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TTT 図の応用による黒曜石ガラスの形成過程
The formation process of obsidian; Insights from the application of TTT diagrams to Tokachi-Ishizawa obsidian

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Why obsidian contains low crystal amount, namely mostly glass, though it experiences the effective undercooling and long crystallization time during magma ascending and cooling, has been a big problem in volcanology. In generally speaking, glass can be formed because of a high effective undercooling and a short cooling time. However, ascent rates of obsidian lava eruption are expected to be relatively small.

In order to evaluate the development of glass formation in obsidian lava eruption, we applied Time- Temperature- Transformation (TTT) diagram for natural obsidian lava, and estimated critical cooling rate to form the obsidian. The TTT diagram has been used to predict the cooling rate to form the glass (Uhlmann, 1982; Weinberg and Uhlmann, 1989; Rao 2002). The TTT diagram is a contour map of crystallized volume fraction as function of crystallization temperature and time. A contour line for a given crystallization fraction has the cone shape with its “nose” which corresponds to a minimum time and a temperature required for the time. We simulated the 2 types of situations; decompression-induced crystallization and cooling-induced crystallization after decompression. The nucleation and growth rate were calculated based on the classical theory (James, 1985; Hammer, 2004; Rao, 2002). The crystallized fraction, under the assumption that nucleation and growth rate are constant for time, is given by the Avrami-Johnson-Mehl equation. We applied TTT diagram for Tokachi-Ishizawa obsidian lava, and estimated the critical cooling rate. Based on the calculation results, critical cooling rates are highly dependent on interfacial energy and the pre-exponential factor of nucleation rate.

We compared estimated critical cooling rates with cooling rates estimated from the microlites number density (Sano et al., 2015). Our calculation results show that obsidian glass can be formed during decompression and cooling, especially under the high interfacial energy. We investigated the glass forming conditions based on parameters such as interfacial energy and pre-exponential factor, and suggest that obsidian can be formed although it experienced the low effective undercooling and long crystallization time during eruption.

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