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High-pressure deformation experiments using a modified Kumazawa-type apparatus

Ichiko Shimizu[1*]

[1]Faculty of Science, University of Tokyo

Rheological properties of rocks and minerals at high-pressures (P) and temperatures (T) above 500°C have been investigated by axial compression or torsion machines that use inert gases or soft solid materials as confining media.
High-T creep tests using gas-medium apparatus are generally conducted at a confining pressure (Pc) around 300 MPa, which corresponds to a depth of approximately 10 km in the upper crust. For the deformation experiments at higher pressures, Griggs apparatus and its modifications have been employed with relatively weak solids such as talc, pyrophyllite, lead, and NaCl as confining media. The axial force acting on the sample is measured by an external load cell placed outside the pressure vessel. However, the high confining pressure generated in the solid medium causes high frictional stress on the cylindrical surfaces of the sample and the pistons, making precise values of differential stress difficult to determine. Piezometric relations of recrystallized grain size obtained at deformation experiments with solid-medium assemblies are largely scattered (Shimizu, 2008), suggesting significant errors in stress measurements. Molten salt cells reduce the friction between the sample and its surroundings, but the problem of friction due to the solid parts of the assembly after 'hitting' the sample is still not fully resolved.

To acquire reliable mechanical data at high-PT deformation experiments, we have been employed a different approach using a special solid-medium apparatus, named MK65S. This apparatus was designed by M. Kumazawa at Nagoya University and built by OKUMA Co. in 1965 (Kumazawa and Shimizu, 2006). The most unique feature of MK65S is its stress measurement system. Frictional forces in a solid assembly during pressurization, heating, and constant strain-rate tests are corrected in real-time and differential stress is accurately determined (Shimizu et al., 2006). However, confining pressure generated in MK65S is restricted to 1 GPa, which corresponds to a depth of about 30 km.

For rheological studies of rocks and minerals at higher pressure, we developed a new solid-medium apparatus based on Kumazawa's design. The new apparatus, built by Sumitomo Heavy Industries Ltd., consists of 100 and 20 ton press frames for the confinig and axial forces, respectively, hydraulic ram driven by a hand pump, motor-ball screw system, cylindrical pressure vessel, and two concentric opposing pistons. The outer pistons provide confining pressure, while the inner pistons lead a sample to axial strain. A standard pressure vessel with an inside diameter of 24 mm and a cylindrical sample with a 8 mm diameter enables constant strain-rate tests at confining pressure up to 2 GPa, axial stress up to 4 GPa, and temperature greater than 1000°C.

References

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