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Rock Deformation Apparatuses at Kyoto University

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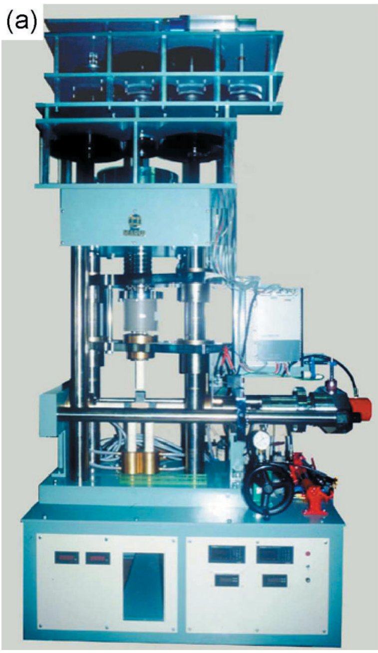
We introduce four testing machines currently in use at Kyoto University ; (1) high-temperature biaxial frictional testing machine for very sensitive friction experiments, free from O-ring friction, (2) a rotary-shear high-velocity frictional testing machine, reproducing seismic fault motion, (3) a high-pressure high-temperature deformation and fluid-flow gas apparatus for studying mechanical and transport properties, and (4) an intra-vessel deformation and fluid-flow apparatus for very easy experiments on deformation and fluid flow. For details of the machines, see Shimamoto et al. (2006) in this issue.

High-Temperature Biaxial Frictional Testing Machine



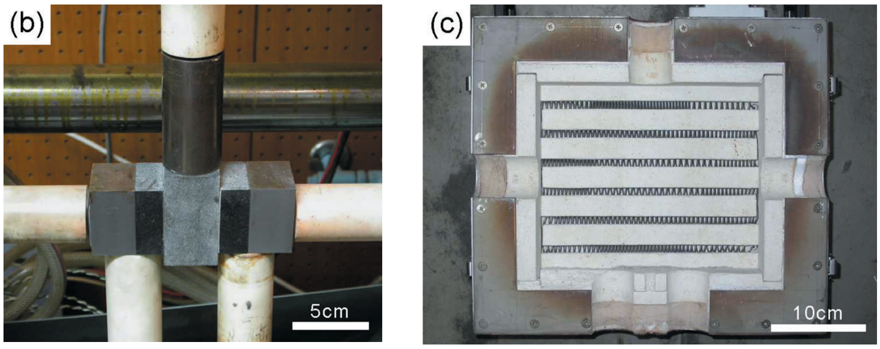


Fig. 1 Photographs of a biaxial frictional testing machine. (a) A photograph of the full apparatus. On the top is the gear-motor system controlling the loading velocity. On the lower right is an oil press that applies the normal force perpendicular to the simulated fault, up to approximately 200 kN. In the middle are three rock specimens for studying two simulated faults between them. (b) The sample assembly. Ceramic pistons push against blocks/cylinders so that the middle block is pushed downward while horizontal force is exerted by the two side blocks. (c) The furnace covers the whole sample assembly controlling the temperature up to 1000℃. The temperature gradient around the samples is minimized down to less than about 10% of imposed temperature by adjusting the density distribution of coils of Kanthal heating wire.

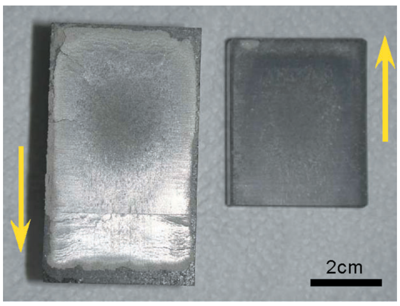


Fig. 2 The gouge surface opened after 20 mm displacement, with arrows showing sliding directions. Shiny surfaces and slickenlines are observed. Normal Stress : 30 MPa, shear velocity : 0.0014–14 mm/s, sample type : gouge from Gokasho-Arashima Tectonic Line.

