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Verification of unstable frictional behavior for smectite as elevated temperature

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Introduction: Subduction thrust faults are known to generate earthquakes over a limited depth range (Hyndman et al., 1993; Shimamoto et al., 1993; Tichelaar and Ruff, 1993). The seaward up-dip limit of seismicity is important for tsunami generation, and the total seismogenic width can be related to the maximum magnitude of great earthquakes along the interface of a subducting plate. Therefore, an understanding of the factors controls the updip and downdip limits of the seismogenic zone is important for seismic hazard assessment. There are various factors that possibly control the updip limit of the seismogenic zone. We focus on transition from unsolidated to solidated sediments because of dehydration of clays, which leads to coincidence with transition from aseismic frictional behavior to seismic frictional behavior. Along plate boundary subduction thrusts, the transformation of smectite to illite within fault gouge at temperatures around 100~200C is one of the key mineralogical changes thought to control the updip limit of seismicity. Clay in the fault gouge has been suggested as an explanation for the general lack of earthquakes in the upper 5-10 km of continental fault zones (Marone and Scholz, 1988). Frictional coefficient and velocity dependence is depending on humidity (Ikari et al., 2007). However, previous works were limited at room temperature although the updip limit of seismogenic zone is thermally controlled that occurs at temperature around 150C. Moreover, there is no verification for the ef-fect on dehydration under rising temperature. Therefore, in this study, we determined the effect of tempera-ture of frictional properties of smectite and discuss whether the dehydration for clay minerals as elevated temperature accounts for the updip limit of seismogenic zone along subduction thrust.

Experimental methods: Frictional experiments were performed using a biaxial frictional testing ma-chine at Hiroshima University. The powder materials of clays were placed on the simulated fault surface and two side blocks were placed together to produce a double-direct shear configuration. Normal stress was ap-plied via a hydraulic ram on the side block with 60 MPa, and then, shear stress was applied by advancing the central block downward at a constant velocity. The sample assembly was heated by an external furnace up to 200oC that is monitored by thermocouples located close to the central block. Mechanical data were recorded continuously with a sampling rate of 10 Hz and the frictional coefficient was calculated from the shear force divided by the normal force assuming zero cohesion.

Results and Discussion: Our experiments showed three phase change as elevated temperature. 1. De-creasing frictional strength, 2. Increasing frictional strength, and 3. Appearance of persistent stick-slip behavior. At phase 1, expansion of interlayer water due to rising temperature may open interlayer of clays, weakening adhesion. At phase 2, dehydration leads to healing adhesion and frictional strength. At phase 3, we observed persistent stick-slip behavior. This frictional behavior implies to have a potential of velocity weakening behavior, and temperature has significant influence on frictional behavior of clay minerals.

Keywords: frictional experiments under rising temperature, the updip limit along subducting plate, smectite-illite transformation, frictional property for clays, the effect of temperature, the effect of interlayer water