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Viscosity and fragility of natural (volatile-rich) multi-component melts.

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The rheological properties of silicate melts strongly control the transport dynamics, eruption styles, and the rates of physicochemical processes in natural magmas such as degassing, crystallization and mixing. Magma viscosity can vary by more than 10 orders of magnitude due to relatively small variations in melt composition, temperature (T), proportions of solids and volatile content. Processes operating in the volcanic conduit including cooling, crystallization, vesiculation, frictional heating can, thus, cause substantial viscosity gradients to develop in the erupting magma. The magnitudes of such gradients within conduits are critical inputs to forward fluid-dynamic simulations for the ascent and eruption of magma. Here we present a multicomponent model for the compositional and T-dependence of Newtonian melt viscosity for volatile-rich (H_2O and F) silicate melts. The experimental data include micropenetration and concentric cylinder
viscometry measurements covering a viscosity range of 10^{-1} to 10^{13} Pa s and a T-range from $\sim$ 300 to 1700 ˚C. These published data provide a high-quality database comprising $\sim$ 1500 experimental data on $>$ 56 well-characterized melt compositions.

The numerical optimization is based on the well-known Vogel-Fulcher (VF) equation (VF: η = A*expB/(T-T_0)) which accommodates the non-Arrhenian temperature dependence of silicate melt viscosity. Our model assumes that all silicate melts converge to a common value at high-T; in other words the VF-parameter A is independent of composition. The compositional dependence of melt viscosity is, thus, partitioned between the pseudo-activation energy term B and the VF-temperature T_0.

Our approach is strongly supported by the capability of the proposed model to accurately reproduce the large number of viscosity measurements on natural and natural-equivalent multi-component melts. The model is used to explore relationships between melt fragility (m) and styles of volcanic eruption.