V201-P006 **Room: Poster Session Hall** **Time: May 14**

Deformation and fracture of magma around glass transition temperature-Part 1: uniaxial compression test on synthetic melt

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An adequate criterion for magma fragmentation is required to develop numerical models of volcanic explosion. An important factor to be considered is the rheology of magma near its glass transition temperature, Tg. The Tg of magma has already been well studied and been described as a function of the strain rate and composition. However, how a magma passes its glass transition and fractures have not been sufficiently investigated experimentally. Even for normal glasses, such as soda-lime glass, systematic studies on fracture behavior around iTg have just been undertaken. In this context, we have started a series of experiments intended to evaluate the mechanical and fracture properties of magma. Here, we present the first report containing methods and results of uniaxial compression test on a magma analogue.

1. Analogous material

We use a synthetic magma with diopside-anorthite eutectic composition. Reasons to chose the composition are as follows. Firstly, it represents the melt structure of actual magma well and simply. Secondly, its properties including viscosity and glass transition temperature are well documented. Thirdly, the glass transition temperature is relatively low and reachable by the present experimental apparatus. We made cylindrical specimen with diameters of 10mm or 14mm, and length of 7-14mm. The specimenwere annealed and polished before the tests.

2. Experimental methods

Experiments were conducted at Technion. We used a servo- hydraulic compression apparatus (MTS-810) for low strain-rate (less than 0.001 1/s) tests, and aKolsky (Hopkinson) bar apparatus for high strain-rate (~1000 1/s) tests. The compression bars in both apparatus are made of a nickel base superalloy (Inconel 718) which retains a high strength up to 900 degree C. The specimen was sandwiched between two compression bars and heated in a furnace. Then it was deformed at a given constant strain rate and stress-strain curves are obtained.

3. Results

Experiments were conducted at various temperatures and strain rates over the glass transition condition. Then various behaviors of the material such as elastic deformation, fracture, and flow were observed. In most of the low-rate tests below Tg, fractures started with longitudinal cracks developing at aobout 2 MPa. The phenomenon is similar to what is called slabbing fracture mode. In one test at room temperature, the specimen sustained stress as large as 1.5 GPa witout cracking and then completely fragmented into powders. On the other hand, large flow of a specimen was observed in the fluid side condition of the glass transition. Elastic-plastic deformation was observed at the transition. In high-rate tests, the specimen sustained stress of up to 1 GPa and fragmented into powder at temperatures well above the static glass transition temperature. In all the cases, the solid-like fractures occurred in elastic regime of the material with very little ductile flow. On the other hand, fracturing was not clearly noticed during flow.Further analyses of the data are planned, including considerations on magma behaviors including fracturing and non-linear deformation.