Reactive transport simulation for clarifying ore generation processes in the Izena Hole hydrothermal field, Okinawa Trough

*Shohei Albert Tomita[1], Katsuaki Koike[1], Tada-nori Goto[2], Katsuhiko Suzuki[3], Takafumi Kasaya[3]

1. Graduate School of Engineering, Kyoto University, 2. Graduate School of Life science, University of Hyogo, 3. Submarine Resources Research Center, Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Seafloor massive sulfide deposits have been attracting attention as new metal resources. Their exploration needs an understanding of the genesis of the deposits. Previously, we conducted a hydrothermal flow simulation of the Izena Hole hydrothermal field, Okinawa Trough and clarified the essential factors of ore generation: temperature distribution, phase separation zone, and fluid flow pattern. However, chemical factors that have a significant impact on the ore generation process, such as fluid chemistry, chemical compositions of fluids and rocks, and chemical reaction were out of our consideration. Aiming at clarifying more detailed ore generation processes by incorporating these chemical factors into the simulation, this study adopts a reactive transport simulation for the Hakurei site in the same hydrothermal field using TOUGHREACT software, which can handle coupled modeling of subsurface multiphase fluid and heat flow, solute transport, and chemical reactions.

A 2-D numerical model covering 2.0 km depth range by 4.5 km width below the seafloor was set for the simulation. Almost all model setting conditions were chosen based on the field observations (i.e., seafloor drilling, heat flux, temperature, and fluid geochemistry measurements). The left side of the model represented a fluid conduit (50 m width) where the hydrothermal fluid ascends from the bottom to the seafloor. The shallow subseafloor consists of alternating layers of pumiceous sediment, hemipelagic sediment, and low-permeable caprock. These layers were underlain by a volcanic basement. The initial and boundary conditions were set as shown in the figure.

To clarify a general pattern of chemical processes as a first step, simple geochemical settings were given by typical rhyolite composition of quartz (39%), oligoclase (26%), K-feldspar (22%), and annite (13%) for the initial rock. Secondary minerals by the water-rock interaction were anhydrite, pyrite, and sphalerite. Because of the limitation of the temperature range of the thermodynamic database (up to 300°C), the hydrothermal fluid source temperature was set as 300°C. Under those conditions, the numerical simulation was conducted for 5,000 years to understand mineral precipitation and accumulation over an order of thousands of years.

As a result of the simulation, the following features were derived: first, hydrothermal fluid ascended through the conduit and discharged from the conduit top, along with the lateral flow within the pumiceous sediments. Second, within the conduit and pumiceous sediments, low pH (approximately 4-5) and high concentrations of K^+, H_2S(aq), SiO_2(aq), Zn^{+2}, and Fe^{+2} were observed, due to the hydrothermal fluid flow, whereas SO_4^{-2} was recharged to the shallow subseafloor by the seawater percolation. Third, when hydrothermal fluid ascended through the conduit, oligoclase and annite dissolved into the hydrothermal fluid, whereas K-feldspar, anhydrite, pyrite, and sphalerite precipitated from the hydrothermal fluid. Fourth, in the shallow subseafloor, laterally flowing hydrothermal fluid and percolating seawater were mixed and resultantly, pyrite and sphalerite precipitated primarily beneath the mound (the conduit top), with a lateral extension. In addition, anhydrite, quartz, and K-feldspar precipitated in the shallow subseafloor, with much precipitation near the conduit top. Those features generally correspond with the field observations (i.e., drilling and fluid geochemistry).

Because of the above-mentioned thermodynamic database limitation, our simulation temperature is slightly lower than the maximum observed temperature (326°C). Thus, our next step is to develop the thermodynamic database for a wider temperature range, e.g., 0-370°C, and incorporate the phase separation and its effect on fluid chemistry into the simulation.

Keywords: numerical simulation, TOUGHREACT, seafloor massive sulfide, mineral precipitation, chemical reaction