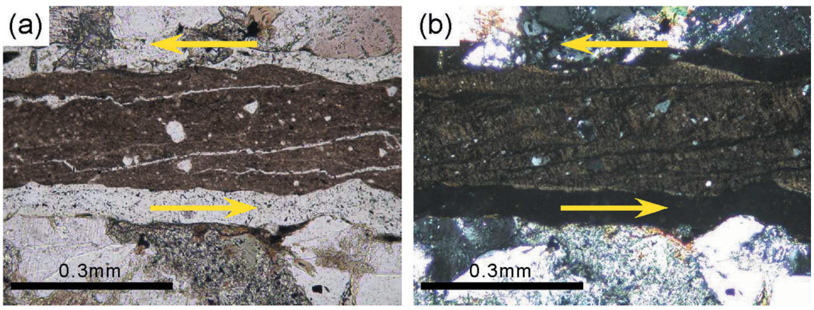


Fig. 3 Typical micro-structures of simulated fault gouge layers after experiments observed under a microscope ; (a) under plane polarized light and (b) under crossed polarized light. Arrows show the relative sliding direction. The gouge layer is detached from the gabbro blocks on the bottom side in the photograph. Many R1 Riedel shears formed within the gouge layer. Normal Stress : 30 MPa, shear velocity : 0.016–16 mm/s, sample type : black clayey fault gouge from Hanaore fault.

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Rotary-Shear High-Velocity Frictional Testing Machine

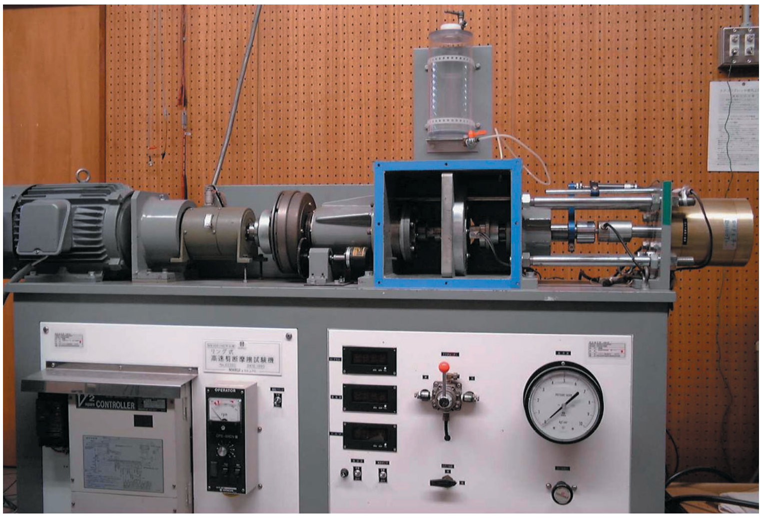


Fig. 4 Photograph of the rotary-shear high-velocity frictional testing machine.

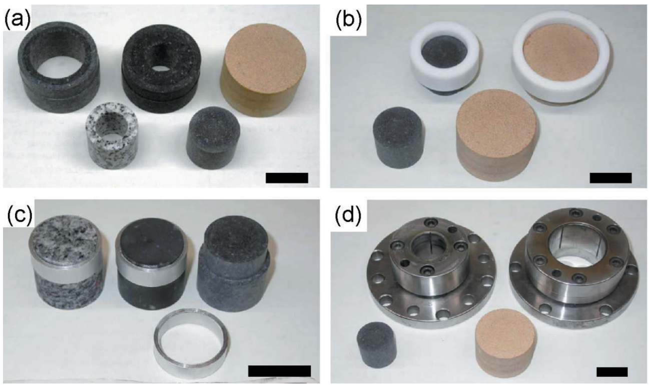


Fig. 5 Different specimen configurations for high-velocity friction experiments ; (a) solid and hollow specimens of different sizes, (b) solid specimens with teflon rings for high-velocity gouge experiments, (c) solid specimens with Aluminum rings for high normal-stress experiments (>2 MPa), and (d) holders of specimens with 25 mm diameter (left) and 40 mm diameter (right). Scale bars are 20 mm.

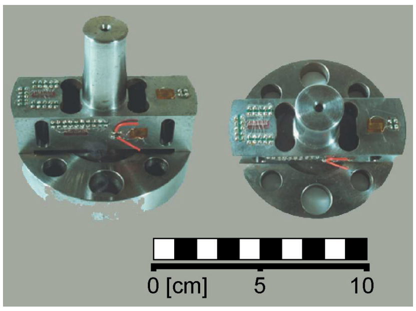


Fig. 6 A torque-axial force gauge used in the right chamber of the blue frame in Fig. 4. Strain gauges are bonded in bridge configurations on thin walls next to four elongated holes sensing deformation due to torque and axial force.

