Image analysis on experimentally sheared granitic rocks: Shear zone development at brittle-ductile transition zone

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Despite numerous experimental studies focusing on crustal rheology within the transition from brittle to semi-brittle (e.g., Bos and Spiers, 2002; Pec et al., 2012) and fully ductile (Holyoke and Tullis, 2006) regimes, associated with microstructural development including strain partitioning remain poorly understood. We report the results of Griggs-type solid medium deformation experiments using gneiss (Gneiss Minuti, the same material used in Holyoke and Tullis, 2006) composed of 20 ~ 30% quartz, 40 ~ 50% plagioclase, and 20 ~ 40% micas. Samples of ~1.2 mm in thickness are cut into halves in a direction normal to shear direction, after which a strip of Ni is inserted to serve as an in-situ strain marker. At temperature of 800°C, strain rate of 2×10^{-5} s^{-1}, and confining pressure of 1.5 GPa, the peak strength measured 700 ~ 800 MPa at bulk shear strains ($\gamma \approx 1.0$). The strength monotonously decreased towards 200 MPa, however steady-state flow was not achieved even for bulk $\gamma \approx 7.2$. Electron dispersive spectroscopy in a scanning electron microscope (SEM-EDS) revealed that the sample deformed to bulk $\gamma \approx 7.2$ developed several narrow shear bands. The shear bands are oriented oblique (20 ~ 30°) to the shear direction. Using the in-situ strain marker, the strain away from the shear zone is measured to be γ ~ 1.1, while the most of deformation is localized as slip along the shear bands. We analyzed back scattered electron (BSE) images of starting material and sheared samples (γ = 1.4 ~ 7.2) with the software "ImageJ" to analyze their microstructures. Analysis on quartz and biotite revealed the aspect ratio of grains increases, while the cross-sectional area of grains decreases with increase in shear strain. Most of grains are rotated toward shear direction, and the proportion of grains oriented to S-plane increases at high strain. Those microstructural characteristics indicate that grain size reduction and grain rotation progress in the host rock (outside of shear zone) by γ ~ 1.1, then the localized slip along the shear zone becomes dominant at higher strain. In the presentation, we will also report the deformation mechanism of each minerals as a function of strain.

Keywords: Brittle-ductile transition zone, Griggs-type apparatus, Granitic rocks, Shear zone, Image analysis