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Viscosity of lunar high-Ti magma at high pressure

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Introduction

Viscosity of magma (silicate melt) at high pressure is very important to understand the magmatic processed in the terrestrial planets and their satellites. The viscosities of terrestrial basalt magmas are relatively well investigated [e.g., 1], however, extraterrestrial magmas are not well known.

It has been proposed that the pressure dependence of viscosity is strongly related to the structure of melt. Viscosity measurements of various silicate melts revealed that polymerized and depolymerized melts exhibit different pressure dependences. In the case of polymerized melts, an initially negative pressure dependence of viscosity is observed, whereas the viscosity of depolymerized melt increases with increasing pressure. In our previous studies, we reported that the viscosity of melts with intermediate polymerization have minima and the pressure dependences of viscosity change from negative to positive at a certain pressure.

Titanium in silicate melt is regarded as a tetrahedrally-coordinated cation (T–cation) at ambient pressure [2]. Because the viscosity change at high pressure is estimated to be affected by the structural change of TO_4-network, it is very interesting to know the influence of Ti on the pressure dependence of viscosity.

Lunar volcanic rock is characterized by the variety of Ti content. In this study we investigated the viscosity of melt with the composition of the Apollo 14 black glass, which is a volcanic glass containing the highest amount of TiO_2 among the lunar pristine glasses.

Experimental

Starting material was a synthetic analogue of the Apollo14 black glass (SiO_2=34.00 TiO_2=16.40 Al_2O_3=4.60 Cr_2O_3=0.92 FeO= 24.50 MnO=0.31 MgO=13.30 CaO=6.90 in weight percent). We used the density data of the molten Apollo 14 black glass measured by the buoyancy test by Circone and Agee [3]. We conducted in situ falling-sphere viscometry by using the MAX-III press and the Kawai-type apparatus at BL-14C2 beamline. Experiments were performed at 1460 and 1530°C in the pressure range 1.0–2.3 and 2.4–3.5 GPa, respectively. In a high pressure cell, a rhenium sphere was placed near the top of the sample chamber, and it fell through the molten sample at superliquidus temperatures. The sphere's position was monitored continuously using a CCD camera to determine a time-distance relationship, from which we derived the terminal velocity.

Results and discussion

Figure 1 shows the variation of melt viscosity with pressure at 1460 and 1530 °C. The negative pressure dependence of viscosity is observed from ambient pressure to 1.0 GPa. The viscosity of lunar high-Ti magma may reach a minimum in the pressure 1.0-2.3 GPa.

Titanium in silicate melt is known to be the network–former (T–cations) at ambient pressure [5]. The structure of Ti-bearing silicate melt was investigated by Paris et al. [6]. On the basis of a XANES (X-ray absorption near edge structure) study of $K_2TiSi_4O_{11}$ glasses synthesized in the pressure range 0.5–3.0 GPa, they showed the increase of coordination number of Ti with increasing pressure. The results of this study suggest that the viscosity minimum is related to the coordination change of titanium in the lunar high–Ti magma.

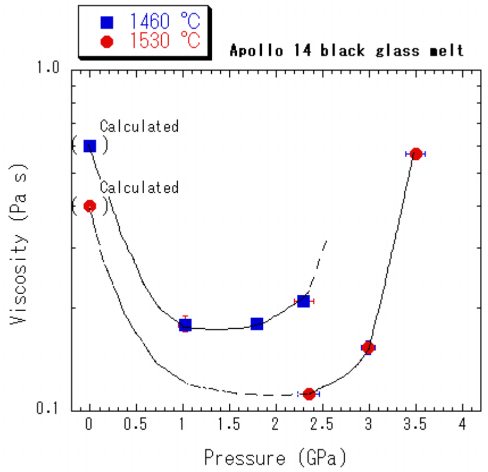

Figure 1: Viscosity of lunar high-Ti magma with pressure. Plots in parenthesis are calculated by extrapolating the data of Murase and McBieney [4]

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