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3D subsurface imaging by aeromagnetic data: regularization with effective source volume minimization

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In survey methods using potential field such as in aeromagnetics, there is a theoretical difficulty of non-unique source solution for the observation, whereas data includes structural information of wide depth range. In order to overcome this difficulty, the analysis methods with any structural regularization have been developed, and the validity of the strategic regularization would be a primary concern in practice.
In this paper, we deal with the effective method of 3D subsurface imaging from the helicopter-borne aeromagnetic anomaly data in a mountainous region. Based on the works by Li and Oldenburg (1996), Pilkington (1997), Portniaguine and Zhdanov (2002), etc., we discussed the simple minimum norm solution of 3D subsurface imaging, and pointed out the importance of the parameter scaling related to the volumes of source models (Nakatsuka and Okuma, 2006). However, the simple minimum norm solution cannot give a focused image of subsurface structure, but tends to result in a broader shape of source with vague boundary especially towards deeper side as an equivalent source model. It is expected that we can overcome this point by the introduction of the compactness criterion (Last and Kubik, 1983; Portniaguine and Zhdanov, 200 2).
In treating the actual magnetic anomaly data, it is obvious that the resolving power for the subsurface structure depends on its depth, and the modeling with variable source size (coarser at deeper sources) is preferable. Portniaguine and Zhdanov (2002) used a method of minimizing the number of discrete sources, which actually minimizes the source volume, because they discussed the model consisting of constant volume cubes. If we use an analysis model with the ensemble of variable volume blocks, the scheme of minimizing source volume is a little different. We are developing the analysis scheme for such model.
In the process of iterative solution of the problem, the trade-off parameter e plays an important role. To minimize the misfit term, e is decreased during iteration process. However, if e is decreased too fast, the existence of regularization term becomes ineffective and the solution resembles the minimum norm one. To make sure the solution is compact, relatively large value of e should be maintained as long as possible.

Keywords: aeromagnetic survey, helicopter survey, mountainous region, 3D imaging, compact inversion, source volume minimization