Analyses of pseudotachylyte from Hole-B of TCDP; their implications for seismic slip behaviors during the 1999 Chi-Chi earthquake

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Among the fault zones found in TCDP Hole-B those at 1194m, 1243m and 1314m depths are associated with old pseudotachylyte (PT) layers 7-28mm thick.

1) Grain size frequency of protoliths and their volume fraction

We measured 7400 grains by using SEM at magnifications up to x4000. They show close to power law associated with a cut-off at 1micrometer due to the resolution limit and with a roll-off at 100 micrometer. Even for only the grains larger than 1 micrometer, the volume fraction of protoliths attains 63%, indicating very low melting degree.

2) Chemical composition of PTs

The similarity in chemical composition suggests that the original rock of the PTs is sandstone of host rock. When the rest other than SiO2 is normalized to 100%, the matrix of PTs is richer in Al, Fe, and Mg, and poorer in K and Na than the bulk.

3) Lines of evidence of melting

Gruel-like surface textures with many vesicles, rounded quartz grains sticking on the surface, hourglass-shaped strings stretching across the voids, non-stoichiometric chemical composition of the PT matrix, they all suggest the PTs are melt-origin. Gelation of quartz power is excluded, because Si is not concentrated in the matrix.

4) Temperature of PT melts

∗Judging from the chemical composition of PTs, the melt would have heated higher than 720 degree C which is melting temperature of granite under a certain condition.

∗Pyrite melts incongruently to pyrrhotite and sulfur at 742 degree C. However, pyrite grains remain somewhere, while sulfur pellets are found other parts in the PTs.

∗Glass transition temperature of PT is about 800 degree C. Many recycled PT grains remain but they are rounded.

∗Not only quartz grains are rounded, but also some hourglass-shaped strings are very rich in Si.

∗The difference in chemical compositions between bulk and matrix of PTs is likely
to be attributed to the selective melting of kaolinite rich in Al and chlorite rich in Fe and Mg.

∗The chemical composition of PT matrices is homogeneous but with unignorable variations. This will reflect the nearby mineral species.

The temperature estimates above have very wide range from 750 to 1750 degree C.

5) Frictional resistance of melt layers of low melting degree

True contact areas of granular material are very small and very heterogeneous in contact stress. Therefore, some contacts are easily flash melted, and temperature distribution also very heterogeneous in the scale of grain size. Such situation is maintained also in the partial melting regime. The pin-on-experiments of Montgomery (1976) revealed that friction coefficient of ca.0.4 turn up dramatically to ca.1.2 in the partial melting regime. Very wide variation among the temperature estimates above is consistent with the assumption that the PT melts were in the partial melting regime.

6) Seismological significances of PT melt layers of low melting degree

Prior to TCDP shallow boring was conducted at Fengyuan (northern segment) and Nanto (southern segment). Otsuki et al. (2005) found many clayey injection veins in the 150-450m depth of the Fengyuan hole and PT of low melting degree at the depth of 175m of the Nanto hole. And they advocated that elastohydrodynamic lubrication promoted large and smooth slips on the shallow part of the northern fault segment during the 1999 Chi-Chi earthquake, while on the shallow part of the southern segment melt patches of low melting degree hampered it.

Now old PTs were found also at the deeper part of TCDP Hole-B. Therefore it is likely that the seismic slip was suppressed also at deeper part than 1200 m. Waveform inversion analyses (ex. Ji et al., 2003) depicted a area with local minimum of slip, slip velocity, and stress drop about 3km east (3km depth) of the fault trace. This will be correlated to the assumed locus of melt patches. Severe damage by strong ground vibrations at Tung-Shih city also is consistent with the supposition above.