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Fault geometry affecting spatial distribution and evolution of fracture zones

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There are many major, mature faults in Japan which have been in the plate boundary zone for more than 200 Ma. Such mature faults mostly have heterogeneous structures as a result of interactions between multiple faults. In this presentation, heterogeneity of the spatial distribution and characteristics of fracture zones in mature faults is discussed based on detailed and broadscale geological mapping, including the case study in the area around the Atotsugawa Fault, a long-lived active fault in central Japan (Niwa et al., 2008, J. Geol. Soc. Jpn.; Niwa et al., 2011, Eng. Geol.).

Specifically in fault tips and steps, models of pervasive development of fracture zones are proposed (Sibson, 1986, PAGEOPH). First, the occurrence of a compressional step was recognized by means of aerial photograph interpretation and regional distribution of fracture zones. Detailed geological observation suggests that shear planes with NNE-SSW and NW-SE strikes, high-angle oblique to the trend of the Atotsugawa Fault, are characteristically developed in the step. The shear planes with NNE-SSW and NW-SE strikes can be a part of the composite planar fabric such as R_2 surfaces (Davis et al., 1999, JSG) or deformation band (Okubo and Schultz, 2006, Geol. Soc. Amer. Bull.), which are dominantly developed within compressional steps. Fracture zones in the step are characterized by high densities of fractures and intense brecciation of fragments and minerals, but displacements and rotations of fragments are poorly developed. These characteristics are consistent with the previously proposed conceptional models of fracture zone development in steps (e.g. Sibson, 1986, PAGEOPH).

In addition, more broadscale geological mapping was carried out in the western part of the Atotsugawa Fault to elucidate the spatial distribution of the fracture zones. Within 500 m of the fault trace, the number of exposed fracture zones increases sharply and most fracture zones greater than 2 m width are concentrated. The number and width of the exposed fracture zones display almost the same pattern between a compressional step and a long strand, in contrast with several concepts that fracture zones are pervasively developed around a compressional step. Based on rock features and deformation fabrics at meso- and microscopic scales, once fracture zones had formed, epigenetic deformation was concentrated in the older fracture zones.

Fracture zones less than 2 m width are sparsely but widely distributed in the study area. Most of them are formed by fracturing and weathering accompanied by displacement along joints, schistosities or lithological boundaries, and lack continuity at geological map scale. From a viewpoint of the microscopic observation, they display brittle fracturing characterized by the development of network-patterned cracks and simple fragmentation without ductile shearing, indicating deformation near the surface, under low confining pressure. Various origins of them are proposed: e.g., subsidiary displacement accompanied activities on the surrounding major faults; dilatation due to the decrease in the confining pressure near the land surface; or the displacement of the weak planar structures caused by non-tectonic movement such as gravitational sliding, etc. Based on the comparison with epicenter distribution in the study area, some of them possibly indicate an evidence of ancient shallow earthquakes at a point distant from the fault trace.