6. CONCLUSIONS

This numerical modeling study has investigated the fundamental physics of galvanic source EM methods and demonstrated how galvanic source EM methods can sense a thin resistor effectively.

Unlike the loop TEM and MT methods, the GESTEM method generates vertical as well as horizontal transient currents. The rapidly diffusing and highly concentrated vertical current interacts with a thin horizontal resistor and thus can produce a measurable perturbation in the surface electric field. In contrast, the loop TEM and MT methods fail to sense a thin horizontal resistor because their responses are inductive. In using the GESTEM method, the magnitude of perturbation to a thin resistor depends on the source waveform. When the step-off waveform that mainly consists of low frequency signals is employed, the perturbation due to a thin resistor is relatively small. An alternative to analyzing the electric fields directly from the step-off responses is to take the time-derivatives in order to approximate impulse responses and thus provide higher frequency information. The detailed analysis of non-standard transient EM transmitter waveforms and their sensitivities to resistors is necessary and left for future work. In order to improve the magnitude of perturbation, especially due to a localized small 3-D resistor, the diffusion angle of the vertical transient current, 45º should be considered to make vertical currents coupled to a resistive target efficiently. The major drawback of the GESTEM method lies in the fact that the GESTEM sounding is very sensitive to near-surface inhomogeneity. Thus, it is required to develop 2-D or 3-D interoperation schemes rather than force layered-earth models to fit the responses of 2-D or 3-D structures.

The marine FDCSEM and TDCSEM methods have been investigated numerically, and compared to the MMT method. In contrast to the MMT method, the marine FDCSEM and TDCSEM methods are very sensitive to thin resistive hydrocarbon reservoirs at depth, since their response is both galvanic and inductive. For the FDCSEM method, the location of the normalized peak response is determined by where the airwave starts to dominate seafloor EM responses in the background model. This point is a function of source frequency, seawater depth and seafloor resistivity. The peak magnitude depends on whether the high concentration of vertical currents can reach and interact with the reservoir effectively or not. Bathymetry is another important factor for the peak magnitude and thus high quality bathymetry data should be collected for an accurate interpretation of the FDCSEM data. The magnetic field responses are similar to electric ones but the benefit of using magnetic field responses is that the noise level contour of the magnetic receiver theoretically allows for greater surface coverage compared to that of the electric receiver.

Like the GESTEM method, the TDCSEM method also requires the use of a proper transient EM pulse such that relatively high frequencies are produced. The impulse response of the TDCSEM method is characterized by two-path diffusion of the EM signal. The initial response is caused by faster signal diffusion through the less conductive seafloor, while the later arrivals result from slower diffusion through the more conductive seawater. Therefore, at larger separations, the effects of the seafloor and seawater are somewhat separable. This can be useful in relieving the airwave problem associated with the FDCSEM method in shallow marine environments. The detailed investigation of non-standard TDCSEM source waveforms and their responses is left for future work.

This modeling study illustrates that the vertical electric field measurements on the sea floor can be a useful additional measurement for both the marine FDCSEM and TDCSEM methods. In contrast, the vertical electric field measurement is not useful for the MMT method.

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