Hydrothermal fluid flow simulation in a seafloor vent area for metal resource estimation

*Shohei Albert Tomita[1], Katsuaki Koike[1], Tada-nori Goto[1], Katsuhiko Suzuki[2]

1. Kyoto University, 2. Japan Agency for Marine-Earth Science and Technology

Seafloor hydrothermal deposits are regarded to have high potential metal resources, which is crucial to Japan that relies on other countries for most metal resources. Iheya North Knoll is one of the promising seafloor hydrothermal deposits in Japan. In this area, many investigation data by seismic survey, sampling and chemical/physical analysis of drilling cores, and heat flow measurement have been accumulated. However, the large-scale temperature distribution and hydrothermal fluid flow pattern in this area have not been clarified yet. These thermal characteristics are important for estimating high potential zones of metal resources and assessing the reserves. Although numerical calculation is indispensable to clarify such thermal characteristics, the calculation for seafloor hydrothermal deposits is difficult due to lack of detailed information. Based on that background, this study aims to clarify geological structures, distribution of physical properties, and hydrothermal fluid flow pattern using TOUGH2 by selecting the Iheya North Knoll as a case study.
TOUGH2 can analyze gas-liquid two-phase flow and three-dimensional heat flow. The size of study area is 1.2 km from north to south, 4 km from east to west, and 2 km along the vertical direction. The seafloor was set as the top boundary where temperature and pressure were fixed at 4 ℃ and hydrostatic condition, respectively. As the initial condition, we set the hydrostatic pressure and 4 ℃ at the surface with thermal gradient 0.12 ℃/m, which is the average gradient in this area except for the vent sites, and physical rock properties by referring to the field survey data. The values of discharge rate, mass in rate, and permeability (hereinafter called *k*) were adjusted appropriately through trial and error. To realize the vertical flow of hydrothermal fluid from the deep part, a volcano conduit with $k = 10^{-13}$ m² was placed along the vertical direction from bottom to surface. Additionally, cap rock with $k = 10^{-16}$ m² were distributed near the surface to enable lateral hydrothermal fluid flow. Anisotropic *k* of the volcanic basement was set so that horizontal *k* was one order larger than vertical *k*, by considering a fact that thin impermeable layers were observed several times in the volcanic basement in the surveys. Under those conditions, we implemented the natural state simulation.
Through the simulation, we obtained a plausible hydrothermal fluid flow pattern and compared the calculated heat flux and temperature with the measured values. As a result, the calculated heat fluxes generally corresponded with the measured values, even around the discharge zone in which the flows tend to be complicated. As for the temperature profile at one drilling site, calculated temperatures were also consistent with the measured values in general except for the high temperature at 50mbsf. However, at a drilling site apart from the vent, calculations were about 30℃ higher than measured values. This overestimation is caused probably by that the recharge from the surface could not be expressed well in the present model.
The effectiveness of the present model was verified by the following two points. By a model without the volcano conduit, the hydrothermal fluid did not ascend to the seafloor along the vertical direction. Accordingly, the tendency of measured temperature and heat flux could not be reproduced. Furthermore, by a model with isotropic *k* of the volcanic basement with $k = 10^{-15}$ m², lateral hydrothermal fluid flow could not be expressed and trends of temperature and heat flux were far away from the measured values. Consequently, the location and physical properties of the volcano conduit and the permeability of volcanic basement were clarified as significant factors controlling the accuracy of hydrothermal fluid flow simulation.

Keywords: seafloor hydrothermal deposit, Iheya North Knoll, TOUGH2, heat flux, temperature