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# A diagnostic technique of the origin of dark fault rocks using ESR spectrum analysis

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In fault zones, we often observe dark fault rocks indurated and magnetized by frictional heating. Although the magnetic source of dark fault rocks may be magnetite ($Fe_3O_4$) or maghemite (gamma-$Fe_2O_3$), it is difficult to distinguish between magnetite and maghemite because both have a similar crystal structure and can be transformed into each other by oxidation or reduction (Fukuchi, 2012). When the magnetic source is magnetite, it means that the fault rock was formed in a reductive environment, whereas the existence of maghemite indicates that it was formed in an oxidative environment. Therefore, it is important to determine the magnetic source for understanding the oxidation-reduction reaction occurring in the fault zone in earthquakes. On the other hand, siderite ($FeCO_3$), which is often detected from fault zones, can produce magnetite or maghemite via wustite (FeO) by thermal decomposition, so that siderite may be concerned in the magnetic source of dark fault rocks. The thermal decomposition products from siderite remarkably vary their phases with the abundance of oxygen and temperature (Darken & Gurry, 1946). Therefore, detailed heating experiments controlling the degree of vacuum are required to investigate the thermal decomposition products. In this study, I carried out heating experiments of natural siderite under various conditions of temperature and pressure and identified component minerals of the thermal decomposition products from natural siderite by XRD (X-ray diffraction) analysis. In addition, I revealed that the lineshapes of ESR signals detected from the thermal decomposition products vary with temperature and pressure using ESR spectrum analysis. Moreover, I attempted to diagnose the origin of dark fault rocks in the Nojima fault zone or other fault zones on the basis of the type of ESR lineshape.

The XRD and ESR measurements show that there are three types of magnetite as a thermal decomposition product of siderite, that is, disproportionation-originated, oxidation-originated and melting-originated magnetites and that the ESR lineshape obtained from magnetite depends on the origin of magnetite. As a result of ESR spectrum analysis, the disproportionation-originated magnetite with low crystallinity has a g-value of 2.1-2.3 and a half-linewidth/peak-to-peak linewidth ratio (Delta ratio) of 1.45-1.62, implying the intermediate lineshape between the Gaussian line (1.177) and the Lorentzian one (1.732), while the oxidation-originated magnetite has a g-value of 2.2-2.4 and a Delta ratio of 1.10-1.30 close to the Gaussian line. The melting-originated magnetite has a similar g-value of 2.2-2.3 but a much lower Delta ratio of about 0.9 than the Gaussian line. On the other hand, dark fault rocks in the Nojima fault zone show a g-value of 2.13-2.24 and a Delta ratio of 1.423-1.487, consistent with the values obtained from the disproportionation-originated magnetite with low crystallinity. This means that the Nojima dark fault rocks have not been melted and oxidized and besides have been instantaneously produced at temperatures of 350 degree C or more under a reductive environment.

References

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