Extreme sulfur isotope fractionation in the seafloor hydrothermal deposit of the Okinawa Trough revealed by SIMS analysis

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Seafloor hydrothermal deposit, one of the types of seafloor mineral resources, has long been paid attention as a future producer of Cu-Pb-Zn±Au±Ag resources. This type of sulfide deposit is mainly composed of pyrite, sphalerite, galena and chalcopyrite with other sulfide/sulfate minerals. Sulfur in the main constituent sulfide minerals has been generally derived from mixture of magmatic and seawater sulfur [1,2]. Here, we report an extreme sulfur isotope fractionation in pyrite grains due to the bacterial sulfate reduction from the two modern seafloor hydrothermal deposits of the Iheya-North Knoll and Izena Hole in the middle Okinawa Trough revealed by the SIMS analysis.

We used drilling core samples of the Iheya-North Knoll and Izena Hole obtained through the IODP Exp. 331 and cruise CK16-05 (Exp. 909). Based on the visual core descriptions and microscopic observations, the drill core sample in the subseafloor sulfide layer beneath a sediment of the Izena Hole has a pyrite texture of (1) framboid (including recrystallized one), (2) colloform (including marcasite) and (3) euhedral (including pyrrhotite pseudomorph) along with maturation processes/hydrothermal overprinting. Sulfur isotopes ($d^{34}S$) of the framboidal, colloform and euhedral pyrites have ranges from -38.91 to -2.84‰ (-17.28 ±10.21‰; n = 47, average ±1SD), -13.63 to -2.96‰ (-7.36 ±2.47‰; n = 29) and -13.43 to -3.80‰ (-6.78 ±2.69‰; n = 19), respectively. The framboidal pyrite in the pumice layer above the subseafloor sulfide layer exhibits the especially narrow and light $d^{34}S$ from -34.31 to -37.13‰ (n = 6). Moreover, the subseafloor sulfide layer is considered to be formed by the replacement/mineralization of porous pumice layer based on the microscopic observations [3]. Similar sulfur isotope fractionation was also observed at the flank of the mound in the Iheya-North Knoll whose framboidal and euhedral pyrite grains have $d^{34}S$ ranging from -38.03 to -10.35‰ (-28.25 ±9.84‰; n = 10) and +0.36 to +3.86‰ (+2.85 ±1.11‰; n = 15), respectively. Combined with the recently reported extreme sulfur isotope fractionation in the Spanish and American volcanogenic massive sulfide (VMS) deposits [4,5], a replacement mineralization process beneath a seafloor using framboidal pyrite grains derived from bacterial sulfate reduction plays a key role to form a large-scale seafloor hydrothermal deposit.

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