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A new fault-thermometer based on vitrinite maturation by coseismic frictional heating

Manami Kitamura (1), Hideki Mukoyoshi (2), Takehiro Hirose (1,3)

(1) Depart. of Earth and Planetary Systems Science, Graduate School of Science, Hiroshima University, Hiroshima, Japan (kitamuram@hiroshima-u.ac.jp), (2) Faculty of Education and Integrated Arts and Sciences, Waseda University, Tokyo, Japan (h.mukoyoshi@kurenai.waseda.jp), (3) Kochi Institute for Core Sample Research, Japan Agency for Marine–Earth Science and Technology, Kochi, Japan (hiroset@jamstec.go.jp)

To detect frictional heating effects along faults provides key insight into the dynamics of earthquakes and faulting [e.g., Brodsky et al., 2010]. Evidence of substantial frictional heating along a fault is also a reliable indicator determining whether a fault has slipped at high velocity in the past, which is crucial for assessing earthquake and tsunami hazard. The reflectance (R) measurement of vitrinite, one of the primary components of coals, has been considered a possible thermometer of fault zones, especially in accretionary wedges where vitrinite fragments are common [e.g., Sakaguchi et al., 2011]. Under normal burial conditions, vitrinite reflectance (R) increases by irreversible maturation reaction as temperature is elevated and thus sensitively records the maximum temperature to which the vitrinite is subjected. However, the commonly used kinetic models of vitrinite maturation [e.g., Sweeney and Burnham, 1990] may not yield accurate estimates of the peak temperature in a fault zone resulting from fast frictional heating rates [Kitamura et al., 2012; Fulton and Harris, 2012]. Thus, we performed high-velocity friction experiments aimed at revealing coal maturation by frictional heat generated at slip velocities representative of natural earthquakes up to 1.3 m/s. Our experimental results indicate that coal can mature in typical earthquake rise time (e.g., $\sim$10 seconds) and R increases exponentially with increasing peak temperature [Kitamura et al., 2012]. In addition to these results, we will present the effects of water, atmosphere condition (oxygenic/anoxic), and initial R value and grain size of coal on coal maturation during coseismic faulting, and eventually propose a new fault-thermometer based on coal maturation by rapid frictional heating.

Using the correlation between R and temperature rises we estimate the dynamic friction during coseismic faulting in the shallow portions of a megasplay fault in the Nankai trough. The fault zone has a $\sim$20 mm thickness of shear localized zone. An average R of vitrinite grains in host rocks is $\sim$0.24% which corresponds to a maximum burial temperature of about $<20^oC$ using the geothermometer by Sweeney and Burnham (1990). In contrast, R values in the localized zone were as high as 0.57%, and some spots with R of $>$0.80%. Although Sakaguchi et al. (2011) reported $\sim 390^oC$ using a kinetic model of Sweeney and Burnham (1990), the high R corresponds to $\sim 150^oC$ using our new thermometer. This temperature anomaly can be explained by dynamic shear stress of 0.53 MPa (dynamic friction of $\sim$0.18), assuming fault displacement of 15 m at the current depth conditions. These results are consistent with the estimate of dynamic friction from temperature measurement across the fault zone after the 1999 Chi-Chi, Taiwan earthquake [e.g., Kano et al., 2006] and with the result of high-velocity friction experiments [e.g., Di Toro et al., 2011]. The fault-thermometer based on vitrinite maturation can be a possible tool to estimate of fault parameters from natural fault zones.