Temperature measurement of frictional heat generated by seismic fault slip using ferrimagnetic resonance signal

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Fault gouge is often magnetized by frictional heating during seismic fault slip. The ferrimagnetic mineral that is responsible for the magnetization of fault gouge is considered to be maghemite (gamma-Fe2O3), which is produced by thermal dehydration of lepidocrocite (gamma-FeOOH), a kind of iron rust in fault gouge. Maghemite shows a strong ESR (electron spin resonance) absorption due to ferrimagnetic resonance (FMR). The FMR signal obtained from maghemite is available for the detection and temperature measurement of frictional heat (Fukuchi, 2003; Fukuchi et al., 2005). According to the results from heating experiments using artificially synthetic magnetic minerals of high purity, the FMR signals detected from magnetite (Fe3O4, g=3.045) and maghemite (g=3.018) show quite different linewidths and intrinsic g-values from those from lepidocrocite-originating maghemite (g=2.236-2.394). This is attributed to extremely low crystallinity of the lepidocrocite-originating maghemite. The resonant magnetic field of the lepidocrocite-originating maghemite shifts toward the lower field with increasing crystallinity and consequently its g-value becomes larger. The lineshape of FMR signal obtained from the synthetic maghemite with high crystallinity is sharper than that from the synthetic magnetite with high crystallinity and both FMR signals also are clearly distinguished from each other.

Generally, maghemite of high purity transforms into hematite (alpha-Fe2O3) by heating over about 400 degree C and its FMR signal intensity decays, however impurities existing inside lepidocrocite thermally stabilize resultant maghemite. We synthesized lepidocrocite by a wet method using iron sulfate (FeSO4) and sodium hydroxide (NaOH) and investigated the thermal stability of maghemite originating from the synthetic lepidocrocite. As a result, the FMR signal of the maghemite does not decay even at 500 degree C. The stabilization of the maghemite may be attributed to Na+ ions existing inside the synthetic lepidocrocite. Thus, natural maghemite in fault gouge may be thermally stabilized by Na+, K+ or univalent cations.

Another FMR signal is detected from granite-originating pseudotachylyte that is not derived from fault gouge. Heating experiments using biotite extracted from granite indicate that a part of biotite changes into magnetite due to thermal decomposition by heating at 800 degree C and more (1 hour). The magnetite produced from biotite at 800 degree C has so low crystallinity that it cannot be detected even by X-ray diffraction analysis. However, ESR is a so sensitive technique, and we can easily detect it by ESR. The lineshape of FMR signal obtained from the magnetite with low crystallinity is clearly different from that from the lepidocrocite-originating maghemite with low crystallinity.

The temperature measurement of frictional heat by FMR signal has been carried out using the fault gouge in the Nojima fault DPRI 500m drill cores (Fukuchi et al., 2005). As a result of inversion using FMR signal intensity, the maximum temperature of frictional heat generated on the Nojima fault plane at about 390m in depth in the 1995 Kobe earthquake has been estimated as about 390 degree C. Since the frictional heat temperature strongly depends on the thermal properties (thermal conductivity, specific heat, etc.) of fault gouge, it is very important to accurately determine these parameters to obtain a meaningful value.

References

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