Mineralogical and Geochemical Study of Hydrothermal Deposits from the Noho Site in the mid-Okinawa Trough

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The mid-Okinawa Trough is recognized as an area with extensive hydrothermal activity. The Noho site is located in graben a few km south of the Iheya Small Ridge. Water depth of the Noho site is around 1600 m, which is deeper than many of other active hydrothermal fields in the Okinawa Trough. Temperature of vent fluids was recorded as high as 338 ℃ at the Yubikuwae Chimney Vent, which is the highest temperature in the Okinawa Trough. Since its discovery in 2014, the Noho site has been investigated by some dive expeditions. This is the first scientific report for mineralogy and geochemistry of hydrothermal deposits (chimneys and mound ores) obtained from the Noho Site.
Most part of the seafloor in the Noho site is covered with sediment, whereas outcrops of lava flow were observed in the Hitoshi Site that is adjacent to the northern side of the Noho Site. Mound structures sometimes higher than 10 m are recognized as aligned along three parallel lines in the direction of northeast-southwest. Many chimneys at the top of the mounds are characterized by "flange structure", which extends laterally as if overlapping eaves. It is often observed that vent fluids emanated from chimney walls formed a pool below the flanges and overflowed from the rim. One giant complex chimney structure called Yakushiji Chimney associated with several layers of flange towered up at ~45 m high from the sediment basin.
Samples we studied were recovered during NT15-02 and NT15-13 cruises. Because most of the samples were fragile, we made polished sections after infiltrating epoxy resin. Identification of ore minerals were conducted by observation with a reflection microscope. We conducted also EPMA (Electron Probe Micro Analyzer) and EDS (Energy Dispersive x-ray Spectroscopy) analysis for chemical analysis of major ore minerals and identification of minor minerals.
A typical mineral assemblage of chimneys was dominant pyrrhotite ($Fe_{1-X}S$) and sphalerite (ZnS), and minor galena (PbS), cubanite ($CuFe_2S_3$), barite ($BaSO_4$) and anhydrite ($CaSO_4$). Dendritic texture of sphalerite and galena was commonly recognized in chimneys, which is considered as evidence for rapidly cooling. Specific texture indicating pyrrhotite growth towards the fluid pool was recognized in the flange part of chimneys. Another common type of chimneys was a sulfate chimney that composed of mainly barite. This type of chimney included pyrite and As- and Sb-minerals as sulfide minerals. Mound breccia was composed mainly of sphalerite, and minor galena, chalcopyrite and cubanite. As sulfate minerals, anglesite ($PbSO_4$) was identified, which might be secondary occurrence. In the mound breccia, barite was rarely identified.
Iron content in sphalerite was determined to discuss chemical condition for sulfide minerals precipitation. The chimneys of the Noho site showed Fe content in sphalerite as high as 18.30 mol%, whereas the mound breccia showed 8.95 mol %. These high Fe content suggest sphalerite precipitation in reductive environment. According to a compilation of Fe content among hydrothermal deposits in the Okinawa Trough, most of them were in a range from 0 to 5 mol %, and only few samples showed such high ratios.
Another specific characteristic of mineralogy of hydrothermal deposits from the Noho site is occurrence of pyrrhotite and cubanite. In hydrothermal deposits from other hydrothermal fields in the Okinawa Trough, chalcopyrite and pyrite were commonly observed as Cu-Fe-S minerals. The mineral assemblage of pyrrhotite and cubanite suggests low sulfur fugacity and reductive precipitation

environment, which is in accordance with the high Fe content in sphalerite. As well as the reductive precipitation condition, high temperature fluid as 338℃ could be favorable for formation of Cu, Pb, Zn -rich sulfide deposits in the Noho Site.

Keywords: Iheya Small Ridge, Seafloor hydrothermal deposit, Flange structure, NT15-02 Cruise, NT15-13 Cruise

