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Interpretation of gravity data using logistic function and total horizontal gradient (LTHG) - A case study: Charak anticline

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Extended Abstract

Summary

Determination of the boundaries and edges of gravity anomalies is of particular importance in the interpretation stages of geological and tectonic structures. In this paper, the ability of different edge enhancement filters, such as total horizontal gradient, analytical signal, tilt angle, total horizontal derivative of tilt angle, theta map, normalized total horizontal derivative, and tilt angle of total horizontal gradient to determine the edges of synthetic and real gravity anomalies is examined and compared. Moreover, in this research, another filter based on logistic function and total horizontal gradient filter is introduced. In order to evaluate the ability and quality of the total horizontal gradient logistic filter in determination of the boundaries of gravity anomalies, first, the filter is applied to the synthetic gravity data of prisms having different depths and density contrasts with noise and without noise, and after observing successful efficiency of the filter on the synthetic gravity data, it is applied on the gravity data related to Charak anticline in Hormozgan Province, Iran. Based on the obtained results, it can be concluded that this filter is superior compared to other boundary filters, and the obtained results are in good agreement with the geological information of the study area. Hence, the total horizontal gradient logistic filter can reliably be used in the qualitative interpretation of gravity anomalies. The synthetic gravity model, results and filter algorithm have been prepared in MATLAB program environment.

Introduction

Edge determination filters play an essential role in the interpretation of potential field data. In recent years, edge enhancement methods have been widely used in the interpretation of mineral exploration and tectonic studies data. These filters are mainly defined based on horizontal gradients and vertical magnetic and gravity data. In this paper, the ability of different filters in order to determine the edges of synthetic and real field gravity anomalies is investigated and compared. The filters, used in this paper, include total horizontal gradient, analytical signal, tilt angle, horizontal derivative of total tilt angle, theta map, total horizontal derivative of normalization and total horizontal gradient tilt angle. The main purpose of this study, while introducing the total horizontal gradient logistic filter, is to investigate the ability of some common filters to determine the boundaries of gravity anomalies. These filters are more applicable in recent years.

Methodology and Approaches

The introduced filter in this paper is the logistic function of the total horizontal gradient (LTHG), based on the ratio of the vertical derivative to the total horizontal derivative and the logistic function. This filter is used to determine the edge of small and large amplitudes of potential field anomalies. The idea of introducing this filter is that the logistic function is a mathematical function that produces a sigmoid curve. The logistic function has a S shape, which is a much like the reverse tangent function in TA, TDX and TTHG filters that can be used for edge enhancement of potential field

anomalies. The LTHG filter is defined as follows:

$$LTHG = \left[1 + \exp\left[-\frac{\frac{\partial THG}{\partial z}}{\sqrt{\left(\frac{\partial THG}{\partial x}\right)^2 + \left(\frac{\partial THG}{\partial y}\right)^2}}\right]\right]^{-\alpha}$$

The α variable is a positive constant that controls the filter efficiency of the total horizontal gradient logistic function and its value is determined by the interpreter. However, the results obtained on synthetic models have shown that the α numerical value should be considered between 2 and 10 for different models (Pham et al., 2019). The main characteristic of the filter is the maximum amplitude on the edges of the anomaly, the insensitivity to increase the depth of the source, and the balancing of the anomalies resulting from deep and shallow sources (Pham et al. 2019). All maps and computations in this study have been carried out using MATLAB software.

Results and Conclusions

The results obtained from applying the LTHG filter on the synthetic model, even with the presence of high noise, show that the boundaries of gravity anomalies at different depths are well identified, indicating that the low sensitivity of the LTHG filter to noise is less than the other edge enhancement filters used in this research. The LTHG filter is suitable for determination of the edges of potential field anomalies because it is independent of depth. In this filter, the boundaries of thick and thin synthetic sources are well determined. The main purpose of this study has been the determination of the boundary between Charak anticline and salt, and also, identification of deep faults using the LTHG filter that cannot be extracted directly from the gravity map of the study area. The maximum amplitude of the LTHG map indicates the edge of anomalies. The salt in the anticline, deep faults and the main boundary of Charak anticline are clearly visible in the LTHG map.