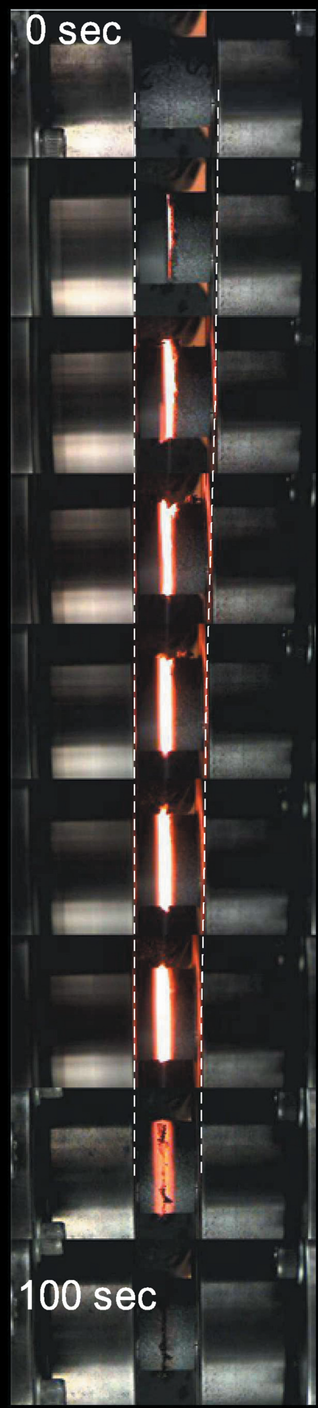


Fig. 7 A series of photographs from a frictional melting experiment on gabbro.

Reference

Shimamoto, T., Tsutsumi, A., Hirose, T., Aizawa, Y., Sone, H., Uehara, S., Tanikawa, W., Noda, H. and Mizoguchi, K., 2006, Friction, deformation and fluid-flow apparatuses at Kyoto University. Japanese Jour. Struct. Geol., no. 49, 49–71 (in Japanese with English abstract).

High-Temperature High-Pressure Deformation and Fluid-Flow Gas Apparatus

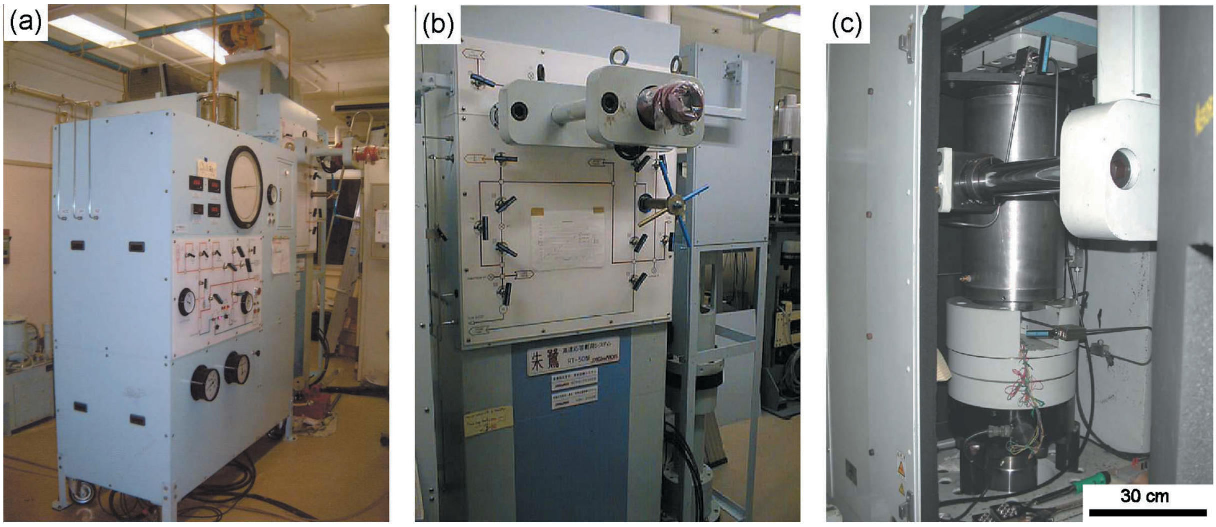


Fig. 8 Photographs of a high-pressure and high-temperature deformation and fluid flow gas apparatus. (a) A safety chamber containing a pressure-generating system. (b) A quick-operating servo-controlled actuator (up to 500 kN in force with up to 200 Hz frequency), and a serve-controlled actuator for controlling either pore pressure or confining pressure in a tower to the right. (c) A pressure vessel sitting on the serve-controlled actuator for axial loading.

