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Experimental confirmation of viscous heating effects in calc-alkaline magmas.

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Viscous heating can play an important role in the transition from effusive, low mass flow rate to explosive, high mass flow rate eruptive behaviour of calc-alkaline volcanoes. Recent numerical models on the dynamics of explosive volcanic eruptions show that the heat generated by viscous friction produces a local increase in temperature near the tube walls. Consequently a decrease in viscosity and a strong stratification in the viscosity profile is obtained which can promote the transition from effusive to explosive behaviour, as well as allow a high discharge rate explosive eruption to be sustained. Here we present for the first experimental proof of temperature increasing of silicate melts by 10's of Kelvin due to dissipated mechanical energy by using a newly developed uni-axial high temperature, high load apparatus. The apparatus accommodates samples that are up to 100 mm in diameter and 100 mm long, and can be used to run constant displacement rate and constant load experiments. The rig is ideal for volcanological studies because it uses experimental conditions that closely match those found in volcanic processes: stress (0 to $>$ 500 MPa), strain rates (10-6 to 10-2 s), total strain (0 to 100%) and temperature (25 to 1300 °C). To study the rheology of silicate melts, we performed a viscosity study on a synthetic "SRM 717a" (Borosilicate glass, viscosity standard) and natural calc-alkaline glasses. The samples were placed between the two pistons of the apparatus and heated up to the desired temperature above the calorimetric glass transition temperature and the temperature was determined with 3 equi-spaced thermocouples inside the samples. After allowing the system to reach thermal equilibrium (˜ 8 hours) a force was applied (up to 110 MPa), and held up to several 10's of seconds. The temperature increase due to viscous dissipation inside the sample is a function of applied force, time, composition and viscosity. For instance, a NIST sample at 610 °C heats up by 14 °C when subject to

110 MPa for 25% strain. In the raw data (viscosity versus time, assuming no viscous heating effect) an apparent onset of Non-Newtonian flow behaviour is observed at stress and strain rates consistent to prior data from fibre-elongation studies (up to 0.4 log Pa s at 110 MPa). However if the data are corrected for the effect of temperature increase on viscosity, the "apparent" onset of Non-Newtonian flow behaviour is completely eliminated. The viscous heating effect clearly masks the possible true onset in compression experiments and it remains open to show that the results of the fibre-elongation studies might be affected in a similar way. More experiments are currently undergoing, to validate the numerical model of viscous heating.