A sand-box experiment for understanding marine self-potential anomalies

*Yoshifumi Kawada[1,2], Takafumi Kasaya[2]

1. International Research Institute of Disaster Science, Tohoku University, 2. Japan Agency for Marine-Earth Science and Technology

The marine self-potential method has advantages in detecting hydrothermal ore deposits by its simple observation procedure: Only towing multiple electrodes connected with a voltmeter in the seawater can detect signals from ore deposits up to 100 m above the seafloor. The self-potential signal is negative above ore deposits in most cases (e.g., Sato et al., 2017; Safipour et al., 2017; Kawada and Kasaya, 2017, 2018; Constable et al., 2018). At present, there is only one example of a positive self-potential anomaly observed at the Oomuro-Dashi (Kawada and Kasaya, JpGU2019).

The self-potential signals from ore deposits are probably explained by the geo-battery mechanism of Sato and Mooney (1960), in which an oxidative and reduced environments are connected by an electric conductor. A negative self-potential is expected above the oxidative (upper) side of the conductor; a positive signal is expected below the reduced side, where the conductor is being corroded. In the marine environment, the oxidative environment is maintained by seawater, the reduced environment is due to reduced sub-seafloor sediments, and an ore body crossing these environments can be a conductor. The oxidative-reduced boundary is not necessarily the seafloor itself because the recharge of seawater could deepen the boundary. In this case, a completely buried ore body may be detected above the seafloor. In this presentation, the concept of geo-battery mechanism extending to the marine environment is tested by an analog experiment inspired by Rittgers et al. (2013).

To set up the marine environment, a plastic container of 35 by 50 cm footprint and 30 cm height is filled by a 10-cm-thick sand layer filled with saline water (~3.5 wt%NaCl) mimicking the surface sediment and another 10-cm-thick layer of saline water above the sand layer for the ocean. Steel bars (mostly, 5-cm-long and 2-cm-diameter) mimicking ore deposits are installed in the sand layer with the top 0 to 1cm being exposed from the layer; an exposed ore deposit is approximated. The system is kept at rest for over a month. Two Ag/AgCl electrodes, one fixed at a corner of the plastic container and another moved by hand manipulation within saline water, connected to a voltage logger are used to scan the distribution of self-potential inside the container. Reference electrodes for general chemistry are used because of their small diameter (~2 mm), but electrodes designed for marine electromagnetic surveys (3 cm diameter; manufactured by Clover Tech Inc.) can be used as well.

From the very beginning of the experiment, we can detect negative self-potential anomalies above exposed steel bars, whose order is of the order of 10 microvolts. An almost completely buried steel bar is also accompanied by a negative self-potential anomaly. The results are reproducible including their amplitude, indicating that this is a quasi-steady-state behavior. In this case, steel bars above the sandy layer are not under corrosion but those below the sand are corroding. Though a very rare case, a positive self-potential anomaly was observed near the boundary between the sandy layer and a steel bar. However, this is not always the case, indicating that this is a time-dependent behavior. In this case, corrosion is occurring above the sand or near the boundary. The positive self-potential anomaly observed at the Oomuro-Dashi might be reflected by progressive corrosion occurring at or near the seafloor.

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