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Assessment of fault activity by the ESR dating technique

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After the 2011 off the Pacific coast of Tohoku Earthquake, the definition of active faults, which was described as the faults having moved after 120-130 ka BP in the Advanced Safety Examination Guideline for Seismic Design for Nuclear Power Plant, was modified. As a result, we must evaluate the activity of faults having moved after 400 ka BP. However, it is not easy to evaluate the activity in case of the active faults whose tectonic topography is ambiguous or on which there is no sediment available for dating. Thus, we require a new dating technique for directly estimating the absolute dates of fault movements from fault rocks that preserve the past records of fault movement. The ESR (electron spin resonance) method is a dating technique to estimate the absolute dates of fault movements using ESR signals in minerals (quartz, clay minerals, etc.) forming fault rocks that have been once reset by frictional heating or ESR signals intrinsic to the minerals newly generated by faulting (Fukuchi, 2010).

When we apply the ESR technique to active faults, it is the most serious problem whether or not the ESR signals in fault rocks have been completely reset (Fukuchi, 2004). If the ESR signals have been incompletely reset, the ESR ages obtained from the signals will be older than the actual age (Ta) since the total dose of natural radiation is overestimated. However, the ESR ages (Te) give the theoretical upper limit of the actual age ($Ta \leq Te$). Therefore, if the ESR ages obtained give the young ages showing the middle Pleistocene to Holocene, we can utilize the young ages for the assessment of fault activity. Moreover, when deep drill core samples are available for ESR dating, the problem on the complete resetting may be solved. On the other hand, thermally unstable signals that are bleached by light may decay under higher temperature at deeper sites and consequently may give much younger ages even though frictional heat has not been increased. Therefore, caution is necessary in using thermally unstable signals.

Here, I introduce the case of the Shimotsuburai and Hoozan faults in the Itoigawa-Shizuoka Tectonic Line (ISTL) Active Fault System, whose increase of fault activity has been pointed out after the 2011 Earthquake. As a result of ESR dating of black intrusion veins produced by the latest fault movement of the Shimotsuburai fault, which has moved during the Holocene, the Al and Ti centers derived from quartz give 1.3$\pm$0.2 Ma (Coefficient of determination; R-value is 99.8%) and 2.0$\pm$0.3 Ma (R-value is 99.2%), respectively. Although these centers have been incompletely reset by frictional heating, the age (T) of the Shimotsuburai fault is estimated as $T \leq 1.3\pm0.2$ Ma, from the Al center, the most unstable signal in quartz. On the other hand, as a result of ESR dating of gray gouge produced by the latest fault movement of the Hoozan fault, whose activity during the Quaternary period is unknown, the quartet signals derived from montmorillonite and the Al center derived from quartz give 1.4-1.9$\pm$0.2 Ma (R-value: 99.2-99.5%) and 1.2$\pm$0.2 Ma (R-value: 99.0%), respectively. In addition, the hyperfine structure (hfs: g=2.0187) of the Al center gives 0.6$\pm$0.1 Ma (R-value: 98.8%). Since the whole of the Al center is overlapped with another signal and its ESR age is overestimated, the age (T) of the Hoozan fault may be estimated as $T \leq 0.6\pm0.1$ Ma, from the hfs of the Al center.

References

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