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放射光Ｘ線とＡＥ６－６システムを用いた反応、流動、剪断不安定のその場同時観察手法の開発
In-situ observations of reaction, plastic flow, and shear instability by using synchrotron X-rays and the AE 6-6 system

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Intermediate-depth earthquakes are seismic activities in Wadati-Benioff zone at depths from 60 km to 300 km, where subducting plates deform plastically rather than brittle failure. Dehydration embrittlement of serpentinite (Raleigh and Paterson, 1965) is an important mechanism for the seismicity at lower pressures than ~2.2 GPa. To understand the fault mechanisms above this pressure, there have been some acoustic emission (AE) measurements with multi-anvil apparatus to monitor shear instabilities (e.g., Dobson et al., 2002; Jung et al., 2006 and 2009; Gasc et al., 2011). However in these studies, the relationships among dehydration, plastic flow and shear instability were unclear because quantitative flow and reaction kinetics data could not be obtained simultaneously. To conduct quantitative measurements of these processes, we developed a new in-situ observation system combined with synchrotron monochromatic X-ray and AE 6-6 system (multiple acoustic emission measurement for multi-anvil 6-6 type system) using Deformation-DIA (D-DIA) apparatus. In this study, we report results of some preliminary experiments using this system.

In this system, deformation experiments with constant strain rate mode are conducted at high pressure and high temperature using a 1500-ton uniaxial press (SPEED-Mk.ii) with a D-DIA type guide block installed at BL04B1, SPring-8 (Katsura et al., 2004; Kawazoe et al., 2011). 50 keV monochromatic X-ray are used to measure two-dimensional X-ray diffraction (2D-XRD) patterns and X-ray radiography images of sample. Reaction kinetics can be monitored by time-resolved 2D-XRD measurements. Stress and strain of sample are determined by d-value variations with azimuth angle from 2D-XRD patterns and by distance of strain markers from X-ray radiography image, respectively. We developed MA 6-6 type system (Nishiyama et al., 2008) to monitor shear instabilities by AEs from maximum six piezoelectric devices positioned between first and second stage anvils. The multiple AE measurements enable us to determine characters of the seismic event such as origin time and location of seismic source, and focal mechanism.

In the present study, two kinds of experiments were performed at high pressure and room temperature using the new AE 6-6 system, where an X-ray transparent cBN anvil was used as one of the second-stage anvils in down-stream side to collect 2D-XRD patterns. One is cold compression of quartz beads (grain size ~0.1 mm). Another is in-situ X-ray observation of constant strain rate deformation of polycrystalline antigorite cylinder cored from high-temperature serpetinite (Eigami, Nagasaki, Japan). A total of four PZT transducers were used to monitor AEs arising from the sample. AE waveforms were recorded using a four-channel 8-bit digital oscilloscope, which has a resolution of 1000-10000 point at a sampling rate of 50MHz. The AE recording was triggered when the amplitude of the signal was higher than a threshold level.

In the quartz beads experiment, the sample was pressed to 20 ton (~2 GPa) with monitoring AE by three AE detectors (East, West, and Bottom anvils). Many AEs were recorded during cold compression. The AE frequencies became maximum at the load of about 7 ton, and no AEs were recorded at more than 12 ton. These data suggest that the quartz beads were compacted to almost zero porosity by reaching 12 ton. Differences in arrival time from two detectors (E and W) indicate that most sources of those events were located within the sample.

Three deformation experiments of polycrystalline antigorite were conducted with a strain rate of about $3 * 10^{-5}$ s^{-1} at pressures of ~0.1-3 GPa. We observed that the constant flow stress of ~2 GPa reached at the sample strain of more than 5%. AE events were not recorded during the deformation stage. These results suggest that mechanical behavior of antigorite is plastic flow under this condition, which is consistent with previous studies (e.g., Escartin et al., 1997).

Keywords: acoustic emission, stress and strain, deformation-DIA, in situ X-ray observation, high pressure, antigorite