Rheological property of basaltic lava at rigid-deformable transition

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The viscosity of Izu Oshima basaltic lava flows, effused from summit crater in 1950-1951 and 1986 eruptions, were estimated from slope angle, thickness and surface velocity with supposed density of the flowing lava (Murauchi, 1950; Minakami, 1951; Shirao, 1986). They seem to be curious in that the viscosity of 1950 lava changed over two orders within 15 ˚C (1.7×10^4 Pa s at 1063 ˚C and 3.3×10^6 Pa s at 1048 ˚C), and 1950 lava at 1048 ˚C had over two orders higher viscosity than 1951 lava at 1038 ˚C (2.3×10^4 Pa s). Minakami (1951) also pointed out that the viscosity from field observation were several tens times higher than the measured viscosity in laboratory by Kani (1934). To solve these paradoxical observation results uniaxial compression viscometry was performed for 1986 LC lava cored cylindrically with 15 mm diameter and 30 mm high (Goto, 2017, JpGU meeting). Contrary to the expectation before the experiment that the viscosity decreases continuously with increasing temperature, the lava became deformable drastically at around 1100 ˚C, which did not seem to be by fluidization but by brittle failure; the middle of the cylindrical core was crushed and their surface skin was pushed out brittly. Below this temperature viscosity changed continuously with temperature, although they were almost at solid state range and much higher than the observed viscosity. These rheological properties were common for other Izu Oshima lavas: 1777 pahoehoe, 1950 aa and two types of 1951 pahoehoe (Goto, 2018, VSJ Fall meeting). A new question arose whether these properties were also common for other basaltic lavas. To confirm it Miyake-jima 1983 lava and Mt. Fuji Kemnarubi 1 (porphyritic) and 2 (aphyric) lavas were newly used for uniaxial compressional viscometry.

Similar deformation was seen for Miyake-jima and Mt. Fuji basaltic lavas, indicating that brittle behavior is common for most, if not all, basaltic lava when the drastic deformation occurs. As was also seen for Izu Oshima lavas the highly deformed sample had enough strength not to separate into pieces after the experiments, indicating melt phase surely existed. Melt composition analysis was impossible for Izu Oshima samples after the uniaxial compression experiments due to dendrite crystallization during cooling (10 ˚C/min); alternatively samples quenched after annealing was used for melt composition analysis to calculate the viscosity using the model by Giordano et al. (2008). The melt phase viscosity scattered within few orders even in each sample, i.e., at the same annealed temperature, due to the variation of the melt composition, and was almost similar with or within few orders higher than the viscosity observed by Murauchi (1950) and Minakami (1951) at the same temperature range. If 1 wt% water was supposed 2 orders viscosity decrease was expected, but high crystallinity (e.g., 50 vol% at 1105 ˚C and 78 vol% at 1095 ˚C in annealed sample) might compensate the viscosity decrease by water or rather heighten the bulk viscosity than observed lava flow viscosity. The mechanism of brittle deformation is not interpreted yet, but high mobility after the brittle deformation may sustain the low bulk viscosity of lava flow, and variation of melt composition at the same temperature may be the source of the above mentioned curious observed viscosity.

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