Characterization of marine hydrothermal deposits from petrophysics and frequency-domain central loop electromagnetic soundings

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SUMMARY

The development of geophysical methods for the assessment of spatial extent, composition, and inner structure of seafloor massive sulfide (SMS) deposits is crucial to evaluate their resource potential for future deep-sea mining prospects. Challenges to acquire high resolution near-surface electromagnetic (EM) data in such geologically and morphologically complex marine environments have been addressed by our recent development of the deep-sea profiler GOLDEN EYE that utilizes a frequency-domain EM in-loop sensor, 3.5m in diameter. This system has been used to map active and relict hydrothermal vent fields in the German License-Areas for polymetallic sulfides at the Central- and Southeastern-Indian-Ridge in 2015 and 2017. Aside from technological developments, new data processing routines and methods to unravel the conductivity-depth-distribution, induced polarization and magnetic susceptibility are important milestones. This paper will address a combined interpretation of marine field data and petrophysical laboratory analysis.

In-situ magnetic susceptibility, electric conductivity and chargeability data of the Edmond hydrothermal area were resolved from half-space models with complex and frequency-dependent conductivity (Figure 1). Lateral dimensions of active and inactive (partly buried) hydrothermal deposits were clearly mapped and classified by EM derived petrophysical properties. In contrast to time-domain data where chargeability often contributes with negative sign and counteracts the conductivity signal, both, chargeability and conductivity, amplify the signal amplitude with specific frequency and phase dependency.

The subsurface architecture is approximated from 1D inversion and 3D gridding techniques. The volume of sulfide-bodies and mineral characteristics were derived from marine field data in combination with electrical impedance spectroscopy and rock magnetic analysis of 33 inch-sized SMS samples from the working-area. Cross-plots of conductivity versus chargeability, time-constant and porosity confine pore-fluid and sulfide-mineral contributions. Our findings emphasize the benefit of combined susceptibility-conductivity-chargeability modelling to retrieve a comprehensive image of compelling near-surface properties, to localize high-grade ores and to derive the subsurface-architecture of hydrothermal deposits.

Figure 1. Maps of apparent magnetic susceptibility (a), electric conductivity (b) and chargeability (c) depict the lateral extends and characteristics of active and inactive hydrothermal mineral deposits of the Edmond vent site (23°53' S, 69°36' E) in 2900 to 3300 m water depth. White dots mark sample locations; X and Y in meters.

Keywords: Marine Near-Surface EM, Mineral Deposits, Frequency-Domain EM, Chargeability, Petrophysics