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Development of intrafolial folds at deeper extension of seismogenic fault

Hideaki Kaneko[1*], Jun Muto[1], Hiroyuki Nagahama[1]

[1]Inst. Geol. Paleontol., Tohoku Univ.

It has been considered that the main ruptures of large inland earthquakes start in the brittle-plastic transition zone, as their hypocenters are generally located in the deepest region of the seismogenic zone. This suggests the significance of plastic flow in the brittle-plastic transition zone for the generation of large inland earthquakes. The Hatagawa Fault Zone (HFZ) in the north-eastern Japan consists of various kinds of fault rocks such as cataclasite, pseudotachylyte and mylonite, indicating the HFZ were formed under brittle-plastic transition zone.

We found intrafolial folds within the granitic ultramylonite in the HFZ. Intrafolial folds in the ultramylonite are different from other intrafolial folds grew in sedimentary or metamorphic rocks, because the observed intrafolial folds are developed in initially non-foliated granitic rocks. Fukudome (1986) proposed that intrafolial folds were developed by Kelvin-Helmholtz instability due to strain rate differences across the interface between foliations. Such plastic instability occurs at deeper extension of seismogenic fault may cause significant stress accumulation to upper seismogenic fault locked during interseismic period.

We analyze the quartz LPO and grain size, using SEM-EBSD analysis, and estimate the deformation condition. We explain the formation mechanism of the intrafolial folds that causes stress concentration in seismogenic faults.

Intrafolial folds are observed on the plane normal to the foliation and parallel to the lineation (XZ thin sections) of the ultramylonite. The folds consist of monominerallic recrystallized quartz aggregates. The folds show asymmetric profiles and wavelength are below 1cm order. The wavelength / thickness ratio is 1.2 - 4.5. The folded quartz aggregates have LPO, indicating that quartz aggregates were deformed by dislocation creep. On the other hand, matrix consists of fine-grained mixtures of quartz, feldspar and mica without significant LPO, indicating that matrix was deformed by diffusion creep.

EBSD analysis clarified that the LPO pattern of quartz in the folded part is parallel to Y of the strain ellipsoid (Ymax). The average grain size measured by EBSD orientation maps is in the range of 6.32 +/- 3.86 - 14.27 +/- 6.67 micrometers. Stipp and Tullis (2003)'s piezometer predicts differential stresses of 81 - 154 MPa. Presence of syndeformational hornblende and Ymax LPO indicate that the ultramylonite was formed at a temperature of 450 - 500C. Strain rates of folded quartz layer are estimated on the order of 10^{-12} and 10^{-10}/s, using Hirth et al. (2001)'s quartzite flow law. The strain rate folded quartz layer is 5 orders faster than current east-west contraction strain rate estimated from GPS observations in the NE Japan (10^{-15}/s: Miura et al., 2004). Because the intrafolial folds are developed by the difference in strain rates (Fukudome, 1986), the fine-grained matrix might be deformed at higher strain rates than the competent quartz layers. This implies that the strain concentration in deeper extension of seismogenic faults results in stress accumulation to upper faults locked during interseismic period.

Keywords: intrafolial fold, plastic instability, ultramylonite, Hatagawa Fault Zone, inland earthquake