Thermal analyses of black zones in the Taiwan Chelungpu fault drilling project Hole B cores using ESR and VSM

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Main fault gouge zones were recognized around 1136m, 1194m and 1243m in depth by geological analysis of Taiwan Chelungpu-fault Drilling Project (TCDP) Hole B drill core samples (Hirono et al., 2007). These gouge zones respectively have a black zone with high magnetic susceptibility, which may have been caused by seismic frictional heating (Mishima et al., 2006; Hirono et al., 2007). Especially, the 1136m fault gouge zone may have been active in the 1999 Chi-Chi Earthquake (Lin et al., 2008). Thus, we have carried out thermal analyses using ESR (electron spin resonance) and VSM (vibrating sample magnetometer) to estimate the origin and degree of heat generation detected from the black zones in the TCDP drill cores.

As a result of ESR and VSM analyses, FMR (ferrimagnetic resonance) signals, which are indicators of frictional heat generation (Fukuchi et al., 2005), are not clearly detected from the 1136m black zone, and the magnetic susceptibility remains almost unchanged in the 1136m fault gouge zone, however the black zone has high coercive force. Furthermore, the E' center derived from oxygen vacancies in quartz has decayed, whereas an organic radical center has increased. On the other hand, the 1194m black disc and fault gouge zones show high FMR signal intensity and high magnetic susceptibility however they have low coercive force. Although the E' center has also decreased, the organic radical has increased. Similar results to the 1136m black zone are obtained from the 1243m black disc and gouge zones.

The 1136m black zone shows low FMR signal intensity, low magnetic susceptibility and high coercive force. This indicates that frictional heat temperature may have not risen so much (less than 350 degree C) in the 1999 Chi-Chi Earthquake. Also, the high coercive force is probably attributed to hematite (a-Fe_2O_3). Maghemite (g-Fe_2O_3), which can be produced in the fault gouge due to thermal dehydration by frictional heating, transforms into hematite by further heating. The transformation temperature from maghemite to hematite strikingly decreases in hot fluids. According to our hydrothermal experiments, maghemite can perfectly transform into hematite at 170 degree C for 24 hours. The E' center in quartz and organic radical show that the 1136m black zone may have been subjected to past frictional heating at 400 degree C or more. However, maghemite that was then produced by the frictional heating is now undetected, because it may have transformed into hematite due to hydrothermal reaction with hot fluids having passed through the gouge zone after its production.

Ishikawa et al. (2008) indicated on the basis of the results from chemical analyses that hot fluids passed through the 1136m black zone. However, it is still unclear whether hot fluids passed through the present black gouge zone in the 1999 Chi-Chi Earthquake or at deeper sites in the past. Thus, we carried out detailed ESR measurements to estimate the passing age of hot fluids. As a result, quartet ESR signals intrinsic to smectite have been almost completely annihilated in a part of the 1136m black zone. The equivalent dose and its errors are estimated as 1.3+or-61.2Gy (1sigma) by artificial gamma-irradiation. Using the general annual dose of muddy rocks (2+or-1 Gy/ka), the passing age of hot fluids may be estimated as 1+or-31 ka (1sigma). This result means that hot fluids may have passed through the 1136m black zone within the last 30,000 years. To estimate a more exact passing age, we will in detail determine the concentrations of radioactive elements around the ESR samples.

[References]
T. Fukuchi et al., 2005, JGR, 110, B12404, doi:10.1029/2004JB003485.
T. Hirono et al., 2007, JGR, 112, B07404, doi:10.1029/2006JB004738.
T. Ishikawa et al., 2008, Nature geosci., doi:10,1038/ngeo308.
W. Lin et al., 2008, GRL, 35, L01305, doi:10.1029/2007GL032158.
T. Mishima et al., 2006, GRL, 33, L23311, doi:10.1029/2006GL028088.