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Frictional melting during experimental stick-slip events: Characteristics of melt layers and their effects on slip behaviors

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We analyzed the slip surfaces of the samples experimented by Koizumi et al. (previous presentation) by using Digital Highscope, SEM and EPMA.

[Observational results]

(1) The areas where striations are well developed (about 20%) were distinguished from non-contact areas, and the fractal dimension of the former is 1.83.

(2) Rock fragments were picked off from contact areas, and the river patterns were well developed on the surfaces where the fragments were removed, suggesting tensional fracturing during picking off.

(3) The contact areas between the slip surface and rock fragments were melted. The melt was squeezed out forming the low banks of the melt on the both sides of the fragments.

(4) The intact surface was remained on the non-contact areas, but many cracks are developed on the surface.

(5) Strings and bubble structures are well developed on the slip surfaces that experienced large stick-slip events, indicating distinctive melting. The thickness of the melt layers is about 1micro-m. Many un-melted fragments also remains.

(6) According to the BEI images of the thin sections across the slip surfaces, the thickness of the melt layer varies from 1 to 5 micro-m. The slip surfaces of both sides are firmly adhered and this structure well remained being free from the destruction by the slip events thereafter.

(7) The element composition of the melt varies from place to place, and it is very similar to that of mica, potassium feldspar, plagioclase or quartz. This indicates that the maximum temperature attained higher than 1,730 degree.

[Implications to slip behaviors]

(a) The micro-cracks on the slip surfaces will be formed by the stress concentrations at the peripherals of the contact areas. This micro-cracking will correspond to the high frequency and low amplitude oscillations of the axial load and slip prior to the main slip phase.

(b) Picking off of rock fragments will be a cause of the high frequency oscillations appearing in the axial load and slip signals that were observed for small slip events and early slip phases of large events.

(c) The low banks of melt (see (3)) make the contact areas increase and consolidate. This is the cause that the frictional strength increases as stick-slip events repeated.

(d) The later slip phases of large slip events are not associated with high frequency oscillations. This will be attributed to the formation of a melt layer that the slip surface makes homogeneous.

(e) Assuming the viscosity of the melt as 10Pas, its thickness as 2 micro-m, and the slip velocity as 100m/s, frictional resistance is 50Mpa. Therefore, whether melting will promote or restrain the slip is unclear.

(f) The time duration for 1 micro-m thick melt layer to solidify is 0.1 micro-sec. Therefore, only if slippage is retarded during even such very small time intervals, it is very likely that the solidification acts very effectively as a negative feedback mechanism and the slip will stop.

(g) Just after the slip stops, the melt layer solidifies and the slip surfaces are healed very quickly.