Resistivity Structure around Off-Okinawa Hydrothermal Area Using Two-Dimensional Inversion of Marine DC Resistivity Survey

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Global demands for metal resources have increased interest to development of deep-ocean hydrothermal ore deposit called as SMS (Seafloor Massive Sulfide). SMS deposits, including rare and precious metals, have been often found out around hydrothermal active areas; for example in the Okinawa and Izu-Bonin areas, located in the Japanese Exclusive Economic Zone, and in the mid-Atlantic ridge. Geophysical explorations with electromagnetic (EM) methods are recently carried out around the SMS deposits because the SMS deposits are known as low resistivity material and the resistivity distribution below the seafloor can be a good indicator for the buried SMS deposits. However, the resistivity structure below hydrothermal active areas has not been clearly investigated. In this study, I developed a two-dimensional inversion of a marine deep-towed DC resistivity survey as an effective tool to exploration of SMS deposits. Marine deep-towed DC resistivity survey system was originally developed as a sensitive tool to gas hydrate, but the numerical simulations how the survey is sensitive to the SMS deposits have never been conducted. The inversion developed in this study is based on the model space Occam’ s inversion method and the finite-difference method is applied in the forward modeling calculation to solve potential difference between electrodes at the electric-current injection to the seawater. We tested the system using the synthetic data and found that the inversion can estimate the buried SMS deposits effectively. The first test is based on newly-developed inversion with smoothness constraint, frequently used to solve ill-posed inverse problems. Although the ordinary constraint assuming a smooth model can detect the low resistivity anomalies, the real distributions of SMS deposits are concentrated at narrow (thin) zones, and cannot be treated as the smooth model. In order to obtain sharp-change of resistivity matching the petrophysical information, I add a guided Fuzzy C-Means (FCM) clustering constraint into the objective function in the inversion procedure. Two balance parameters in this objective function should be controlled in the inversion, but the optimal ways to adjust these parameters have not been proposed. Therefore, I propose an algorithm to choose these parameters properly. The new algorithm is based on the two stages; the first stage with the ordinary Occam scheme, then the second stage with the FCM constraint where the inverted model and parameter in the first stage are the initial model and the fixed parameter. The other parameters are decided with the scaling scheme. The refined inversion results show that the inversion with the FCM constraint can produce sharp boundaries in resistivity structure, which can handle with the realistic petrophysical information. Finally, I applied the inversion code to the field data obtained at the Okinawa Trough; the inverted resistivity anomalies are consistent with the known geological investigations of hydrothermal fluid flows and the observed distributions of seafloor venting sites.

Keywords: Direct Current resistivity survey, Seafloor massive sulfide deposits, Inversion

