VISCOSITY MEASUREMENTS OF ALBITE MELT UNDER HIGH-PRESSURE USING AN *IN SITU* X-RAY RADIOGRAPHY TECHNIQUE

An understanding of the viscosity of silicate melts under high-pressures is essential in contemplating the behavior of magma and volcanic eruptions. A variety of silicate melts have been investigated, leading to the conclusion that the viscosity of highly polymerized silicate melts decreases with increasing pressure, in sharp contrast to the behavior of normal liquids [1]. Thus far, the viscosity have been measured using a quench-falling sphere method, in which the terminal sinking velocity is determined by altering the quench rate [2-4]. In this method, however, the determination of the terminal velocity may involves uncertainties, due to the limitation of the sinking distance and the quench rate. The use of synchrotron radiation has enabled *in situ* observations of the falling sphere by implementing an X-ray radiography technique. This new method has many advantages over the traditional quench-falling sphere method [4,5]: (i) the precise terminal velocity of the falling sphere can be obtained, (ii) P-T condition is experimentally determined by combining *in situ* X-ray diffraction, and (iii) low-viscosity melts can be measured. Here, we report an *in situ* viscosity measurement under high pressure using an X-ray radiography falling sphere method. The first trial was performed on albite melt, which is one of the most important silicate melts.

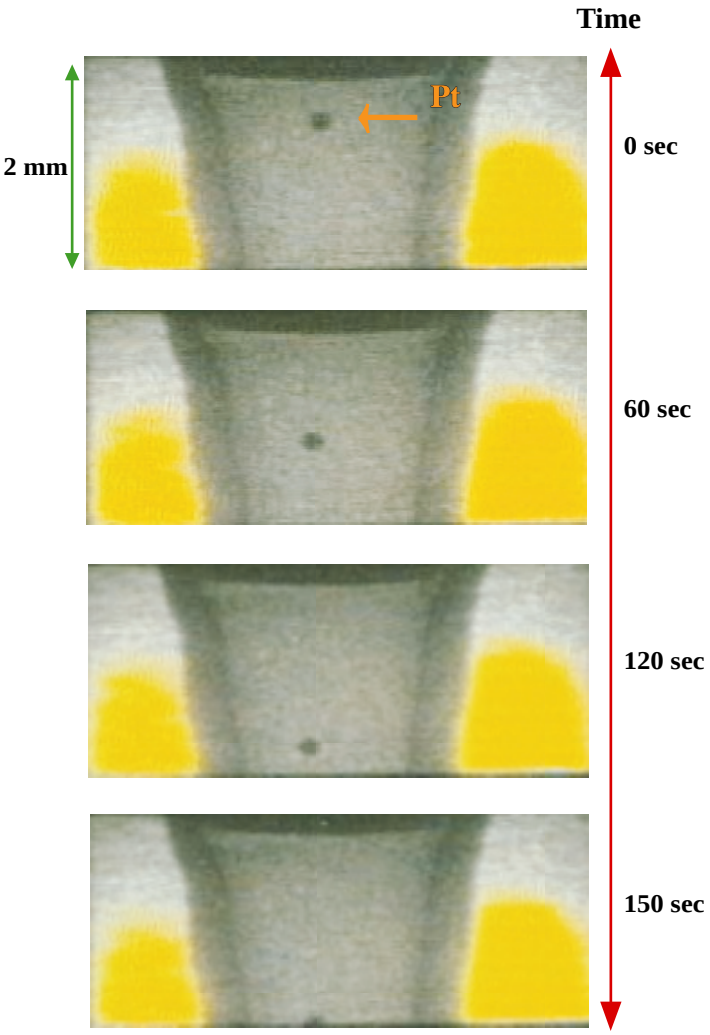

Fig. 1. The observed images detected by a high-speed CCD camera at 3.3 GPa and 1600 ℃. The measurable window was about 2 mm, because of the narrow anvil gap due to the compression. Each frame of these images was captured at intervals of 1/30 s.

We have set up an *in situ* viscosity measurement system combined with a multi-anvil apparatus at SPring-8 [6]. The system has been installed on a large volume multi-anvil apparatus (SPEED-1500) at beamline **BL04B1** [7]. Pressure is generated by a double-stage system with tungsten carbide cubes with a truncation edge length of 12 mm. The incident white X-ray from the bending magnet irradiates the sample cell through the anvil gap, and an image of the sample is projected on the fluorescence screen. This image is then magnified and detected by a high-speed CCD camera. For this experiments, a Pt sphere with a radius of 50 - 80 μm was embedded in the upper part of the albite sample. A fine powdered mixture of MgO and BN was filled surround the sample capsule as the inner pressure marker, and the pressure was calculated from the observed lattice constant of MgO. A thermocouple was placed on the top of the sample capsule. The sample was first compressed at the room temperature, followed by heating at a constant applied load. To avoid the differentiation effect or partial melting, the compressed sample was first annealed at 1000 °C, and then ramping was performed to reach the target temperature (1600 °C and 1700 °C). The heating rate was regulated to be about 200 °C/second. Once the target temperature was attained, the Pt sphere began to fall into the melt. The observed images from one of the series (3.3 GPa and 1600 °C) are shown in Fig. 1. The measurable window was about 2 mm, because of the narrow anvil gap due to compression. Each frame of these images was captured at intervals of 1/30 second. The high-speed and high-resolution CCD camera allowed for very good visual contrast between the Pt sphere

