Geological fault and ESR -Approach using ESR dating method-

ER120006E

1. Introduction

The earthquake is a phenomenon that the fault surface is cracked by the surrounding force to pull or push and then, the base rock moves rapidly on the boundary of fault plane. This base rocks shift is called the geological fault.

The active fault is the geological fault that has the possibility to move repeatedly in recent geological age and in the future. The fault is classified to the normal fault, the reverse fault, the strike-slip fault and the left-lateral fault by the difference in the movement displacement. Also it often appears as a deflection of layer in case of soft layer.

Identification of the active fault and evaluation of the activity is important to make basic data for site selection of large buildings and for the aseismic design. In this process, it is important to elucidate activity period of fault.

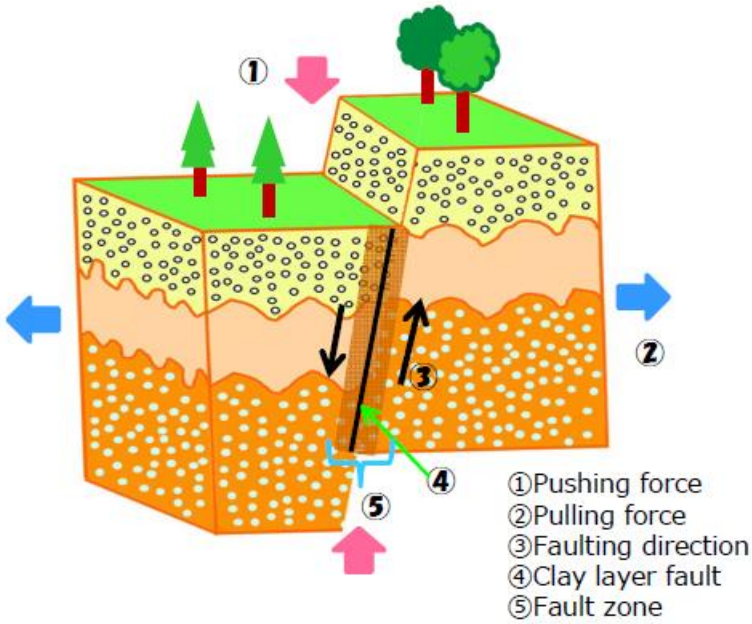


Figure1.The normal fault

2. Investigation of active fault

The position of the active fault is estimated from fault displacement observed in the aerial photographs taken from airplanes and satellites. Then the geological layer is observed in detail by excavating the fault outcrops. At this time, samples were taken from the geological layer to identify the tephra or to measure the age after extracting specific mineral. Based on these investigation, parameters such as average slip rate, earthquake recurrence interval, and the fault activity is evaluated.

It is especially urgent need to evaluate the activity of the faults those make earthquakes frequently, those make huge earthquakes, and those moved before the interval of the past earthquake.

The activity cycle of the faults ranges from several hundred to tens of thousand years and any of these should be observed carefully. Application range of ESR dating method is from tens of thousands to several million years, which is far beyond the limitation in carbon dating.

3. ESR dating approach

Quartz is one of the minerals on the surface of the earth. The cosmic ray and natural radiation is showered on the ground ionizes electrons in the crystal of quartz or atoms in the lattice is knocked off. These damages are so called vacancy. As the age of the quartz grains is older, the degree of damage is increased. The degree of damage is reflected in ESR signal intensity. The following points are important in applying ESR dating method.

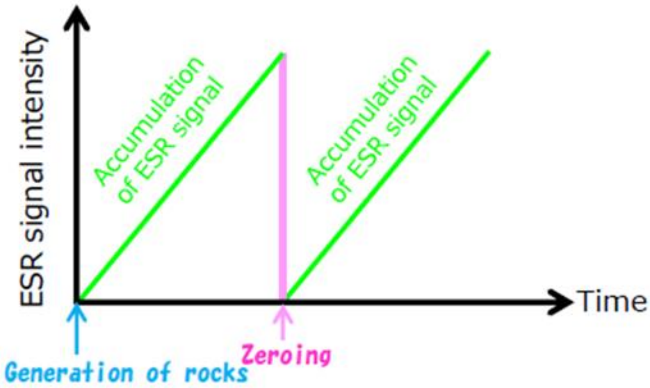
- (1)Zeroing

  Zeroing is the “reset” of accumulated damage in quartz grains in the fault plane by the frictional heat and the shear stress caused by the fault formation or by the fault movement. ESR signal for grains at the fault plane will be approximately zero by the heating. When the fault activity is ended, quartz grains of the fault plane are gradually cooled and the damage will be accumulated again by natural radiation and cosmic ray.

