Introduction to this special section: Gravity, electrical, and magnetic methods

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Geophysics plays an important role in all aspects of geologic analysis, spanning from regional exploration and tectonic mapping to local prospect-level studies and energy transition projects. Out of a variety of geophysical techniques, seismic methods often play the most central role, while less expensive nonseismic methods are less frequently applied. One of the objectives of SEG's Gravity and Magnetics Committee is to promote nonseismic geophysical methods and showcase their value in various geologic applications. As members of that committee, we, the editors of this special section, assert that gravity, magnetic, and electrical methodologies are powerful yet often undervalued tools. We present this special section focused on nonseismic geophysical methods and the impact they can make on various geoscience projects. Included here are a regional tectonic study in Antarctica, a local mining exploration mapping project in Canada, and an analytical methodology capable of providing critical information about subsurface geology and helping to determine the depths of important geologic structures. Although our scope is to provide a broader discussion of different types of nonseismic techniques, all of the papers presented in this special section focus on magnetic surveying.

We open our special section with "Magnetic data — What am I looking at" by Bates et al. This paper was initiated by the SEG Gravity and Magnetics Committee and intends to address the confusion that may exist in the exploration community related to the variety of magnetic deliverables and their sometimes confusing names. People often refer to the result of magnetic surveying as "the magnetic map," but when asked about the type of map or what corrections (if any) were applied to it, a puzzled look is the frequent response. This paper aims to address the general confusion about different magnetic parameters and naming conventions — i.e., addressing what exactly "the magnetic map" shows — using a set of aeromagnetic data over the Oka Complex of Quebec, Canada. The Gravity and Magnetics Committee intends to follow up with a similar paper for the gravity methodology, and we are happy to expand to other methods if we receive requests from the broader community.

The second paper presents a magnetic study in Antarctica. Ferrara et al. analyzed airborne magnetic data sets acquired by the British Antarctic Survey over the West Antarctic Rift System. Despite being one of the largest rifts on earth, this geologic region remains poorly understood because it is buried under at least a kilometer-thick ice cover. It is important to understand the complex geologic setting beneath the West Antarctic Ice Sheet (WAIS) in order to evaluate its impacts on ice sheet dynamics, to assess the ice sheet response to climate change, and to predict its future behavior. Studying subglacial geology beneath the WAIS requires geophysical methods. Magnetic surveying is perfectly suited for surveying inaccessible areas because of the efficient way in which data can be captured, e.g., by a plane or helicopter. The presented multiscale analysis of magnetic data not only resulted in outlining the large tectonic zones, such as the Pine Island Rift, Byrd Subglacial Basin, and Bentley Subglacial Trench, but also made it possible to identify structural features beneath the ice, such as contacts-like or fault sources, dykes, sills, volcanic necks/conduits, and spherical source distributions, as well as to estimate their depth and delineate several interesting tectonic trends. The study maps various geologic features that can be further linked to potential magmatic sources that influence the formation and evolution of the West Antarctic Rift System.

The last paper in our special section, by Thurston and Fornberg, describes the analytic continuation of potential fields to a vertical complex plane using rational complex-series expansion (Padé approximation). The paper presents synthetic examples of potential geologic magnetic sources, such as point and 2D sources, sheets with finite depth extent, thin slabs, and contacts. The use of Padé approximation provides stable downward continuation for distances that are significantly greater than those achievable by Taylor series or by spectral methods. The analytically continued fields for these objects exhibit polarity flips near the source location, which can be used to interpret the source geometry based on the shape of the approximating function. In addition to synthetic examples, the authors also ground truth their methodology by application to the helicopter-based magnetic survey acquired over the sulphide ore deposits in a Canadian greenstone belt. It is noteworthy that in the study area, magnetic rocks associated with ore deposits are overlain by nonmagnetic sedimentary rocks, which prevents surface-based geologic mapping and requires geophysical exploration to map subsurface features. The result of the authors' analytic continuation methodology agrees well with the recent wells in the study area, thus revealing the value of the Padé approximant for subsurface analysis.

In closing, we thank the authors who submitted papers to this special section. We hope that the collected papers will help readers develop a greater appreciation of magnetic surveying in particular and nonseismic geophysical methodologies in general. We remain committed to our goal of promoting the value of nonseismic geophysical methods to the broader geoscience community, as we are highly confident that gravity, magnetic, and electromagnetic methods will play a critical role in addressing some of the challenges associated with the energy transition. TLE

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