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THE EFFICIENCY OF MAFIC-SILICIC MIXING PROCESSES IN MAGMA CHAMBERS: CONSTRAINTS FROM MELT VISCOSITIES; PHASE EQUILIBRIA AND NATURAL CASE STUDIES

Field and geochemical evidence clearly shows that mafic and felsic magmas often come into contact in the crust. Classical features in plutonic rocks which are interpreted to be typical of magma mixing/mingling processes are the presence of mafic microgranular enclaves and oscillatory or reverse zonations in phenocrysts (*e.g*. plagioclase, pyroxene, amphibole). The most common mixing processes probably result (1) from basaltic magmas that pond at the base of the crust and cause a subsequent melting of the rocks from the lower crust or (2) from the injection of basaltic magmas into upper silicic magma chambers. In any case, the extent of mixing between the two end-members will depend, among other factors, on the viscosity contrast. Recent experimental results show that the viscosity behavior of mafic and silicic magmas differs strongly during crystallization.

Silicic magmas formed in the crust have a characteristic magma viscosity of $10^{4.5}$ Pa s during emplacement or at pre-eruptive conditions (Scaillet et al. 1998). Because of the nearly eutectic composition of rhyolitic melts, the crystal fraction increases only slightly during most of the crystallization history (magmas still contain 60-80 wt% liquid 15°C above the liquidus). In addition, if the silicic melt is initially water-undersaturated, the effect of increasing water-content in the residual liquid compensates that of decreasing temperature and increasing crystal-content so that the viscosity of the silicic magma will remain constant (or even decrease) during the first 80% of the crystallization interval. In contrast, dacitic to andesitic or basaltic systems have a crystallinity which increases approximately linearly with decreasing temperature. Thus, the viscosity of such magmas will increase with decreasing temperature over the whole crystallization interval.

Using phase equilibria for basaltic, dacitic and rhyolitic systems, it can be shown that the potential for efficient mixing between silicic and mafic magmas at upper crustal levels is greater if the mafic end-member is relatively water-poor than if the mafic end-member is water-rich. This is confirmed in volcanic systems by the widespread occurrence of poorly mixed mafic-silicic end-members in arc magmas, in which the mafic melts are known to be water-rich.

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Observations allowing to estimate the efficiency of magma mixing processes are more difficult in plutonic rocks, which cooled slowly. Typical features suggesting mixing processes in fully crystallized systems (plutonic rocks) are oscillatory zoning in minerals, especially plagioclase. The classical pattern of rapid increase and gradually decrease of the An content of plagioclase is often interpreted as the result of a repeated replenishment of a magma chamber by a mafic end-member and subsequent mixing (convection) with more silicic melt prevailing in the chamber. On the basis of experimental and petrological observations on active systems (especially Unzen volcanic system, Japan), it is shown that a magma mixing event is not necessarily the only explanation for oscillatory zoning of phenocrysts. In the case of the Unzen magma chamber, the rapid increase of An content in plagioclase is correlated to a sharp increase in Fe (decrease of *mg*#) in the oscillatory zoning of hornblende phenocrysts. Such compositional changes of hornblende and plagioclase are not anticipated from repeated replenishments of a magma chamber by a mafic magma (the *mg*# in hornblende should increase concomitantly with An in plagioclase). In this case, a model involving magma degassing/recharge processes for the formation of the oscillatory zoning is preferred (Sato et al. 2002). The degassing/recharge of volatiles in the magma chamber will result in changes in activities of volatile components (including oxygen fugacity) and may result from the intermittent supply of gaseous phase from hotter and mafic magma located in a lower chamber. Thus, this suggests that, even if evidence of magma mixing is observed in magma chambers, chemical zonations of minerals may not be necessarily related to magma mixing or replenishment events, but only to changes of fluid phase compositions and volatile activities.

REFERENCES

SCAILLET B., WHITTINGTON A., MARTEL C., PICHAVANT M., HOLTZ F., 2000: Phase equilibrium constraints on the viscosity of silicic magmas. II. Implications for mafic-silicic mixing processes. Trans R Soc Edinburgh Earth Sciences, 91, 61-72.

SATO H., HOLTZ F., BEHRENS H., BOTCHARNIKOV R, 2002: An experimental study on Cl/OH partitioning between hornblende and melt and its application to Cl zoning of hornblende phenocrysts in the 1991-1995 dacite of Unzen volcano. Proceedings of the Unzen Workshop 2002, 11-12.