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Electrical resistivity structure of a seafloor hydrothermal system at the southern Mariana Trough spreading axis

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The electrical resistivity structure of the shallow crust is sensitive to the porosity of the crust and seawater temperature within the crustal pore. Therefore, by revealing the electrical resistivity structure of the shallow crust around a hydrothermal system, we can reveal the horizontal and depth distribution of seawater associated the hydrothermal system. In this study, we estimated the electrical resistivity structure around the southern Mariana Trough spreading axis (Snail site;12_57'N, 143_37.2'E) with the Magnetometric Resistivity (MMR) method which is effective to reveal the shallow (~1000m) electrical resistivity structure. The MMR survey was carried out during the KR03-13 cruise of R/V Kairei from Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The vertical bipole source was applied between two electrodes near the sea-surface and just above the seafloor to generate an artificial electric current. Five Ocean bottom electro-magnetometers (OBEMs) were deployed as receivers around the active hydrothermal site to record variations of magnetic field induced by currents flowing into the crust. We determined the one-dimensional crustal electrical resistivity structure by the method of least square by comparing the observed amplitude of induced magnetic field with the analytical solution of Edwards et al. (1981, 1984). Also, we determined the three-dimensional crustal electrical resistivity structure by the trial-and-error method using three-dimensional forward modeling (Tada et al., in prep.) to reproduce the distribution of the magnetic field anomaly. Magnetic field anomaly was calculated from differences in the amplitude between the observation and the prediction from the one-dimensional model determined by the method of least square. We determined the one-dimensional crustal electrical resistivity of 5.6 Ohm-m to a depth of 1500m. We estimated the temperature of crustal pore fluid between 0 and 390 deg C, and increases with depth, from 5.6 Ohm-m uniform structure, a crustal porosity profile at the Hole 504B (Becker, 1989), and Archie's law (Archie, 1942). We also estimated the three-dimensional crustal electrical resistivity structure around the hydrothermal site based on the uniform one-dimensional model. We found that there are four low crustal electrical resistivity regions around the hydrothermal site. These regions have the resistivity of 0.6 Ohm-m, expose at the seafloor, and these maximum depth is 200m. One low resistivity region is located near the Snail site and the others are away to northwest by ~350m from the Snail site. The low resistivity regions of 0.6 Ohm-m correspond to the temperature of crustal pore fluid of between 109 and 148 deg C, is constant at a depth of 200m from the seafloor. If the temperature of pore fluid in the region with the resistivity of 0.6 Ohm-m is supposed to be 0 deg C, which was estimated to be the temperature of pore fluid in the uniform 5.6 Ohm-m resistivity region, the porosity of this region is required to be approximately 60%. However, the crustal porosity of approximately 60% is not realistic because crustal porosity at a young crust is observed to be 34% (Pruis and Johnson, 2002). Therefore, the low crustal electrical resistivity regions suggest the existence of hot pore fluid because the highest porosity region can not have low crustal electrical resistivity. We conclude that there are four low crustal electrical resistivity regions which suggest the existence of hot pore fluid around the Snail site, one is near the Snail site and the others are away to northwest by ~350m from the Snail site.

Keywords: Southern Mariana Trough, seafloor hydrothermal system, Magnetometric Resistivity method