Crystal plasticity as a strain marker of the viscous-brittle transition in magmas

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Quantifying magma transport requires rheological models. Models of suspension rheology have long attempted to deal with crystal fraction, shape and aspect ratio as rheological variables. Recent advances in experimental magma deformation and imaging now provide a substantial opportunity for completing our picture of the viscous behaviour of multi-phase systems. This study reports the first observation of crystal plasticity, identified using electron backscatter diffraction (EBSD), in the phenocrysts and microlites of two natural andesitic magmas that have been deformed experimentally at magmatic temperatures. The deformation yields a plastic response of the crystalline fraction, observable as a lattice misorientation, which grows with increasing stress and strain. Misorientations are less pronounced in pyroxene than in plagioclase (which is both less coherent and strongly anisometric). Phenocrysts which contain brittle fractures show crystal-plastic deformation in the intact segments. Apparently, crystal plasticity plays a significant role in strain accommodation under volcanic conditions. Thus the viscous-brittle transition during magma ascent may incorporate a regime of crystal-plastic deformation, the remains of which may be used as a strain marker. With higher crystal fraction internal misorientations are larger, a phenomenon that will favour strain localisation, shear zone formation and plug flow.