Absolute dating of earthquake faults by the ESR method- Its principle and applicable limits

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There are mainly two techniques for absolute dating of earthquake faults by the ESR (electron spin resonance) method. One technique is based on the assumption that ESR signals can be reset by seismic frictional heating. In this case, the resetting of ESR signals by fault slip around the earth's surface is hardly expected, so that the samples for dating must be collected from deep sites by drilling and so on. According to ESR analysis using the Nojima fault drill core samples, some ESR signals in the fault gouge at a shallow site of about 390m in depth had been largely decayed (Fukuchi & Imai, 2001). Also, recent chemical analysis on the Taiwan Chelungpu fault deep drill core (Hole B) samples indicated that hot fluids of more than 350 degree C passed through the impermeable black fault gouge zone at the time of faulting (Ishikawa et al., 2008). This means that not only frictional heat but also hot fluids associated with fault slip may be able to annihilate ESR signals in the fault gouge. In the case of the technique assuming the resetting of ESR signals by heating, it must be verified that the temperature around the fault gouge sample rose over the resetting temperature of ESR signal used for dating. Heating experiments indicate that the quartet signals derived from smectite, which is detected from the black fault gouge zone of the Taiwan Chelungpu fault, are almost annihilated by heating at 350 degree C (Fukuchi, 1996). Therefore, the quartet signals may have been completely reset by the hot fluids of more than 350 degree C that passed through the Chelungpu fault gouge zone. As a result of gamma-irradiation with a ^{60}Co source, the quartet signals gave the equivalent doses of 1+or-122Gy - 71+or-78Gy (2sigma). If the equivalent dose is divided by the general value of annual dose (2+or-1Gy/ka), the ESR age is temporarily estimated as 1+or-61ka - 36+or-53ka (2sigma). These ages mean quite recent fault movements of the Chelungpu fault although we cannot conclude that they mean the 1999 Chi-Chi Earthquake. Thus, we may be able to determine the age of fault movement younger than 50ka using the quartet signals of smectite according to the annual dose of the sample.

Another technique is to apply ESR signals and/or minerals newly generated by faulting. Fault gouge made from host rocks by faulting immediately reacts with water if water exists around the fault zone, and consequently clay minerals such as smectite or kaolinite are formed. Therefore, we can indirectly determine the age of fault movement from the formation age of the clay minerals by using intrinsic ESR signals derived from these clay minerals. However, in this case, we can not determine the older ages than the formation age of clay minerals, because clay minerals can not exist above the temperature of thermal stability. In addition, the intrinsic signals may be saturated if the age is too old. In the case of the Sakaitoge fault that is an active fault distributed in western Nagano, the quartet signals derived from smectite and the surface E' center formed in quartz by brittle fracture were detected from the fault gouge. The quartet signals and surface E' center gave the ESR ages of 0.84+or-0.36Ma (2 sigma) and 45+or-0.17Ma (2 sigma), respectively. The coefficients of determination for growth curves obtained by gamma-irradiation from both the signals were high values of 0.977and 0.997, respectively. This means that these ages are very credible.

References

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