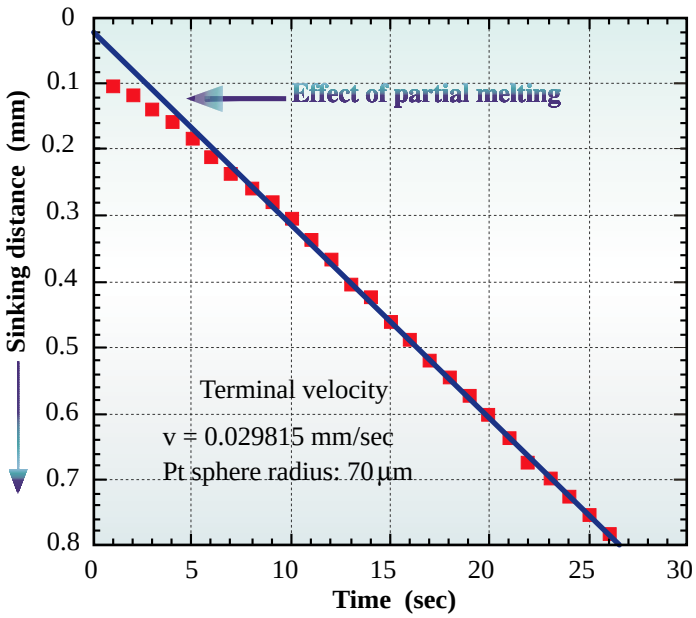

Fig. 2. Sinking distance of a Pt sphere in albite melt as a function of time (4 GPa, 1700 °C).

and albite melt possible in a short exposure time.

These measurements were carried out under the several P-T conditions up to 5.3 GPa at 1600 °C and 1700 °C. To determine the terminal velocity of the sinking sphere, we analyzed the images and obtained the geometrical center position of the Pt sphere from each captured frame. The settled distance (4 GPa and 1700 °C) is plotted in Fig. 2 as a function of time. At the moment the temperature reached 1700 °C, the Pt sphere (with a radius of 70 μm) began to sink slowly and sank at a constant velocity after 10 seconds. We used the linear part of the plot and determined the terminal velocity of the Pt sphere using a linear least square calculation. The viscosity was calculated from this velocity using Stokes' equation, including the Faxen correction for the wall effect [2,8].

The viscosities are summarized in Fig. 3, together with the data obtained by previous quench experiments. The error of our viscosity values is estimated within ±1.5 poise. As shown in this figure, our values clearly indicate the decrease of the viscosity with increasing pressure, which is significantly low (with no more than one order of poise) compared with those determined by the quench studies. Furthermore, at 1700 °C, the minimum viscosity is clearly seen to be around 4-5 GPa, which is consistent with the diffusivity results [9], therefore suggesting that some structural changes may occur at this pressure range.

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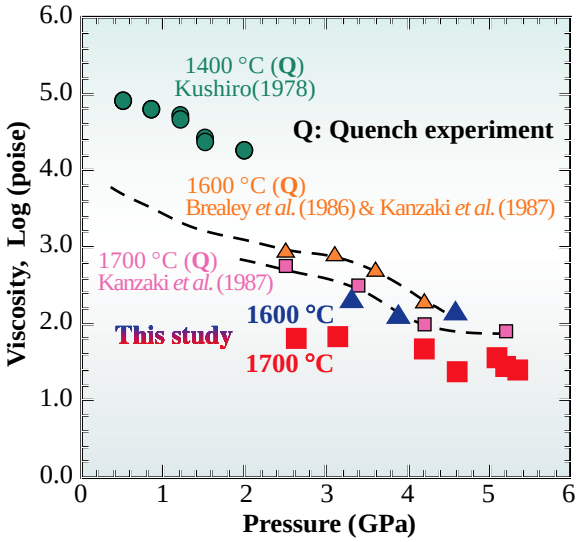

Fig. 3. Comparisons of the pressure dependence of the albite melt viscosity determined by in situ and quench experiments.

References

[1] C.M. Scarfe *et al.*, Magmatic process: Physicochemical Principles **1** (1987) 59, (Geochem. Soc. Univ. of Park, Pennsylvania.)

[2] I. Kushiro, Earth Planet. Sci. Lett. **41** (1978) 87.

[3] M. Brearley *et al.*, Geochim. Cosmochim. Acta **50** (1986) 2563.

[4] M. Kanzaki, Ph. D. Thesis, The University of Tokyo (1987).

[5] D.P. Dobson *et al.*, Earth Planet. Sci. Lett. **143** (1996) 207.

[6] K. Funakoshi, M. Kanzaki, A. Yasuda, A. Suzuki, H. Terasaki and S. Yamashita, Science and Technology of High Pressure, Proc. of AIRAPT-17, **2** (2000) 1023.

[7] W. Utsumi *et al.*, Rev. High Pressure Sci. Technol. **7** (1998) 1484.

[8] H.R. Shaw, J. Geophys. Res. **68** (1963) 6337.

[9] B.T. Poe *et al.*, Science **276** (1997) 1245.