Estimation of the stress state in deeply eroded fault zones based on the microstructure of fault rocks

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It has been proposed that the displacement by plastic flow occurred only in restricted regions with a length of approximately 6 km along the HFZ when the present exhumed level was locate in the P-T conditions were those of the brittle-plastic transition in the Hatagawa Fault Zone (HFZ) in NE Japan (Shigematsu et al., 2003).

To assess the first question, we have studied the Median Tectonic Line (MTL) in the Kii peninsula SW Japan. To assess the second question, we have used a relation between the flow stress and the recrystallized grain size during dynamic recrystallization of quartz (e.g., Twiss, 1977). The microstructure of quartz can also use to estimate the deformation condition, because it changes depending on the temperature and strain rate during the deformation.

For the samples from the MTL, polished thin sections were prepared and etched with a saturated ammonium bifluoride solution to reveal grain boundaries. Then etched boundaries were traced by checking their misorientation using optical transmission microscopy and analyzed the grain sizes and the grain shapes using an image analysis software NIH Image 1.6.

The grain size distributions for all measured samples from MTL show log-normal pattern with standard deviation of approximately 0.3 of logarithm of the grain size. Based on the grain size distribution the samples can be divided into 2 groups, group 1 with logarithm of geometric means from 0.5 to 0.6, and group 2 with logarithm of geometric means larger than 0.8. The quartz microstructure of group 1 corresponds to regime 2 dislocation creep of quartz (Hirth and Tullis, 1992), and the quartz microstructure of group 2 corresponds to regime 3 dislocation creep of quartz (Hirth and Tullis, 1992), suggesting that the samples of group 1 were deformed under lower temperature or faster strain-rate than those of group 2. The outcrop extent of samples belonging to group 1 is limited and has a length of approximately 13 km along the MTL and width of 50-100 m perpendicular to the MTL.

A two-feldspar thermometer (Whitney and Stormer, 1977) yields from 309 to 324 degree in Celsius for one sample belonging to group 1, and from 363 to 393 degree in Celsius for one sample belonging to group 2 with assuming that the measured compositions of feldspars were in equilibrium at the pressure of 300 MPa. The c-axes data after Shimada et al., (1998) also suggest that the samples belonging to group 1 were deformed under lower temperatures than those of the samples belonging to group 2. These suiggest that the displacement by plastic flow occurred only in restricted regions when the present exhumed level was locate in the P-T conditions correspond to those of the brittle-plastic transition in the MTL.

The quartz microstructures of the regions of restricted plastic displacement indicate a differential stress of approximately 160 MPa for the HFZ, and a differential stress of approximately 200 MPa for the MTL based on the relation between the flow stress and the recrystallized grain size (Stipp et al., 2006). It is likely that the restricted plastic displacement regions in the depth range where the P-T conditions were those of the brittle-plastic transition supported especially higher differential stresses the within fault zones compare to other part of the fault zones.