Detection of frictional heating on faults using Raman spectra of carbonaceous material

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The detection of frictional heating on faults is a key to assessing coseismic shear stress and frictional work during earthquakes. Raman spectra of carbonaceous material (RSCM) have been widely used as a geothermometer on sedimentary and metamorphic rocks. We examined whether RSCM can be useful to detect increased temperatures associated with frictional heating on faults. The studied fault rocks are a few millimeters-thick pseudotachylyte derived from chert, 10 cm-thick cataclasite marked by fragments of chert in the carbonaceous mudstone matrix, and ~1 mm-thick pseudotachylyte derived from argillaceous rock, which are distributed in the exhumed accretionary complexes in the Mino-Tamba and Shimanto Belts, Japan. The results indicate that the intensity ratio of D1 and D2 Raman bands (I_{D1}/I_{D2}) markedly increase in pseudotachylytes, while increased I_{D1}/I_{D2} is absent in the cataclasite. The increased I_{D1}/I_{D2} values in pseudotachylytes are considered to represent coal maturation associated with increased heating along the localized slipping zone of less than a few millimeters thick. The absence of increased I_{D1}/I_{D2} values in the cataclasite may reflect the restricted temperature rise, which is consistent with distributed shearing along the 10 cm-thick slipping zone. The I_{D1}/I_{D2} values are also increased in the chert within ~2 mm from the upper boundary of the pseudotachylyte and drop to the background level >2 mm away from the upper boundary. In contrast, the increased I_{D1}/I_{D2} values are not observed in the chert below the pseudotachylyte and the argillaceous rocks above and below the pseudotachylyte. The measurements of thermal properties suggest that coal maturation in the chert within ~2 mm from the upper boundary of the pseudotachylyte is attributed to the higher thermal diffusivity in the hanging wall chert relative to the footwall chert and the argillaceous rock. The increased I_{D1}/I_{D2} values in pseudotachylytes and the chert within ~2 mm from the upper boundary of the pseudotachylyte indicate that coal maturation can occur during short-lived thermal events such as frictional heating on faults. Therefore, RSCM is useful to detect frictional heating. However, the conventional RSCM geothermometer cannot apply for the estimation of peak temperature during frictional heating on faults, because the maximum temperature determined from the RSCM geothermometer is well below the minimum temperatures recorded in the pseudotachylytes. The reaction kinetics incorporating the effects of rapid heating is necessary to establish frictional heating thermometer on faults.

