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Strength evolution below the seismogenic zone: Insights from microstructure and quartz lattice-preferred orientations in mylonites of the Median Tectonic Line, SW Japan

Field-based studies of exhumed long-lived fault zones allow the distribution of fault rocks to be determined in 3 dimensions. These data can be used to constrain the evolution of fault strength and strain distribution during the lifetime of a fault zone. This study aims to constrain the mechanisms of weakening below the seismogenic zone, where rocks deform by dominantly ductile deformation mechanisms. Fieldwork was conducted on the northern side (hanging wall) of the Median Tectonic Line (MTL) in Mie Prefecture, SW Japan, where multiple phases of ductile and brittle deformation are preserved within Ryoke mylonites. The primary goals of this project are to: (1) describe the architecture of ductile and brittle fault rocks surrounding the MTL; and (2) determine whether weakening of the mid-crust occurred, immediately below the brittle–ductile transition zone.

Figure 1. Outcrop of the MTL in Mie Prefecture.

The MTL is the longest onshore fault in Japan and, in the study area, juxtaposes the Sambagawa schist to the south against the Ryoke mylonite to the north, across a steeply north-dipping fault zone (Fig. 1). Mapping results show that cataclasites are constrained to within ~100 m of the MTL, which is represented by a narrow zone of black fault gauge. Further from the fault, a broad zone of protomylonite is observed up to ~1 km from the MTL. Microscopic observations reveal that cataclasites preserve clasts of ultramylonite, suggesting that, prior to brittle deformation, the fault zone consisted of a core of fine-grained ultramylonite, with protomylonite occurring further from the fault.

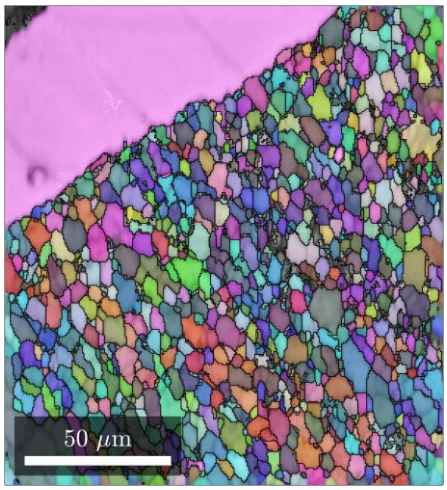

Figure 2. EBSD image of fine-grained recrystallized quartz in an ultramylonite sample.

EBSD analysis, performed at Hokkaido University, reveals a systematic variation in quartz lattice preferred orientation (LPO) with distance from the MTL. At large distances, protomylonite samples yield y-maxima LPO, whereas closer to the MTL, the degree of recrystallisation increases and R-maxima, Z-maxima, and girdle fabrics are observed. Samples from adjacent to the MTL are

extremely fine grained ultramylonites (Fig. 2) that can be divided into two groups. The first group yield R-maxima and type-1 cross girdle LPOs, whereas the second group yield random fabrics.

We interpret these results as reflecting overprinting of deformation during decreasing temperature. Samples with strong LPOs likely deformed by dislocation creep, and Y-maxima fabrics were produced under higher temperatures than R- and Z-maxima patterns. We interpret the lack of LPO in some ultramylonite samples to result from a deformation mechanism transition to pressure solution creep. This transition was likely associated with pronounced weakening and an increase to near-seismic strain rates. The spatial distribution of random-fabric ultramylonites is currently poorly constrained, and therefore a goal for future research is to map their distribution to infer whether they represent a temporal change in deformation mechanism, or whether the transition was limited to locations where fluid penetrated the fault zone. The source of the fluid is currently unconstrained; a stable isotope study could differentiate between magmatic, metamorphic, or meteoric sources. Figure 3 shows the inferred architecture of the hanging wall of the MTL, reflecting progressive overprinting and strain localisation during uplift of the fault zone.

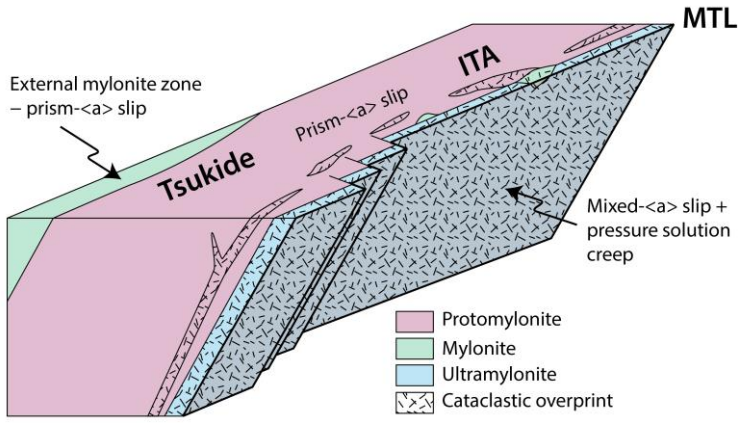

Figure 3. The inferred architecture of the MTL hanging wall in the study area.

Presentations

Czertowicz, T., Takeshita, T., Shigematsu, N., Fujimoto, K. & Arai, S., Heterogenous quartz LPO development and strain partitioning in Median Tectonic Line mylonites, 2017 JPGU-AGU Joint Meeting, Chiba, Japan.

Czertowicz, T., Takeshita, T., Shigematsu, N., Fujimoto, K., Arai, S. & Toy, V., Heterogenous quartz LPO development and strain partitioning in Median Tectonic Line mylonites, 2017 Annual Meeting of The Geological Society of Japan, Matsuyama, Japan.

Czertowicz, T., Takeshita, T., Shigematsu, N., Fujimoto, K., Arai, S. & Toy, V., Heterogenous quartz LPO development and strain partitioning in Median Tectonic Line mylonites, 2017 Crustal Dynamics Annual Meeting, Yonago, Japan.