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Brittleness and shear thinning: the explosive-effusive transition of lava dome experimentally investigated.

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The dome building eruptions generate repeated dome failure and pyroclastic flows. They vary in character and behavior from effusive domes to brittle pyroclastic events. The deformation of highly crystallized dome lavas is key to understanding their rheology and to fixing their failure onset. In this study we investigate the stress and strain-rate dependence on several glasses and Mt Unzen dome lavas. Their rheology has been determined for temperatures from 900 to 1010˚C and stresses from 2 to 60 MPa in uniaxial compression. Additionally, tensile tests were performed on several volcanic products to track down the porosity effect.

This survey aims to distinguish the Non-Newtonian effects affecting magmatic melts also known as indicators of the brittle field. Towards our experiments we observed three majors viscosity decrease types. Two were dependant and typical of the solid fraction (IAVD & DAVD). The first is instantaneous and on the whole recovered during stress release. The second is time-dependent and non-recoverable. The third and last effect observed is attributed to the melt fraction and its self heating under stress (VHE).

The IAVD is typical of that observed in previous experiments on crystal-bearing melts. On crystal free melts, this viscosity decrease is observed at much lower magnitude. We infer that the crystal phase responds elastically to the stress applied and relaxes once the load is withdrawn. The DAVD appears more complex and this regime depends on the stress (and/or strain-rate) history. We distinguish four different domains: Newtonian, non-Newtonian, crack propagation and failure domains. Each of these domains expresses itself as a different regime of viscosity decrease. Due to stress localization, cracking appears in crystal-bearing melts (intra-phenocryst and/or the in the melt matrix) earlier than in crystal-free melts. For low stresses, the apparent viscosity is higher for crystal-bearing melts (as predicted by Einstein-Roscoe equations). However, while the stress (or strain rate) increases, the apparent viscosity is decreasing to that of the crystal-free melt and could be even lower if viscous heating effects are involved.

Through this survey we distinguished apparent viscosity variations linked to the crystal network and/or the glass. Most of them are becoming relevant close the relaxation time scale of the material and may initiate the material failure.

More important, the crystalline phase is commonly believed to increase the viscosity according to the Einstein-Roscoe equations. Indeed, those equations are confirmed here for low stresses and strain rates. However, more importantly, the presence of the crystalline phases results in an apparent viscosity that becomes strongly stress and strain-rate dependent. Einstein-Roscoe overestimates this apparent viscosity by several orders of magnitude. This study demonstrates the dominance of non-Newtonian rheology in understanding the extrusion of dome lavas at Mt Unzen.