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Special Section

Marine controlled-source electromagnetic methods — Introduction

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We are very pleased to introduce this special section containing papers related to marine controlled-source electromagnetic (CSEM) methods. As you will read in the first paper, by Constable and Srnka, marine CSEM methods have been used in academia since the early 1980s. However, their application to resource exploration has developed only recently.

Since 2000, academic and industry surveys have increased rapidly, with relatively slower advancement in processing and interpretation methods. This is changing as contractors, oil and gas companies, and academic institutions alike are increasing their efforts to exploit this method and its ability to measure remotely one of the most fundamental of earth physical properties, electrical resistivity, as it relates to hydrocarbons. This body of work constitutes the first concerted peer-reviewed publication effort on the topic, as it relates to resource exploration, and it represents a significant milestone in evolution of the technology, particularly in the oil and gas industry. Even as a recent application, marine CSEM methods already have demonstrated their usefulness for interpreting the presence or absence of hydrocarbon reservoirs (e.g., Ellingsrud et al., 2002; Carazzone et al., 2005; Choo et al., 2006). Marine CSEM methods are destined to see more widespread use in the future, and we hope this special issue will facilitate further research and development on the topic.

By invitation and open solicitation, papers for this section were compiled with the intent of representing the breadth of problems being investigated within the marine CSEM community. Thus, we include papers that cover numerical simulation, inversion, unconventional acquisition, reservoir characterization, and case study.

Appropriately, we start the special section with a review from Constable and Srnka that presents a historical perspective on marine CSEM with particular focus on how methods were developed from the early years at several academic institutions to the first commercial surveys and modern equipment and acquisition. We continue with a tutorial from Um and Alumbaugh that investigates, through simulation and visualization, the basic physical phenomena of diffusive electromagnetic fields in a conductive earth.

An important problem in marine CSEM, as with all remote-sensing methods, is the quantification of data noise and inverse model uncertainty. Christensen and Dodds present a noise model for CSEM data as well as instructive results for linearized uncertainty estimation derived from the 1D inverse problem. As a first step toward tackling this formidable issue, their paper sets the stage for much future work required to understand how uncertain we are in our solutions to multidimensional diffusive EM problems in marine environments.

Along with conventional marine CSEM acquisition, Scholl and Edwards present ideas for the use of borehole-to-surface CSEM as a means to better sample and constrain thin resistive bodies in the subsurface. Because of the highly dispersive nature of low-frequency electromagnetic fields, resolving discrete formations and sensing deep resistors constitute considerable challenges for the method. A partial solution to these difficulties is to sample the earth at depths as well as at the surface. Although there are specific challenges to the acquisition of such surface-borehole fields, the technique may allow for applying marine CSEM methods to depths significantly below the current limitations of approximately 2–2.5 km. In addition, more complex and challenging targets may be investigated.

Three papers provide insight into methods for more accurate simulation and fast inversion of electromagnetic fields. Works by Li and Key, Li and Constable, and Zhdanov and Grebenko investigate a finite-element formulation, the bathymetric effect, and a fast integral-equation inverse solution to the problem of interpreting data in realistic marine settings, respectively. Because conventional marine CSEM surveys employ sea-bottom receivers and deep-towed sources, near-field bathymetric fluctuations create significant variability in recorded fields and must be taken into account as accurately as possible. Unstructured finite-element solutions, such as that presented by Li and Key, provide for local mesh refinement and accurate

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representations of seafloor variations while maintaining the computational benefits of sparse matrix solvers.

Finally, studies by Chen et al., Darnet et al., and Evans address specific challenges in interpreting marine CSEM data for shallow sedimentary structures and hydrates as well as for hydrocarbon presence and reservoir properties. This topic is perhaps the timeliest because marine CSEM applications are used in more complex geologic settings where overburden heterogeneity, shallow resistors, and ever more subtle target signatures are being investigated. In moving toward a more comprehensive use of geophysical methods, the work by Chen et al. seeks to elucidate methodologies for jointly interpreting seismic AVA and marine CSEM data for reservoir characteristics.

The publication of this body of work was possible only through the collaboration of many people. We wish to thank the SEG publications staff members who provided much assistance and guidance. In particular, Judy Wall and Sheral Danker were instrumental in the submission process of papers in the special section. We also would like to thank Julie Colley and Sarah Tyler of the editorial staff for their ongoing support of the special section. In addition, the diligence of the authors and other reviewers allowed for the short turnaround times required to meet the tight review and compilation deadlines. We also would like to thank the SEG editor, Yonghe Sun, for his efforts in facilitating the entire process, urging us coeditors forward, and supporting a special section on this topic.

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