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From a fluid like to a brittle behavior: Shear thinning effect of crystals on Mt Unzen rheology.

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The dome building eruptions of Unzen generated repeated dome failure and pyroclastic flows. The domes varied in character and behavior from exogenic to endogenic. The deformation of highly crystallized dome lavas is a key to understanding their rheology and to fixing their failure criteria. In this study we investigate the stress and strain-rate dependence of 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. Two kinds of non-Newtonian behavior are observed. The first is instantaneous and on the whole recovered during stress release. The second is time-dependent and non-recoverable. These effects are termed Instantaneous and Delayed Apparent Viscosity Decrease (IAVD & DAVD), respectively. The IAVD is typical of that observed in previous experiments on crystal-bearing melts. It has also been observed for crystal-free melts 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 We infer that the crystal phase responds elastically to the stress applied and relaxes once the load is withdrawn.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 this 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. 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.