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Non-Newton Man: An exploration of magmatic shear thinning sources.

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Natural magmas display at different levels a viscosity dependency with the stress. This non-Newtonian behavior often come off as a decrease of the measured apparent viscosity or shear thinning. However the shear thinning sources, necessary to scale back the flow behavior to natural scales, are poorly constrained. If a few hypothesis have been proposed, none have yet stood up or been clearly quantified. For pure melts we already demonstrated that Non-Newtonian behaviors simply result from viscous heating. With this study we investigate several potential sources to explain the decrease of viscosity in crystal bearing systems. If most of our arguments are based on literature, a rheological characterization of rigid particles suspensions has been performed with a cone and plate rheoscope and is here used as reference. We present various theoretical limits of the potential sources cited in literature for shear thinning (viscous heating, particle migration and crystal breakage) and compare them to experimental results. The reference system does not allow crystal breakage and so remove this potential source for the effect measured in our experiments.
Additionally, numerical simulations are presented to theoretically support the simpler models presented. They are based on elementary lattices and display the variation of local and bulk viscosity for rigid or deformable particles. We first discuss spherical particles suspensions and extend it next to various eccentricities. Finally numerical simulations are presented to theoretically confirm the suggested processes. From these results the sources of Non-Newtonian effects may results from only two effects. The first commonly mentioned in literature is a layering of particles for which we fix for the first time the limits. The second is a violation of volume conservation where the model is here presented for the first time.
These observations conclude on the present problems linked to experimental design and the necessity to rethink rheological and viscosity measurements for magmas. Only better constrained apparatus will allow to fully understand Non-Newtonian behaviors and make possible the scaling to Earth like systems.