Geomagnetic Modeling with COMSOL Multiphysics® Software

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Abstract

Geomagnetic methods can be utilized in a wide range of applications, ranging from small-scale investigations to detect metal scraps near surface and large-scale geologic studies to determine spreading rates of oceanic crust. Using the observed magnetic data, geoscientists apply various quantitative interpretation approaches in order to constrain information regarding the depth to a particular magnetic body, its size and shape, and the orientation and magnitude of its magnetization. The accuracy of the information derived from the data is normally governed by the quality and amount of available data and by the sophistication of the employed modeling techniques. Here we aim to advance geomagnetic modeling approaches using COMSOL Multiphysics® and improve the degree of detail the can be obtained from the measured magnetic field. First, we carried out benchmark tests by comparing the computed results using the widely used analytic solutions for rectangular bodies with arbitrary direction of magnetization [1] with those from the AC/DC Module of COMSOL Multiphysics®. For this purpose, we built a synthetic model of three rectangular bodies situated at different depths [Figure 1]. These objects were regarded as magnetite ores having 30 A/m intensity of magnetization. In addition, we assumed that the magnetization direction of the blocks is same as the geomagnetic field direction. The applied inclination and declination values were 50° and 7.7° respectively, which are the Earth's field direction at Daejeon, South Korea. Comparisons of COMSOL-based results [Figure 2] with the analytic-based ones exhibited good agreement in general. COMSOL-based results, however, appeared to be limited by the size of modeling domain when to compute long-wavelength magnetic signals. We may circumvent such limitations by removing long-wavelength components from the data before modeling only if short-wavelength features are of main interest [2], and by applying boundary element method. Second, we will use bathymetric and marine magnetic data obtained at seamounts in order to model the magnetization direction of underwater volcanic structures. Such geologic information can be very crucial to determine the age and location of seamount formation [3]. Traditional magnetic methods often assume the uniformly magnetized seamounts to simplify computational efforts. However, the inner structures of seamounts constrained by seismic data show a clear distinction between the dense core and edifice layers [4]. Although neglecting small features of a magnetic body would affect modeling insignificantly, the major features such as the dense core and the edifice of seamount must be considered properly. Here we divide the seamount into the dense core and the edifice layers in COMSOL, assign different magnetization direction and intensity to them, and optimize these parameters by minimizing differences between the observed and calculated data. These predicted results will be valuable to understand seamount formation processes in detail. Thus,

functionality and expandable capability of COMSOL Multiphysics® in geomagnetic studies is very promising.

Reference

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Figures used in the abstract

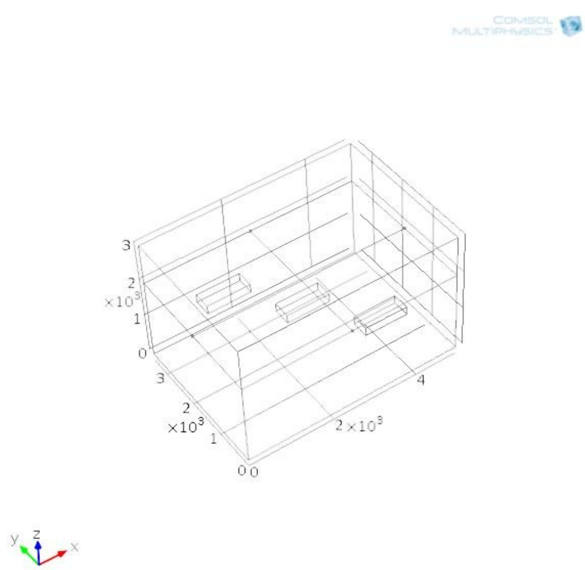

Figure 1: Magnetized rectangular bodies located at different depths.

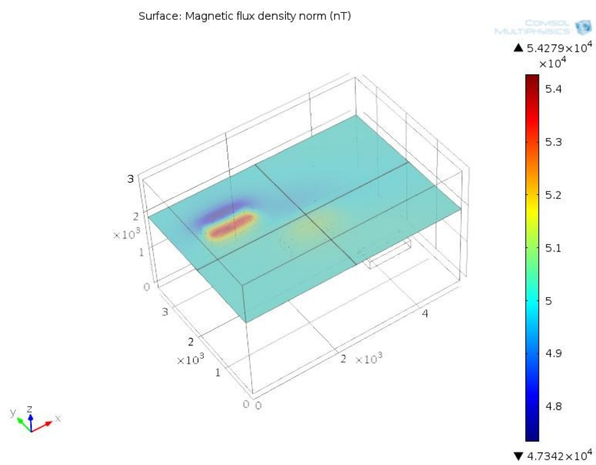

Figure 2: Predicted magnetic anomalies due to the three rectangular bodies using COMSOL.