  Thus ESR dating age of fault grain shows the time of fault activity. Generally, the grains suffered from zeroing are considered to be located on the surface of the fault plane.
- (2) Thermal history

  Several ESR signals are observed in the natural quartz. Each paramagnetic center has different annihilation process by the heating or the fragmentation. The friction heat and the friction coefficient in the fault plane is estimated from the thermal stability and lifetime, which is interesting topic in the field of structural geology[1)].

  There are some reports estimating reset condition due to frictional heat by simulating on the assumption of the amount of displacement of the fault, friction stress, and the friction coefficient. It indicates that it is possible to estimate the degree of reset of ESR signal and the frictional heat once the amount of heat is verified.[2)]



- Figure2. Mechanism of ESR dating of fault

4. Target samples of the ESR dating in the fault

Target samples suitable for the ESR dating, to know the activity period of the fault, are quartz grains generated by the fault movement such as the fault zone[*3], the fault clay[*4], the mylonite[*5], the pseudotachylite*6, and the fault gouge[*7]. It is important to collect the grains close to the fault plane whose ESR signal should be once reset by fault movement.

Figure3. sampling of quartz

Figure 4. Before and after chemical treatment of sample

5. Approach of ESR dating method

There are many paramagnetic defect species in quartz[3] such as E_1’, Peroxy, NBOHC, Al, Ti-Li, Ge, and FMR centers. These ESR signals are used to for ESR dating and for frictional heat. The Al, Ti-Li center signals are used for ESR dating of the volcanic sediments as shown in Figure 5. The procedure of ESR dating using these signals is described in another ESR Application note ER-080002.

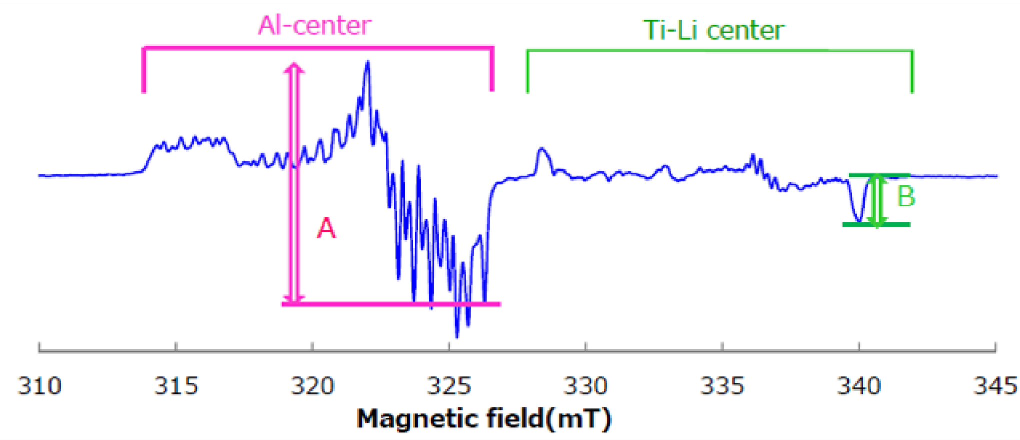


Figure 5. The Al- and Ti-Li center signals from Hiei granite.

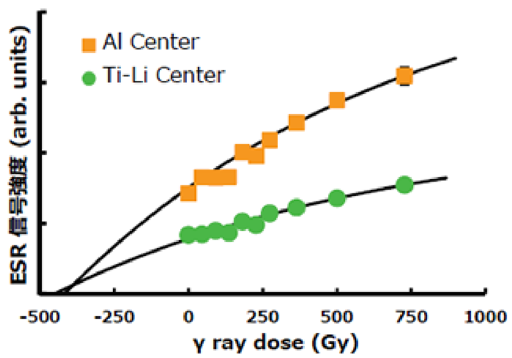
(A) Al center signal inensity, (B) Ti-Li center signal inensity

6. Research Example ～ESR dating of the pseudotakylite～

The pseudotachylite is called “fossil of earthquake” which is generated by melting suffered from frictional heat.

There are some points in the world where the pseudotachylite is generated by the landslide of earth surface plane.

Here is an example of ESR dating for the pseudotachylite generated by landslide in Langtang of Himalaya in Nepal. Geomorphologically, it is revealed that this pseudotachylite is generated by large landslide[4]. This pseudotachylite is supposed to be heated at 1520 degrees centigrade due to mineralogical composition such as glassy phase and chasm generated by rapid cooling after melting[5]. At such high temperature, ESR signal should be “reset” and so the ESR date would be indicating when this pseudotachylite is generated by the landslide. ESR dating measured using quartz extracted from the fault vein of this pseudotachylite was approximately 62000 years ago[6].