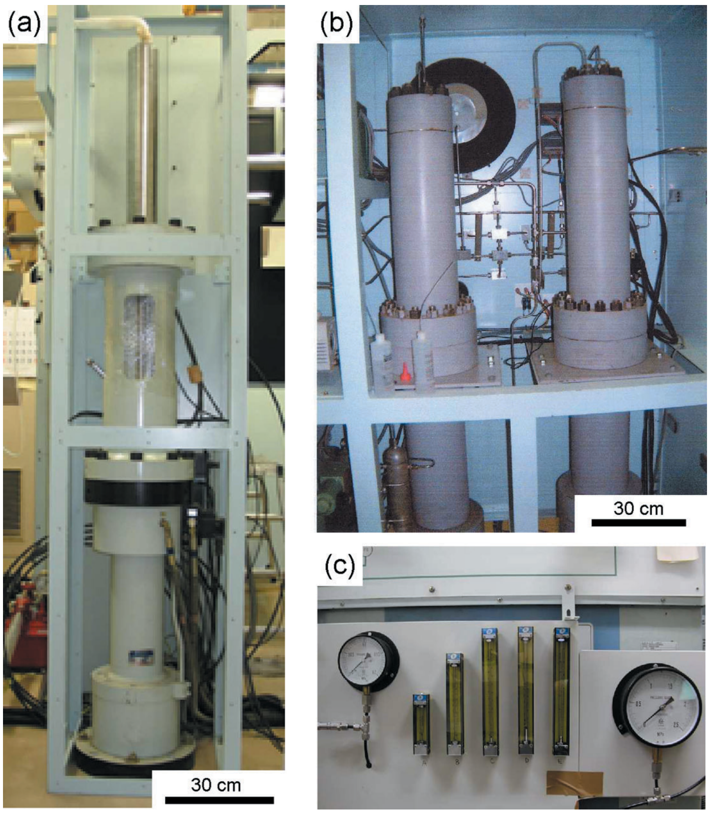


Fig. 9 (a) The serve-controlled actuator for pore and confining pressures. (b) A pressure generator (right ; to 140 MPa) and an intensifier (left ; up to 330 MPa). (c) Float-type flow meters covering ranges of 0.25 ml/min to 30 l/min for permeability measurements.

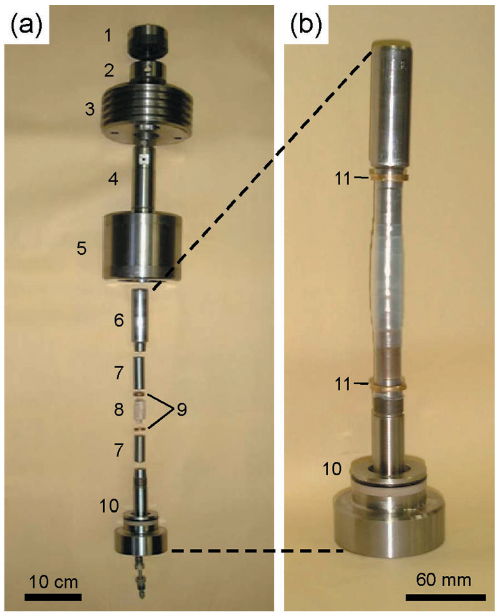
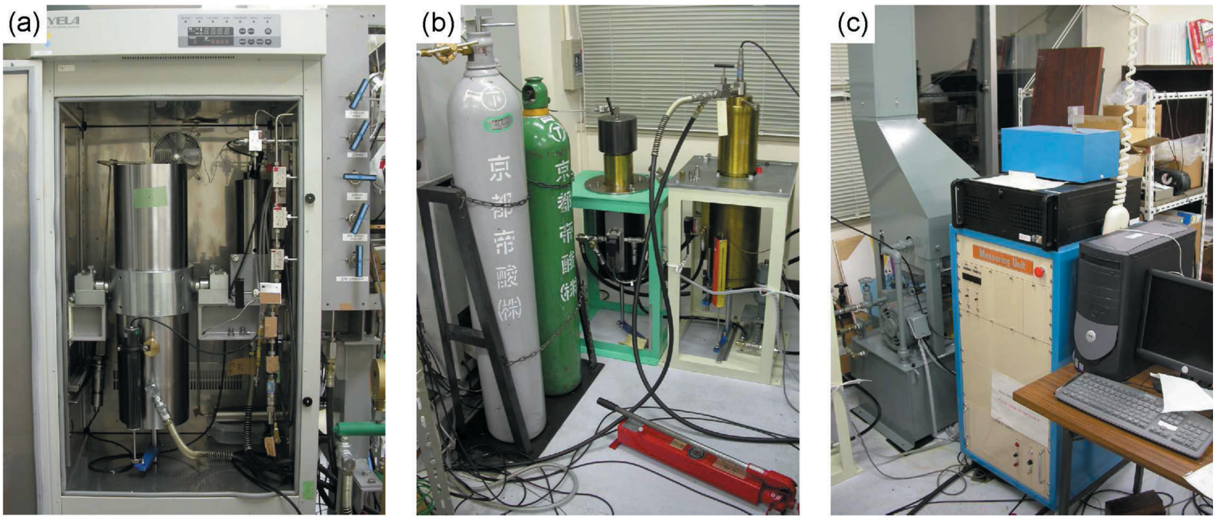


