 0.4 wt% total H_2O (1300-1500°C and 1.0 GPa). Extrapolation to 1.0 wt% total H_2O should be OK, to 2.5 wt% total H_2O might have an uncertainty of a factor of 5. Extrapolations to even higher total H_2O is not recommended. Clearly more experimental data on H_2O diffusion in basaltic melt to cover higher H_2O content and different pressures are necessary.

CO_2 diffusivity in basaltic melt:

D=exp(-7.96-23453/T). (Watson, 1994)

The above formula is actually for an anhydrous sodium aluminosilicate melt at 50 MPa but diffusivity in basaltic melt has been shown to be indistinguishable from it (Watson, 1994). CO_2 diffusion in hydrous basaltic melt has not been experimentally studied. Because CO_2 diffusivity seems to be independent of anhydrous melt composition, one might use data for rhyolitic melts. CO_2 diffusivity in rhyolitic melts has been investigated for two H_2O concentrations, one is dry, and the other with 8.0 wt% H_2O (Watson, 1994). No general equation is available for CO_2 diffusivity as a function of P, T and H_2O content.

Density of basaltic melt as a function of T, P and W:

Need basaltic melt composition. See Ochs and Lange (1999).

Surface tension of basaltic melt:

For dry basaltic melt, surface tension is 0.37 N/m (Walker and Mullin, 1981).
Khitarov et al. (1979) reported the following surface tension values at 1200°C:

P_{total} (atm)	H_2O (wt%)	CO_2 (wt%)	surface tension (N/m)
1			0.4
1000			0.16 to 0.17
3000	4.5	0.3	0.10
5000			0.09

Since the work of Khitarov et al. (1979) was carried out many years ago and at the time measurement of H_2O and CO_2 was not easy, the quality of the data (such as volatile concentrations) is not known. No attempt is made to make the data self-consistent (e.g., with solubility model).

References:

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