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Feasibility study of marine CSEM survey for exploration of submarine massive sulphide deposits

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The recent growth of world-wide requirement of metals demands advanced explorations for finding metal mine and deposits. Especially, the submarine massive sulphides (SMS) have attracted mining companies because of its compactness with high grades. However, few exploration techniques were developed to evaluate the thickness of SMS and to find the buried SMS.
Marine controlled-source electromagnetic (CSEM) survey can give us information of sub-seafloor structures, and is intensively applied to exploration of hydrocarbons (oil / gas) in the recent years (e.g., Constable and Srnka, 2007). However, the character of the SMS is quite different from the hydrocarbons. For example, the electrical conductivity of SMS is higher than the seawater (e.g., 5 S/m) but the value of hydrocarbon is typically 0.01-0.03 S/m. The target depth of SMS deposits is from 0 to 100m below the seafloor, while the range for hydrocarbon explorations is from 100m to several km below the seafloor. These differences request modifications of conventional CSEM technique for the SMS explorations. If we find a new method suitable for finding the very conductive material below the seafloor, it will be a powerful tool for evaluating the sub-seafloor distribution of SMS deposits.
In this study, we demonstrate a feasibility how the electromagnetic sounding methods are effective to find the sub-seafloor highly conductive materials such as the SMS. On the basis of numerical calculations, we tested the various marine electromagnetic soundings: magnetometric resistivity (MMR) survey, conventional CSEM survey and marine DC resistivity survey. For the CSEM survey, a configuration with short source and receiver dipoles is also tested, which is for application to remotely operated vehicles (ROVs) or autonomous underwater vehicles (AUVs). For these various marine electromagnetic surveys, a common sub-seafloor structure is prepared, having a layered feature with a sea layer (water depth of 1400m, 3.3S/m), a sedimentary layer (1 S/m) and a highly conductive layer (thickness of 20m, 5S/m). We varied the top depth of the highly conductive layer (typically 25m below the seafloor) or removed it, and obtained various electromagnetic responses.
We found that the electromagnetic responses of each marine electromagnetic survey are very sensitive to the buried conductive materials simulating the SMS deposits. For example, the MMR survey will give abnormal large magnetic field (>20%) with a source-receiver separation larger than 150m, if the conductive layer is buried. Also, the CSEM method with short source dipole length of 5m makes anomalous attenuation of magnetic field (>30%) with a source-receiver separation larger than 50m. In the latter case, the received electric field with short dipole length of 5m also show us abnormal attenuation of electric field (<10%) with large source-receiver distance (>100m). Thus, we conclude that the CSEM techniques, especially using magnetic field as received responses, can be used for imaging the sub-seafloor SMS deposits. Especially, the result from the short source dipole gives us a chance for developing quite new CSEM techniques with ROVs and AUVs.

Keywords: marine CSEM, electromagnetic survey, submarine massive sulphide, seafloor, AUV, ROV