Nonequilibrium H₂O-CO₂ exsolution and obsidian formation

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The ratio of CO_2 to H_2O in volcanic glasses is one of the few available measurements directly related to syneruptive magma dynamics. Ascent-driven magma decompression results in the exsolution of dissolved volatiles from the melt. This in turn leads to bubble growth and possibly to gas loss from the permeable magma. Pyroclastic obsidian samples from the ca. 1340 A.D. Mono Craters, California eruption (Newman et al., 1988) have relatively high CO_2/H_2O values. These can be explained in terms of equilibrium closed-system (Newman et al., 1988), as well as open-system (Rust et al., 2004), magma degassing. However, both scenarios require the presence of CO_2 -rich vapor to buffer CO_2 exsolution from the melt.

We present results from numerical modeling of nonequilibrium joined CO_2 -H₂O exsolution under open- and closed-system conditions. We find that the Mono Craters CO_2/H_2O trend is well explained by nonequilibrium open-system degassing. Our results are a consequence of the low diffusivity of CO_2 (Watson, 1994). If, during decompression, open-system gas loss occurs at a rate comparable to the rate of volatile exsolution, bubbles remain small. Consequently, the surrounding melt shell remains relatively thick and CO_2 diffusion through the melt is slower than the rate at which CO_2 solubility decreases at the bubble wall. Thus, CO_2 concentrations throughout much of the melt remain above equilibrium.

Consistent with Rust et al. (2004), we conclude that throughout the Mono Crateres eruption, even at ascent rates sufficiently fast to sustain explosive activity, open-system degassing of some magma fraction took place. This resulted in the formation of obsidian. Because open-system gas loss at slow ascent rates will result in equilibrium degassing trends, we conclude that, contrary to conventional views, slow ascent rates or degassing at or near the surface are not a requirement for obsidian formation.

References

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Origin of UG2 and other chromitite layer of the Bushveld Complex

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Chromitite layers are common in large layered intrusions. One widely held view is that the chromitites formed as a consequence of the mixing of more primitive with less primitive magma (Irvine, 1977). This model predicts that the rocks immediately above and below the chromitite layers should be different. In the Bushveld Complex many chromitites are underlain and overlain by lithologically similar orthopyroxenite, suggesting that Irvine's model does not apply. To understand how the Bushveld chromitites may have formed, we have conducted a detailed study of the pyroxenites above and below the platinum group element-rich UG2 chromitite of the upper and another chromitite of the lower Critical Zone (CZ).

In the eastern Bushveld, the UG2 is a massive, 70 cmthick layer. Electron probe data indicate that the Mg# of opx ranges from 79.3-80.6 (En_{77.4-78.3}) in footwall and 80.5-80.9 (En_{77,7–79,1}) in hanging wall pyroxenite, while cpx compositions are $En_{45,3-46,3}$ in the former and $En_{45,3-48,9}$ the latter. Minor element compositions are variable, probably due to post-accumulation requilibration, but fall within the same range in each pyroxenite. In contrast, interstitial plagioclase of the lower pyroxenite is more sodic than that of the upper pyroxenite (An_{45.4 - 54.5} vs An_{64.9 - 72.5}). This difference is not reflected by differences in Al/Si or Na/Ca ratios of coexisting opx or cpx. Furthermore, major and minor element compositions of all three minerals are identical in the rocks underlying and overlying the lower CZ chromitite. Field relations demonstrate that the UG2 acted as a permeability barrier to upwardly percolating interstitial melt. Therefore, we interpret the relatively sodic nature of plagioclase of the footwall pyroxenite to be due to the pooling of interstitial melt Despite the difference in plagioclase in this layer. compositions, the formation of the UG2 chromitite by magma mixing cannot be rationalized in terms of phase equilibria. A different model, such as the pressure release one of Lipin (1993), may better explain the Bushveld observations.

References

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