Fig. 10 (a) Loading column consisting of specimen assembly (bottom) and a chamber compensating force due to confining pressure (top), and (b) the specimen assembly with polyolefin tubes. 1 : Spacer with feed-through for thermocouples, 2 : guide ring for a pore pressure (Pp) line, 3 : nut, 4 : piston with a Pp hole, 5 : compensation chamber, 6 : piston with a Pp hole, 7 : spacer with a Pp hole, 8 : sample, 9 : porous spacer, 10 : gland with a Pp hole and seals, and11 : taper rings for sealing jackets.

Intra-Vessel Deformation and Fluid-Flow Apparatus



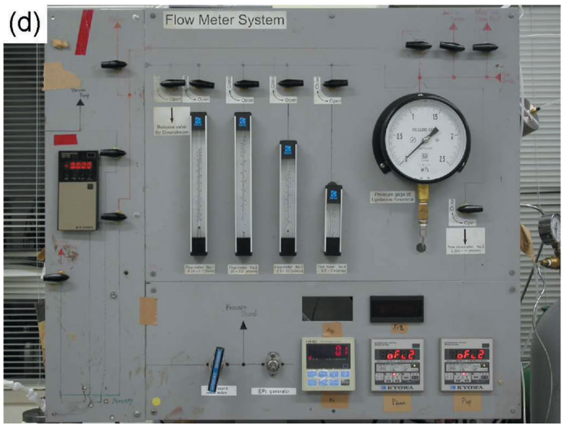


Fig. 11 Photographs of an intra-vessel deformation and fluid-flow apparatus. (a) Apparatus and a mini-pressure intensifier (back-side on the right) set in a temperature-controlled chamber. (b) From left to right : nitrogen gas bottle (gray), carbon-dioxide bottle (green), pressure intensifier for servo-controlled axial loading, pressure intensifier for servo-controlled confining pressure, and a hand pump for manual pressure generation (red). (c) From far left to right : ventilation tower taking heat away from a servo-pump, and a servo-control unit with an operating computer. (d) Confining-pressure and pore-pressure operating panel, with float-type flow meters in the center covering ranges between 0.25–5000 ml/min for permeability measurements.

Fig. 12 A mini-pressure vessel (pycnometer-system) used for grain volume measurements. Three volume-calibrated spacers (near sides) are used to adjust the internal volume of the pycnometer, so that the maximum resolution is obtained for each measurement. Four bolts hold the lid connected to the pore pressure line to the vessel.

Fig. 13 (a) Components for specimen assembly, and (b) a typical sample configuration for permeability measurements. 1 : Sample, 2 : spacers, 3 : porous spacers, 4 : porous spacer for square samples, 5 : end spacers for porosity measurements, 6 : circle-square converting spacer, 7 : lower piston, 8 : polyolefin jacket, 9 : upper piston, 10 : pore-pressure-line connector, and 11 : nut supporting confining pressure and axial load.