Diagenesis- and earthquake-driven transformations of carbonaceous materials and their implication for frictional strength and earthquake rupture dynamics in carbon-bearing plate-subduction faults

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Various physicochemical reactions on fault-forming materials, such as illitization of smectite and crystallization of amorphous silica, have been suggested as possible controls on frictional strength of rocks and thus on earthquake dynamics in plate-subduction zones. Carbonaceous material is one of the universal materials that exist in and around both active plate-boundary and inland faults, and previous studies suggest that transformation of carbonaceous material may affect its frictional strength during frictional slip. However, there is currently no systematic study attempting to investigate the relationship of maturity of carbonaceous material to its frictional strength, and thus how diagenesis- and earthquake-driven transformations of carbonaceous material can affect frictional strength and rupture dynamics of carbon-bearing faults, still remains unknown. We conducted high-velocity friction experiments together with elemental analysis, transmission electron microscope observation, X-ray diffraction analysis, and infrared and Raman spectroscopies, on four grades of carbonaceous material in the form of lignite, bituminous coal, anthracite, and graphite. Our experimental results clearly show that an increase in maturity and crystallinity of carbonaceous material results in a decrease in the peak friction coefficient at the initial stage of slip, from 0.5 (lignite) to 0.2 (graphite). We also infer from our results of spectroscopic analyses that low- (lignite and bituminous coal) and intermediate-grade carbonaceous material (anthracite) increases its maturity by high-velocity frictional slip, but friction applied to high-grade carbonaceous material (graphite) induces an opposite trend. Furthermore, by considering systematic decrease and increase in fracture energy and stress ratio with increasing maturity of carbonaceous material, both of which strongly affect rupture propagation process during earthquake, both diagenesis- and earthquake-driven transformations of carbonaceous material can strongly affect the frictional strength of carbon-bearing faults, potentially affecting the depth-dependences of not only frictional strength but also rupture dynamics on plate-subduction faults.

Keywords: Earthquake, Carbonaceous material, Thermal maturation, Friction coefficient, Plate subduction zone, Rupture dynamics

