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Large strain experiments on crystal- and bubble-bearing silicic magmas: A complex rheology

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We present novel experimental results on the complex rheological behavior of magmas composed of liquid and both, gas-pressurized bubbles and crystals, deformed at magmatic pressures and temperatures, pertinent to the conditions in very shallow magma reservoirs. This study aims to constrain the dependence of rheological properties of 3-phase magmas on the viscosity of the silicate melt, on the relative contents of crystals and bubbles and on the interactions between these three phases.
The starting material is composed of a hydrous haplogranitic melt containing variable proportions of quartz crystals (between 24 and 65 vol.%; 63-125 µm in diameter), but with the same bubble content (between 9 and 12 vol.%; 5-150 µm in diameter; gas-pressurized at 124 MPa). Bubbles are predominantly composed of CO2 whose low solubility let bubbles to withstand the high confining pressure applied during experiments.
The torsion experiments were performed in simple shear configuration using a HT-HP internally-heated Paterson-type rock deformation apparatus (Paterson and Olgaard, 2000) at strain rates ranging between 5•10-5 s-1 and 4•10-3 s-1, at a pressure of 200 MPa and temperatures ranging between 673 and 1023 K.
The experimental results show a sequence of rheological behaviors as function of total strain and applied strain rate. For constant strain rates the viscosity never decreased with increasing strain (no shear weakening). The increase of strain rate resulted in (1) an increase of viscosity (dilatant effect) for samples containing up to 44 vol.% crystals; (2) a decrease of viscosity (pseudoplasticity) for samples containing 65 vol.% crystals; and (3) no effect on the viscosity for the samples containing 55 vol.% crystals.
The bulk strain of the samples is composed of an inhomogeneous strain distribution (strain partitioning) evidenced by the microstructures generated during the experiments. Melt-enriched portions of the samples show strongly deformed bubbles (shear bands). In contrast, regions surrounding these melt-enriched bands, bubbles are almost spherical testifying that these portions of the material suffered a significantly lower amount of deformation. Locally, crystals generate stress concentration that causes bubbles to deform. The strain localization in lower viscosity regions (shear bands) results in a decrease of viscosity with increasing strain rate (shear thinning effect).

BIBLIOGRAPHY

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