5–13 Toward an Understanding of the Role of "Water" in the Earth's Mantle

— Development of a High Pressure, High Temperature Apparatus for Neutron Diffraction at J-PARC —

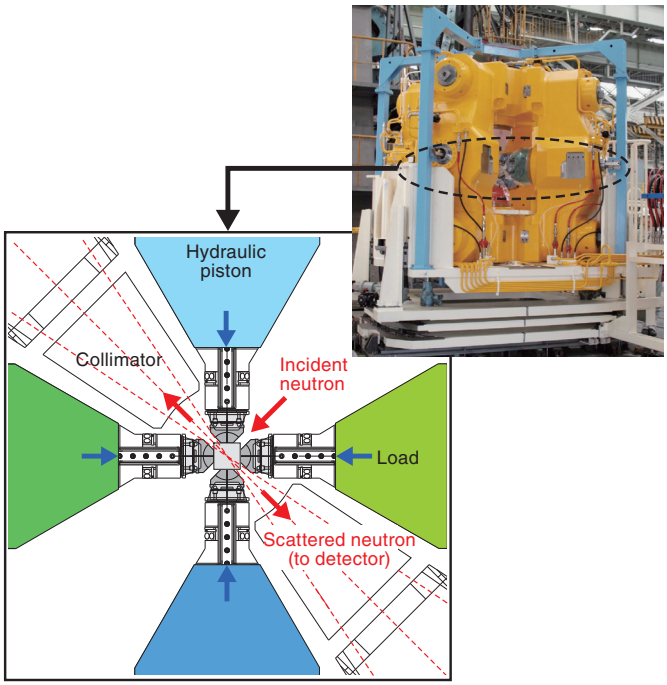

Fig.5-32 Six-axis multi-anvil press "ATSUHIME"
To achieve the extreme conditions of Earth's deep interior, we have developed a six-axis multi-anvil press. A high pressure condition is generated by applying the load with six hydraulic pistons. Neutrons scattered by the sample are detected through the "window" of the press (– – –).

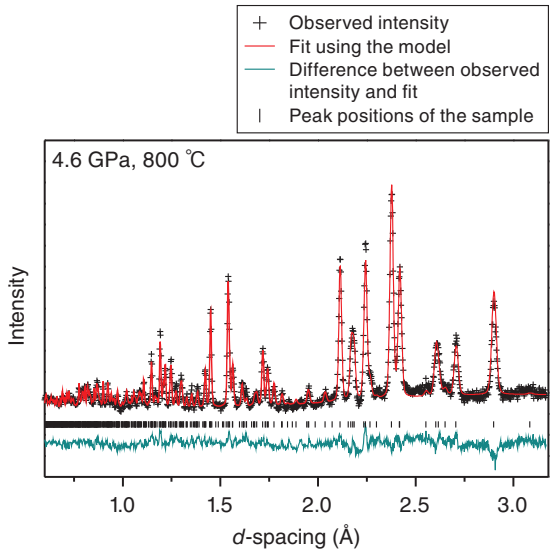

Fig.5-33 Neutron diffraction pattern of the hydrous mineral lawsonite
The neutron diffraction pattern of lawsonite, which is the main carrier of hydrogen in descending oceanic plates, is first obtained at high pressure and high temperature. Hydrogen positions are refined by fitting the observed data (+) with a structural model (——).

The physical properties and structures of minerals and magma change significantly under the high pressure and high temperature conditions in the Earth's interior. *In situ* observation at the extreme condition is thus important for discussions of the Earth's structure and its evolution. Neutron diffraction is a powerful probe for locating hydrogen positions *in situ*, which are difficult to determine by X-ray scattering.

A high pressure condition is achieved by applying force to the sample cell, while high temperature is achieved using a resistive heater in the cell. A conventional multi-anvil press applies a load to a pair of opposed guide blocks using a hydraulic piston. However, when it comes to applying neutrons, this guide block is unfavorable because it limits the "window" for detecting neutrons scattered from the sample. Moreover, the allowable pressure and temperature was limited below 7 GPa and 1000 °C due to insufficient thermal insulation of the small sample cell.

To overcome these problems, we have developed a six-axis multi-anvil press "ATSUHIME" (Fig.5-32). This press comprises six orthogonally aligned hydraulic pistons. The design without guide blocks allows us to enlarge the "window" for neutron scattering and to place the collimation devices near the sample.

The press has been installed in the PLANET beamline at the MLF, J-PARC. We succeeded in conducting *in situ* experiments at 16 GPa and 1000 °C, corresponding to the conditions of the Earth's mantle transition zone where water plays an important role. Thanks to the collimators, high-quality diffraction patterns are available without any parasitic scattering from the high pressure cell (Fig.5-33).

This press constitutes a new tool for understanding the role of water in the deep Earth using neutron scattering.

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Reference

Sano-Furukawa, A. et al., Six-Axis Multi-Anvil Press for High-Pressure, High-Temperature Neutron Diffraction Experiments, Review of Scientific Instruments, vol.85, issue 11, 2014, p.113905-1–113905-8.