Geophysical Research Abstracts
Vol. 18, EGU2016-552, 2016
EGU General Assembly 2016

The effect of crystal plasticity and mineral stability on the rheological properties of magma during spine extrusion at Unzen, Japan

Paul A Wallace (1), Jackie E Kendrick (1), Yan Lavallée (1), James D Ashworth (1), Elisabetta Mariani (1), Felix W von Aulock (1), Rebecca Coats (1), and Takahiro Miwa (2)

(1) Department of Earth, Ocean and Ecology, University of Liverpool, Liverpool, United Kingdom (Paul.Wallace@liverpool.ac.uk), (2) National Research Institute for Earth Science and Disaster Prevention, Ibaraki, Japan

The presence of crystals in silicic magmas is known to have a significant effect on the rheological properties inducing a non-Newtonian response. Plastic deformation of the crystalline phase in magmatic suspensions is believed to be partially responsible for this characteristic behaviour via accommodating strain, but little has been investigated on its role in volcanic processes. The spine extrusion following the final stages of endogenous growth of the 1991-95 lava dome eruption at Unzen volcano, Japan, has provided a unique opportunity to investigate the contribution of the different deformation mechanisms and varying petrological phenomena associated with magma ascent. The spine forms a shear zone consisting of four structurally discrete units over a 6 m transect including: gouge (1), a heavily sheared zone (2) to a moderately sheared zone (3), and an undeformed magmatic core (4). Here we report the first systematic study of the microstructures, mineralogy, crystal stability, geochemistry and crystal size distribution across this shear zone.

The spine samples are porphyritic dacites with varying abundance of phenocrysts (20-30 vol.%), dominantly plagioclase, hornblende and biotite with minor quartz. The groundmass contains the same mineralogy plus pyroxene, magnetite and ilmenite. The microlites (35 vol.%) show a strong trachytic texture in areas of high shear, providing evidence of strain localisation. Brittle deformation is evident across the spine, with the higher sheared samples showing more crystal size reduction of the phenocrysts. By performing high-temperature (900˚C) uniaxial compressive strength tests at constant strain rates (10^{-5} and 10^{-3} s^{-1}), it can be inferred that crystals play a key role in the rheological properties, by forming a rigid but weak network that serves to partition stress and thus localise strain within the flowing melt. Electron backscatter diffraction (EBSD) enables the identification of crystal plasticity in both phenocrysts and microlites, with biotite displaying the greatest evidence of strain accommodation. This permanent strain is induced when the shear stress exceeds a critical point on an orientated lattice plane, resulting in a misorientation of the internal lattice. Crystal-plastic behaviour may thus act as a strain marker for the viscous-brittle transition during ascent. In the highly sheared zone, the rims of both hydrous minerals (hornblende and biotite) and plagioclase show a reaction with the melt suggesting disequilibrium conditions – a feature not as evident in the undeformed magmatic core of the spine. The narrow localisation of the disequilibrium textures suggest that the increased effects of gas flow in the permeable shear zone and/or thermal input due to strain localisation may be contributing factors affecting mineral stability during magma transport.

These deformation microstructures that occur in the shallow conduit, especially during ascent of highly viscous magma, can lead to permeability anisotropy which can significantly alter degassing efficiency and control the explosivity of an eruption. For this reason a thorough petrological/rheological understanding of these deformation processes is vital in constraining the complexities associated with on-going eruptions and shifts from effusive to explosive activity.