Temperatures during high speed friction experiments estimated by ESR measurements and its applications to dating of faulting

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ESR (electron spin resonance) dating method is based on the fact that unpaired electrons are created by natural radiation and accumulated in minerals in geologic time scale. ESR detects unpaired electrons; therefore, the signal intensity corresponds to the age of the minerals. Ikeya et al. (1982) first reported that the ages of fault movements could be obtained by using quartz grains contained in fault gouge. Following studies have focused on (1) the method which proves the complete zeroing at the time of fault movements and (2) the mechanism which erases the ESR signal during faulting. Low speed friction experiments simulating faulting, such as Ariyama (1985), aimed to determine the geological conditions at which ESR signals are erased completely, however, how well such experiments simulates the real faulting has been and is still questionable. As for the mechanism, Miki and Ikeya (1982) proposed that mechanical shearing effect erases the signal while Fukuchi (1989) insisted that frictional heating may also give zeroing effect.

In the present paper, we employed the instrument at Kyoto University, which enables us to perform high speed shearing experiments with conditions closer to real faulting in the aspect of the velocity of friction. The variation of mechanical constants during faulting is another important topic to study, which ESR method could contribute by estimating the temperature during shearing experiments because temperature is an important factor to change the mechanical constants.

Quartz grains were extracted from Mannari granite of Okayama Prefecture. They were irradiated by gamma rays to 730 Gy prior to the experiments. The grains (0.5-1 mm size fraction, 1 g) were sandwitched between two column pieces of gabbro of 25 mm in diameter with a Teflon cap. One piece of gabbro is fixed while the other is rotated by a high speed motor under a pressure of 20 MPa. The experiments were performed several times with varying the rotation speed from 300 to 1500 rpm while total rotation number was kept constant around 120. After shearing, the sample were separated into three, center, middle, and outer parts of the shearing locations.

The ESR signals associated with Al, Ti and Ge were observed where intensities were smaller for outer part which is consistent with higher shearing speed at outer part. The signal intensities were smaller for experiments of higher rotating speed. The results for the E1' center were consistent with those for Al, Ti, Ge centers where the intensity of the E1' center is known to increase on heating. The above results could be interpreted as the heating effects during shearing.

We also performed a stepwise heating experiment to obtain decay coefficients of those ESR signals. The temperatures estimated for those shearing experiments with the above coefficients were, however, not consistent with one another. Discussions will be given considering the temperature elevation and cooling processes during the shearing experiment as well as the crushing effect.

References

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