Ultra-high-pressure internally heated pressure vessels for research on deep magmatic systems

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1. Introduction

Investigating volcanic roots, i.e. deep magma-feeding system, is difficult because we have to remove the effects of shallow structures or processes properly, to reveal deep structures or processes by geophysical or petrological observations. In order to overcome this difficulty, we should apply various types of methods and combine their results.

High-pressure high-temperature (high P-T) experiments are effective to investigate deep magma-feeding system. They reproduce the high P-T condition of the deep system in laboratory to study what is occurring there. We are mainly conducting melting experiments for volcanic rocks to reproduce "magma" and, for example, study chemical reactions under high P-T conditions. Recently, we have installed ultra-high-pressure internally heated pressure vessels (IHPVs), by moving from Tokyo Institute of Technology (TITech) to Geological Survey of Japan (GSJ), AIST (Tomiya, 2017). Since we have just set up and renewed it, we introduce the apparatus here.

2. The ultra-high-pressure IHPVs (max. 850 MPa)

In general, gas apparatus (e.g., IHPV) is used to conduct high P-T experiments less than ca. 500 MPa (=5000 bar; equivalent to ca. 20 km deep). Its strong points are the isotropic pressure and the precision in pressure and temperature. For ca. 0.8 to 3 GPa or so (equivalent to the uppermost mantle), piston-cylinder apparatus is generally used. For higher pressures, multi-anvil press and diamond-anvil cell are the choices. The problem is the range between ca. 500 to 800 MPa, which is equivalent to the mid- to lower-crust; i.e., the conditions of volcanic roots. For this pressure range, making gas apparatus is difficult because it is strictly regulated by the High Pressure Gas Safety Act in Japan, whereas experiments with piston-cylinder apparatus is not good because friction causes considerable error in pressure. Thus, experiments have been limited in this pressure range.

The ultra-high-pressure IHPVs can resolve this problem. They consist of a vessel with the maximum pressure of 850 MPa (equivalent to ca. 30 km deep; SMC-8600) and a vessel with that of 481 MPa (equivalent to ca. 20 km deep; SMC-5000). Both vessels were developed by Prof. Takahashi, E. and others (Takahashi *et al.*, 1996; Suzuki *et al.*, 2004) when he was at TITech. The maximum temperature is 1500 ˚C, enough for even high-temperature primitive basalt to melt. With the drop-quenching system, the melted sample is fallen from the hot spot to the cooler bottom, and recovered as quenched glass for analysis. The maximum sample size is ca. 12 mm in diameter and ca. 25 mm in length.

3. High P-T melting experiments in GSJ

Using our IHPVs, we are conducting several experiments; for example, melting experiments to estimate the P-T conditions of the magma chambers beneath Aso caldera (Ushioda *et al.*, 2020) and Towada caldera (Nakatani *et al.*, 2020). Besides the ultra-high-pressure IHPVs, we have another IHPV, which is easy to operate and has a decompression-speed controller, although its maximum pressure is 196 MPa. We are collaborating with several universities, including Tohoku University (Matsumoto *et al.*, 2020), Shizuoka University (Oida *et al.*, 2020), and Massey University, New Zealand (Coulthard *et al.*, in prep). We welcome collaboration to investigate deep magmatic systems, using our IHPVs, in particular the

ultra-high-pressure IHPVs.

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