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Rheology and microstructure of experimentally deformed andesites from Volcan de Colima, Mexico: an EBSD study

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It is a common phenomenon for volcanoes to rapidly switch from effusive to explosive eruption, aided by the brittle failure of magma at high temperature. The transition from viscous and/or ductile to brittle mechanical behaviour is primarily controlled by stress, temperature and strain rate In addition, the chemical composition, crystallinity (fraction, shape, size, and distribution) and porosity of the magma have a strong influence on its rheological properties and thus on the onset of brittle deformation.

Here, high-temperature, uniaxial deformation experiments were performed along with electron back-scatter diffraction (EBSD) in order to quantify deformation mechanisms recorded in the crystals during deformation of dome lava. Two rocks from Volcán de Colima (Mexico) were chosen and cylindrical samples were deformed in a uniaxial press at constant stresses of 12 or 24 MPa, temperatures of 1000oC (that is above the glass transition temperature of 740 oC) and strain of 20 or 30%. The resulting strain rate varied between 10-5 to 10-2 s-1, which is comparable to strain rates within active volcanic systems.

In this study, both as-collected samples and experimentally deformed samples were analysed using EBSD in a scanning electron microscope to quantify crystallographic fabrics and crystal shape preferred orientation, intracrystalline distortions and grain boundary character in granular aggregates. Minerals analyzed include plagioclase, orthopyroxene and clinopyroxene, which are the main components of the granular fraction in the magma. This also contains minor amounts of hornblende, olivine and iron-titanium oxide phenocrysts set in a microcrystalline, glassy groundmass. From quantitative microstructural data obtained using EBSD, an inference of possible deformation mechanisms in the granular fraction can be made. The evolution of porosity during deformation is also studied using pre- and post-deformation measurements, permeability measurements and optical and SEM images.

This study aims to characterise the mechanical contribution of crystals in magma of known deformation history such that complex rheological processes taking place in volcanic eruptions (including the transition of high temperature magma into the brittle deformation regime) may be constrained.