Geophysical Research Abstracts, Vol. 9, 02378, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-02378

Increase of Viscosity and Shear Thinning: why do Crystals promote complex Rheological Behavior?

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Solid-liquid suspensions tend to show an increase of viscosity with increasing solid fraction and shear thinning behavior (decrease of viscosity with increasing strain rate). The viscosity increase is due to the disturbance of the melt flow lines caused by the presence of suspended crystals. However, the fundamental question to address is: Why does the increase of strain rate produce a decrease of viscosity?

To answer this question, an experimental study has been performed to investigate the complex rheology of crystal bearing magmas as a function of the degree of crystallinity and the stress conditions applied. Quartz particles have been used as suspended crystals in a normatively quartz saturated haplogranite melt. This system has been chosen because of its high chemical stability at the range of experimental conditions attainable by the employed equipment. Torsion and compression experiments have been conducted in a high-pressure, high-temperature Paterson apparatus at 250 MPa, and temperature between 600 and 900 ˚C. The viscosities of the suspending haplogranitic melt have been determined by falling sphere experiments in conventional and centrifuging piston cylinder apparatus.

The microstructures generated during deformation were analyzed by back-scattered electron images obtained in an electron microprobe. All the experiments revealed a tendency of the melt phase to segregate from the crystals resulting in melt enriched bands oriented around 30˚ with respect to the shear plane that showed no relationship with the total strain applied. Numerical simulations were performed to quantify the phenomenon responsible for the generation of the microstructures observed in the experiments. The production of these melt enriched zones has strong implications for volcanological and melt extraction processes because and it is likely to be responsible for the observed shear thinning behavior of magmas.