JOURNAL OF RESEARCH ON APPLIED GEOPHYSICS

(JRAG)

Shahrood University of Technology

2025, VOL 11, NO 2

(DOI): 10.22044/JRAG.2025.16073.1369

Enhancing boundary estimation of potential-field data using tilt and theta angle derivatives

Abdullah Ezam Ahmady[1]; Abdul Hamid Ansari[*2]; Seyyed Hossein Mojtahedzadeh[3]

1. PhD student, Department of Mining and Metallurgical Engineering, Yazd University, Iran.
2. Associate Professor, Department of Mining and Metallurgical Engineering, Yazd University, Iran.
3. Associate Professor, Department of Mining and Metallurgical Engineering, Yazd University, Iran.

Received: 20 April 2025 ; Accepted: 7 June 2025

Corresponding author: h.ansari@yazd.ac.ir

Keywords

Tilt derivative (TDR)
Theta angle
Potential field
Synthetic data
Real data
Pseudo-gravity
Anomaly edge

Extended Abstract

Summary

This study evaluates the tilt derivative (TDR) and theta angle (Cos θ) filters for delineating geophysical anomaly boundaries and suppressing artifacts in potential-field data. Synthetic and real gravity/magnetic datasets have been first corrected for magnetic inclination via reduction-to-the-pole (RTP), which, while improving anomaly focus, induces spurious artifacts. To address this, magnetic data have been transformed into pseudo-gravity fields, neutralizing orientation-dependent effects and spectral distortions. Both TDR and Cos θ filters have been then applied: TDR enhances edge detection by computing the ratio of vertical to horizontal gradients, while Cos θ identifies boundary zones through the cosine of the angle between total and horizontal gradients. The results of applying TDR and Cos θ filters on pseudo-gravity data have led to clearer structural boundaries and improved detection of shallow anomalies, particularly in the case of Anomaly 2 of the Gol-e-Gohar mine, without RTP-induced artifacts. Directional dependency can be observed in RTP-processed magnetic data filtered using TDR, whereas Cos θ filter has proved more orientation-invariant. In real gravity and pseudo-gravity datasets, both filters delineated boundaries independently of source trend, though TDR slightly exaggerated body widths. Random noise tests confirmed the numerical stability of each method. Integrating RTP, pseudo-gravity conversion, TDR, and Cos θ filters within a unified workflow substantially enhances boundary interpretation accuracy and robustness for mineral exploration in complex terrains.

Introduction

Potential field data, such as magnetic and gravity data, are essential for delineating subsurface structures and guiding mineral exploration, yet they require sophisticated processing to suppress noise, correct for magnetic orientation, and avoid spectral distortions. The tilt derivative (TDR) leverages angular variations to sharpen shallow anomaly boundaries, while the theta angle (Cos θ) filter computes the cosine of the angle between total and horizontal gradients to highlight boundary zones with orientation-independent stability. However, both methods, applied directly on magnetic data, can suffer from artifacts introduced by reduction-to-the-pole (RTP) filtering. Here, we convert magnetic measurements into pseudo-gravity data to neutralize orientation biases, then we apply TDR and Cos θ filters in a unified RTP + pseudo-gravity + (TDR & Cos θ) workflow. Tests on synthetic models and real datasets; including Anomaly 2 of Gol-e-Gohar mine, show that this combined scheme markedly enhances boundary clarity, reduces spurious effects, and discriminates overlapping sources more reliably.

Methodology and Approaches

We have employed a unified workflow integrating two complementary edge-detection filters, namely TDR and Cos θ, to enhance potential field data interpretation. First, magnetic data have been corrected for inclination and declination angles by applying RTP on the data. Recognizing the tendency of RTP to introduce spectral artifacts, we convert the RTP output into pseudo-gravity data to neutralize orientation-dependent effects. Next, both TDR and Cos θ filters have been applied on the pseudo-gravity datasets as well as to real gravity data. TDR computes the ratio of vertical to horizontal gradients to sharpen boundary edges, while Cos θ calculates the cosine of the angle between total and horizontal gradients to highlight boundary zones with orientation-invariance. We have validated this processing chain on synthetic models under noise-free and noisy conditions, then we have applied the procedure on real field data including Anomaly 2 of Gol-e-Gohar mine. Comparative analyses in this research have demonstrated that combining RTP, pseudo-gravity conversion, TDR, and Cos θ yields superior structural delineation, suppresses spurious artifacts, and reliably distinguishes overlapping sources.

Results and Conclusions

This study introduced an integrated processing framework (RTP + pseudo-gravity + TDR and Cos θ) to elevate potential field data interpretation accuracy. Converting RTP-corrected magnetic data into pseudo-gravity data neutralized directional biases and spectral artifacts, effectively removing spurious anomalies. In synthetic tests, TDR offered high precision for north–south boundaries, while Cos θ delivered uniform edge detection across all orientations; gravity analyses remained orientation-independent. The workflow was applied on the real field data from Anomaly 2 of Gol-e-Gohar mine. The results of applying the workflow on the real data clarified east–west structural limits and demonstrated robustness under random noise. Key limitations include residual directional sensitivity in TDR-processed magnetic data and boundary-width overestimation inherent in integral transforms. To address these, we recommend geometric width refinement via inversion and hybridizing TDR/Cos θ with Euler deconvolution for improved source-orientation constraint.