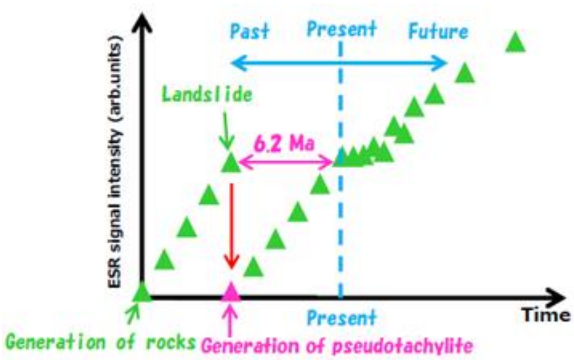


Figure 6. γ ray irradiation dose response   Figure 7. formation of ESR ages of the pseudotachylite

7. Summary

The information of the fault activity obtained by ESR dating is summarized below.

- The activity age of fault

  It is possible to estimate ESR age for the quartz grains located at fault plane if zeroing is confirmed in fault movement.
- Thermal history

  It is important to expect the amount of heat in the fault movement.

  For example, in the geological layer of Figure 8 (a), grains are sampled from A to I. ESR signal intensity as shown in Figure 8 (b) is expected. ESR signal intensity for the sample close to the fault plane would be small because of the thermal history.

  ESR dating is a unique and important method that can reveal the activity of the fault. By applying ESR dating globally to obtain fault data, it is possible to visualize the active faults map including activity age, activity period, and the frictional heat widespread.

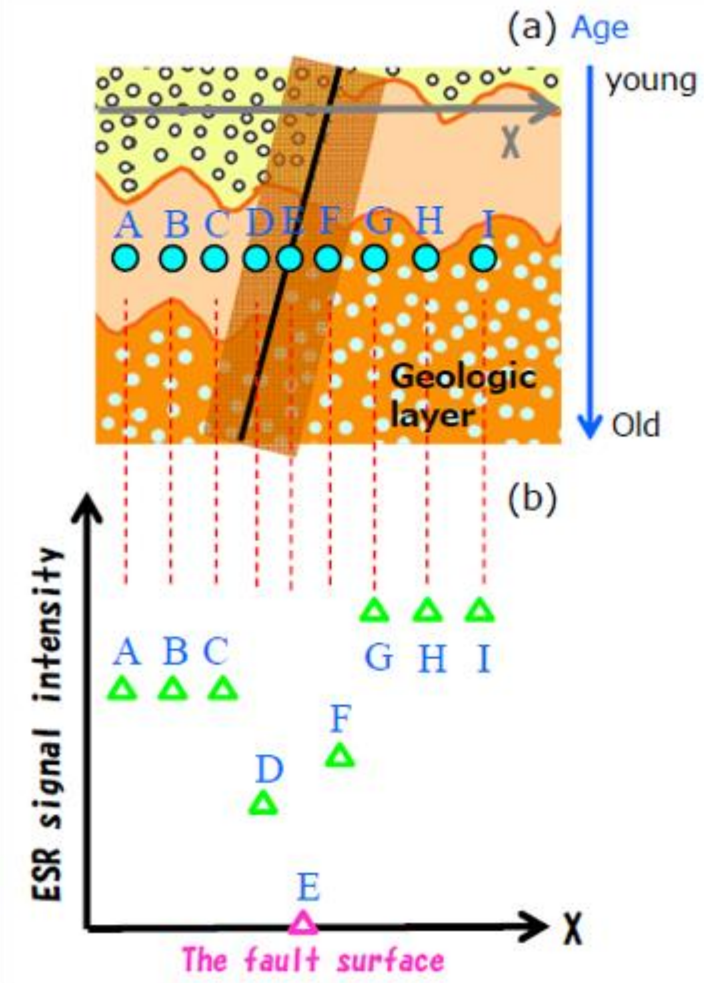


Figure 8. Difference between the ESR signal intensity due to the distance from the fault plane.

(a) Example of the geologic layer.

(b) ESR signal intensity of quartz grains after the fault movement.

Explanation of Terms

- *1. Deposition such as ash and pumice that covers wide range when a massive volcanic eruption occurred.
- *2. The stress acting to slip the object to the direction parallel to the internal surface.
- *3. The large gap between the rock debris which is made by the base rock crashed around the fault plane.
- *4. The clay fine-grained rock fragments which were milled by crushing around the fault zone.
- *5. The rocks causing plastic deformation due to high temperature at the deep part of the geological fault.
- *6. The rocks causing melt by the frictional heat as the result of high-speed slip along the fault under the strong pressure at the deep part of underground, then solidified by rapid cooling.
- *7. The clay-like in shatters which is made by the rocks destroyed by friction due to intense fault movement.

Reference

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