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Isotopic compositions of volatile elements trapped in fluid inclusions in hydrothermal ores

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Fluid inclusions are microscopic babbles of liquid and gas that are trapped within minerals. Fluid inclusions reflect the information of hydrothermal fluid during the formation of mineral. Therefore, we can know chemical compositions of hydrothermal fluids forming a hydrothermal ores by measuring compositions of fluid inclusions. Noble gases preserved in fluid inclusions reflect the composition of vent fluids and they are sensitive indicators of the source of hydrothermal fluids [1-3]. In this study, we measured the isotopic composition of noble gases contained in the fluid inclusions of hydrothermal ores to discuss the origin of the hydrothermal fluids. Further, in order to provide constraints on the formation process of hydrothermal ore, we also measured isotopic ratios of nitrogen in fluid inclusions of hydrothermal ores reported by only a few studies.

Hydrothermal ore samples were collected during NT11-20 expedition using ROV Hyper-Dolphin (JAMSTEC), from Okinawa Trough. Approximately 1 g of ore sample picked up and put it in a stainless-steel crusher with a stainless-steel ball. Each ore sample was baked at approximately 200 degree for 12 hours under vacuum to remove atmospheric components absorbed on the sample surface. When the crusher was shaken up and down, the minerals in samples were crushed by the stainless-steel ball movement. Then, gases in fluid inclusions were extracted and introduced into a vacuum line. These gases were purified, and $^{3}He/^{4}He$ and $^{20}Ne/^{4}He$ ratios were measured by a noble gas mass spectrometer(Helix), and a quadrupole mass spectrometer, respectively. In addition to noble gas, we measured d15N and $N_2/^{40}Ar$ ratios by a nitrogen isotopic mass spectrometer (MicroMass 3600). At that time, we also measured $^{40}Ar/^{36}Ar$ and $^{4}He/^{40}Ar$ ratios by a quadrupole mass spectrometer.

Measured $^{3}He/^{4}He$ ratios were 1.17 to 7.38Ra(Ra means atmospheric $^{3}He/^{4}He$ =1.4x10^{-6} [4]). These values display the mixing of atmospheric and MORB type helium(=8+-1Ra[4]), and suggest that hydrothermal fluids were originally derived from a upper mantle. From the results of $^{20}Ne/^{4}He$ and $^{3}He/^{4}He$, helium and neon in fluid inclusion can be explained by a mixture of hydrothermal fluids and pore waters, and hydrothermal fluids were greatly affected by pore water. Considering MORB and pristine diamond data, d15N values of -3 to 7%o are expected in upper mantle[5]. On the other hand, all samples showed positive values of +2.47 to +4.16 %o in this study and these values are similar to sediments in the Okinawa Trough[6]. Measured $N_2/^{40}Ar$ values of 54 to 112 are close to reported value of atmosphere(=85) and seawater(=55), and $^{40}Ar/^{36}Ar$ values of (3.29 to 9.92)x10^2 displayed slightly higher than that of atmospheric ratio (=2.96x10^2) and obviously lower than that of MORB ratios($>$40000)[7]. Then we estimated contribution of three nitrogen sources (mantle-derived, sedimentary and atmospheric nitrogen) using d15N, $N_2/^{36}Ar$ and $N_2/^{3}He$ values. As a result, 35 to 65% nitrogen was derived from sediment, and the contribution from the upper mantle was rarely seen. This result is in harmony with geological background that Okinawa Trough is covered with thick sediments and that observed helium and neon are greatly affected by the pore water. When estimating the origins of hydrothermal ores, d15N, $N_2/^{36}Ar$, $N_2/^{3}He$ in fluid inclusions may be a useful tracers to understand contribution of sediment.

Keywords: fluid inclusion, noble gas isotope, nitrogen isotope, hydrothermal ore, Okinawa Trough