Experimentally determined strength profile of the Median Tectonic Line fault zone

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Strength of crustal-scale fault can determine the strength of the crust. Strength experiments on one typical rock (such as granite) under variable temperature and pressure conditions suggest a simple model of the fault strength profile, so-called Christmas tree. However, crustal-scale faults in nature usually have complicated architectures, implying that the fault strength profile may "not be simple". Here, we tried to establish a new strength profile regarding the deformation history of the Median Tectonic Line (MTL) fault zone as an example of the crustal-scale faults, using a frictional experiment technique.
Previous study by Shigematsu et al., (2017) revealed that the MTL fault zone at Awano-Tabiki outcrop exposed in the eastern Kii Peninsula, Japan, had suffered four stages of faulting under different depths in brittle regime. The newest deformation at the Awano-Tabiki outcrop (stage-4) is characterized by a localized zone with a normal faulting sense of slip within ~ 1 cm in thickness (gouges-B and F). Those gouges are rich in smectite, indicating that the depth to activate the MTL fault at this stage would be relatively shallow at which the temperature is ~ 100 deg.C. On the other hand, the oldest deformation, stage-1, is widely distributed with a dextral sense of slip. The gouges at stage-1 (e.g., gouge-D and gouge-I) are rich in whiltemica and illite and they show an evidence of plastic deformation, indicating that corresponding temperature could be ~250 deg.C. Additionally, for intermediate stages (dextral slip for stages-2 (gouge-E1, -G and -H) and sinistral slip for stage-3 (gouge-E2), respectively), the temperature could be also intermediate and estimated at ~150 deg.C by measuring smectite contents of illite-smectite mixed layer in the gouges (Kameda et al., in prep.). After determining the temperature condition for each stage, then we carried out the friction experiments, using a gas-medium, high-pressure, high-temperature triaxial apparatus at GSJ, AIST, Japan. We used finer gouges after sieving with 75-mm-mesh as experimentally gouges. Axial loading velocity was constant at 1 mm/sec. We measured steady-state shear stress and effective normal stress to determine a friction coefficient for each gouge with changing effective pressure.
We obtained constant friction coefficient for each gouge for earlier stages (stage-1 ~ stage -3), meaning that we obtained a linear relationship between the shear stress and the effective normal stress (σ_n-P_p), summarizing as ~0.5 at gouges for the stage-1, ~0.4 at gouges for the stages-2 and -3. On the other hand, we obtained interesting results on the shear strength for smectite rich gouges (gouge-B and gouge-F) at te stage-4. Values of friction coefficient, showing a dependence of the smectite content, are 0.30 for gouge-B and 0.18 for gouge-F. However, the friction coefficient for both gouges became decreasing significantly towards < 0.1 at σ_n-P_p < 15 MPa. Such low friction coefficients for the gouges at stage-4 might be caused by higher water swelling ability of smectite at lower normal effective pressure.
We could draw the strength profile of the MTL fault zone with assumed thermal gradient. The strength in brittle regime for the MTL fault zone shows much lower strength than that from general model based on the Byerlee's law. For a case with an approximation 20 deg.C/km in the thermal gradient, MTL fault becomes very weak at the depth shallower than 4 km, caused by weakness of the smectite rich gouges.

Therefore, we implicated that the MTL fault at shallow depth cannot support the stress. Our result of the experimentally determined strength profile will evoke a discussion on the depth at which the crustal-scale fault begins to support tectonic and/or regional stress.

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