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3D inverse modeling of magnetic survey data and comparison of the results with drilling data in the Negin exploration area, Yazd Province

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Extended Abstract

Summary

The exploration of hidden mineral deposits beneath Quaternary sediments has become crucial due to the depletion of near-surface resources and increasing global demand. This study focuses on the Negin exploration area in Yazd Province, Iran, aiming to determine the geometry, depth, and extent of subsurface ore bodies using high-resolution ground magnetic survey data. Field data were preprocessed for diurnal correction, international geomagnetic reference field (IGRF) removal, and filters such as reduction to the pole and analytical signal, using Oasis Montaj software. Three-dimensional (3D) inverse modeling of the data was performed using the Li and Oldenburg algorithm in MAG3D software, applying depth weighting and reference model constraints to accurately estimate the subsurface magnetic susceptibility distribution. The results revealed a semi-ellipsoidal intrusive body with high magnetic susceptibility in the central part of the area. Quantitative analysis of the results indicates that the top of this anomaly is approximately 60 meters below the ground surface, consistent with exploratory drilling results. Constrained 3D inversion improved model reliability by reducing non-uniqueness and aligning the results with geological expectations. The high degree of correlation between the 3D model and exploratory drilling data demonstrates the efficacy of constrained inverse modeling in reducing inherent uncertainties associated with potential field methods and accurately delineating complex subsurface structures. This approach demonstrates the effectiveness of advanced magnetic modeling in complex, sediment-covered terrains, providing a robust basis for locating drilling targets, reducing exploration risks, and guiding efficient mineral resource development in the Negin area.

Introduction

Global demand for raw materials, including base and precious metals, has intensified, while near surface mineral deposits have largely been depleted. Modern mineral exploration must therefore target covered and deeper crustal units, where hidden ore bodies occur without surface expressions. Geophysical methods, particularly magnetometry, have become indispensable due to their non-invasive nature, extensive coverage, and ability to provide high resolution information on subsurface structures. Conventional potential field maps, however, mainly offer qualitative horizontal distributions and lack precise depth and 3D shape information. To overcome these limitations, inverse modeling techniques have been developed to transform surface measurements into quantitative subsurface models. These models allow accurate estimation of ore body geometry, depth, and dimensions, significantly reducing drilling costs and operational risks. Previous developments, including the Li and Oldenburg 3D inversion methodology, emphasize depth weighting and geological constraints to address the non-uniqueness of potential field solutions. In Iran, the application of 3D inversion on magnetic data has proven effective in complex geological terrains, including studies in the Negin area, confirming alignment between geophysical models and drilling results.

Methodology and Approaches

This study employed 3D inverse modeling of magnetic survey data to generate a quantitative representation of subsurface ore bodies. The survey was conducted on a regular grid covering the study area, and field data were corrected for diurnal variations and IGRF removal. Filters such as reduction to the pole, analytical signal, and upward continuation were also applied on the data to isolate shallow anomalies from deeper trends. The Li and Oldenburg inversion algorithm, implemented in MAG3D, was used to segment the subsurface into cubic cells and minimize a combined objective function of data misfit and model smoothness. Depth weighting and reference model constraints were applied to mitigate natural decay of the potential field with depth and enforce geological plausibility. Logarithmic parameterization ensured positive magnetic susceptibility values, further stabilizing the inversion process..

Results and Conclusions

The 3D inverse model revealed a central semi-ellipsoidal intrusive body with elevated magnetic susceptibility. Horizontal and vertical sections indicated a concentrated core extending into intermediate depths, consistent with magmatic zoning and hydrothermal alteration. The top of the body was estimated at the depth of 60 meters below the ground surface, closely matching exploratory drilling results, which encountered the intrusive rock at 61 meters depth. Comparison of the results of constrained inversion with those of unconstrained models highlighted the critical role of depth weighting and reference constraints in avoiding shallow overestimation and achieving geometrically and geologically accurate models. Convergence analysis of the inversion algorithm confirmed numerical stability, and the model reliably predicted drilling targets. Overall, the study demonstrates the capability of constrained 3D magnetic inversion to resolve subsurface structures under sedimentary cover, providing a robust basis for optimizing drilling locations, reducing exploration risk, and guiding further mineral development in the Negin area.