Viscosity measurements of crystal-bearing natural lava samples from Unzen volcano, Japan

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Goto (1999) pointed out the apparent viscosity of Unzen lobe lava from field observation, 0.9-4.2$\times10^{10}$ Pa s by Fukui et al. (1991) and Suto et al. (1993), is much lower than predicted from matrix melt viscosity (8$\times10^{12}$ Pa s at 800 ℃) and about 50 vol.% lava crystallinity. This implies the mechanism of lobe lava displacement may be different from the Newtonian flow.

To the contrary Cordonnier et al. (2009) measured the viscosity of Unzen dome lava samples and concluded that their experimental results is in harmony with the observation if, based on the viscosity model by Hess and Dingwell (1997), the viscosity decrease by $\approx$0.2 wt.% water is considered. However, their experimental temperature ranges between 940 and 1010 ℃. If we linearly extrapolate their data down to 800 ℃ lava viscosity should be over 10^{16} Pa s, which is difficult to be lowered to observed viscosity range by water effect. Thus far the viscosity of crystal-bearing lava is still under debate.

We have started viscosity measurement of natural lava sample from Unzen 1991-1995 activity. The rock sample used in our preliminary experiment was collected from 1991 Sep. 15 pyroclasitc flow deposit. The test piece was cored to 14.95 mm diameter and 30.55 mm high for parallel plate viscometry. The core bulk density was 2.24 g/cm^3. The core was loaded 10 N (57 kPa) during the heating for 3 hours to desired temperature (980 ℃) and additionally held for 30 minutes, then loaded up to 1800 N (10 MPa) within a minute and kept at this load for 30 minutes. The total deformation was 47 %. Except the last 10 minutes viscosity was almost constant at each loads, 2$\times10^{10}$ Pa s at 57 kPa and 6$\times10^{9}$ Pa s at 10 MPa.

At the same temperature (980 ℃) Cordonnier et al. (2009) obtained the apparent viscosity to be 2$\times10^{11}$ Pa s at 2.8 MPa and 3$\times10^{10}$ Pa s at 10 MPa. Our experimental result is in harmony with them in that shear thinning occurred and time weakening did not occur at stresses less than 10 MPa, but differs in that the viscosity is lower at the same stress (10MPa) and the shear thinning is less prominent.

Avard and Whittington (2012) pointed out most laboratory studies are typically conducted at higher stresses and strain rates than experienced by lava moving as surface flows, and showed their experiments at low stress (0.085 to 0.42 MPa) yielded apparent viscosities more than one order of magnitude lower than predicted by models based on experiments at higher stress. Our experiment at 57 kPa actually yielded one order lower viscosity than at 2.8 MPa by Cordonnier et al. (2009), but the conclusion by Avard and Whittington (2012) conflicts with shear thinning. We have to explore the rheological property of crystal-bearing lava more.