ESR and radioactive disequilibrium dating of sulfate minerals in sea-floor hydrothermal deposits at the Okinawa Trough

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The time scale how long the sea-floor hydrothermal activities continue is an important issue in the studies on the processes of ore formation and on the evolution of the biological systems sustained by the chemical species arising from hydrothermal activities. For this purpose, radioactive disequilibrium dating methods such as U-Th for sulfide minerals (e.g. You and Bickle, 1998), ^{226}Ra-^{210}Pb and ^{228}Ra-^{228}Th methods for barite (e.g. Grasty et al., 1988, Noguchi et al., 2011) have been used, while recently, the ESR (electron spin resonance) method for barite was proposed and developed (Okumura et al., 2010, Fujiwara et al., 2015).In the present study, we applied ESR and radioactive disequilibrium dating of sulfate minerals, i.e., anhydrite and barite.
Firstly, for anhydrite ($CaSO_4$), we will report the first successful dating results on hydrothermal anhydrite using the ^{228}Ra-^{228}Th method. The hydrothermal ore samples were taken by research cruises operated by JAMSTEC. The anhydrite crystals were physically scratched out of the samples. The radium (^{226}Ra, ^{228}Ra) were measured in the same samples for the ESR method by the low background gamma ray spectrometry. From the activity ratios, disequilibrium ages were obtained to be 0.6-2.5 years by ^{228}Ra-^{228}Th method. As anhydrite is unstable because of the higher solubility increase at low temperature, obtained ages of the anhydrite samples are reasonable.
Secondly, for the barite ($BaSO_4$), three dating methods of ESR, ^{226}Ra-^{210}Pb and ^{228}Ra-^{228}Th methods were applied to the same hydrothermal barite samples. The ESR ages of barite taken from hydrothermal areas in the Okinawa trough range from 4.1 to 16000 years, filling the age gap of the maximum age, 150 years, of ^{226}Ra-^{210}Pb method and the minimum age, several thousand years of U-Th method, being the most appropriate age range to discuss the evolution of the hydrothermal systems. Interestingly, the ^{226}Ra-^{210}Pb and ^{228}Ra-^{228}Th ages for the same samples are the same or younger than the ESR ages. The difference in the ESR and two radioactive disequilibrium ages would most probably due to two or more formation stages of the barite crystals in the sulfide deposits (Uchida et al., 2015). This interpretation is supported by the BSE images where at least two kinds of the barite crystals of different occurrence are observed. Model calculations including two or more formation stages (possibly continuous) may consistently explain the differences among the ESR and the disequilibrium ages, revealing the histories of the episodic hydrothermal activities.

Keywords: barite, anhydrite, hydrothermal activities, electron spin resonance, dating

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