Evaluation of fault history by means of various dating methods available for geological disposal

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Introduction

When we meet a fault at deep underground in a geological disposal site, we have to evaluate its activity in relation to long-term stability. Ages of faulting of such deeply buried faults will be estimated only from analyses and dating of fault materials such as fault breccias, gouges and so on because the stratigraphic method usually employed for earth surface active faults is not applicable to deeply buried faults. In order to know the history of a fault from its birth to present, analyses of fault textures and thermal history relating the faulting are indispensable.

Fault studied

K-Ar (potassium argon), ESR (electron spin resonance), and FT (fission track) methods among many dating methods proved to be much useful for dating of faults through investigation of existing studies on fault dating.

Sakai-toge Fault located in Nagano Prefecture, Central Japan was chosen for this study because it is a well-studied active fault with a length of about 50 km and has cut Cretaceous granite and Jurassic sedimentary melange to which various dating methods are applicable.

The fault zone at outcrops in the granite consists of ultra-cataclasite, cataclasite, and pseudotachylyte, which has been cut by later minor faults. The fault zone at outcrops in the melange consists of cataclasite, gouges and fracture zone with network gouges. In the fracture zone occur cataclasite with porphyroblasts produced by contact metamorphism under the microscope.

Textures of fault zone and altered minerals

At outcrops in the fault zone of the granite occur finely laminated cataclasite, in which micro-textures indicate left-lateral displacement. The ultra-cataclasite looks like gouge in appearance and micas have been disappeared and injected by pseudotachylyte. The ultra-cataclasite contains mixed-layer minerals of illite/smectite produced by hydrothermal alteration. Most parts of pseudotachylyte have been hydrothermally altered to smectite. At outcrops in the fault zone of the melange occur gouges consisting of mixed-layer minerals of illite/smectite, in which P-shear indicates left-lateral displacement.

Result of dating

Smectite and zircon from the pseudotachylyte in the granite have a K-Ar age of 32 Ma and a FT age of 62 Ma respectively. Smectite from the ultra-cataclasite in the granite has an ESR age of 2-4 Ma.

Smectite from the gouge in the melange has a K-Ar age of 52 Ma and an ESR age of 1-3 Ma.

Summary and conclusions

The granite is estimated to have intruded around 74 Ma (FT age of zircon). The fault began to exist around 62 Ma under a temperature of 250-400^{o}C, which is estimated from the presence of the laminated cataclasite. After that age, the ultra-cataclasite was formed, and then the pseudotachylyte was formed. The FT age (62 Ma) of the pseudotachylyte indicates the age of the early faulting because spontaneous fission tracks of ^{238}U in zircon have not been shortened. Upheaval accompanying faulting occurred in the area after a long inactive interval more than several tens of million years. The ESR ages (4-1 Ma) from smectite indicate the ages of faulting during the upheaval. In fact, it is known that extensive upheaval along the Hida Mountains in Central Japan became active about 3 Ma. The K-Ar ages are far older than the ESR ages although both of the ages were obtained from the same specimens of pseudotachylyte or cataclasite. This discrepancy suggests that the daughter nuclide ^{40}Ar was not reset during the formation of smectite, or smectite has trapped ^{40}Ar from surroundings.

ESR dating of smectite and FT dating of pseudotachylyte proved to be very useful for analyzing a fault history. Thermal history of a fault zone also proved to be useful for improving confidence of dating. Further studies concerning behavior of ^{40}Ar are needed. The methods employed in this study should be applied to other active faults and deeply buried faults.