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Potential Field Applications in Paleozoic Basins of Brazil: From Regional Mapping to Prospect-Scale Modeling

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Introduction

Potential field methods have long supported regional-scale basement mapping. In Brazil's Paleozoic basins—Paraná, Parnaíba, and Amazonas—extrusive and intrusive igneous rocks are embedded within sedimentary sequences. These rocks play a critical role in petroleum systems and generate localized magnetic anomalies. This study presents geological scenarios and survey resolutions across these basins. Regional magnetic data were used to delineate structural lineaments and tectonic domains, while high-resolution data at the prospect scale enabled 2D modeling to estimate the thickness of igneous rocks, often associated with seismic pull-up effects. Integration with seismic and well data is essential to reduce interpretation ambiguities. The effectiveness of potential field methods in hydrocarbon exploration depends on the geological setting, the alignment between target features and data resolution, and robust integration with complementary datasets.

Method and/or Theory

In all studied basins, most available surveys provided only magnetic data at varying resolutions. Gravimetric data were generally limited to low-resolution regional surveys, except in the Amazonas Basin. For magnetic data, regional interpretation was performed using grid knitting of multiple airborne magnetic and gravimetric surveys. To harmonize interpretations across different resolutions, upward continuation was applied to match the lowest resolution survey. A regional Bouguer anomaly map was used to delineate basement tectonic domains, while the first derivative of the Bouguer anomaly highlighted major structural lineaments. In the Amazonas Basin, high-resolution magnetic surveys were available, and 2D GM-SYS modeling was employed to better constrain lateral variations in the thickness of igneous intrusions.

Results and Conclusions

In the Paraná Basin, only mid- to low-resolution magnetic data are available. Regional structural lineaments and tectonic domains were mapped, and integration with seismic data allowed identification of areas with varying densities of dike occurrence. In the Parnaíba Basin, although high-resolution magnetic data cover large areas, they do not cover the main hydrocarbon exploration blocks, which are covered by mid-resolution surveys (500–2000 m line spacing). This resolution suffices for mapping major structures but is inadequate for detailed sill and dike identification. Correlation between gravimetric data and geochronology suggests Cretaceous magmatism was limited to eastern domains, while CAMP-related systems extended across the basin. In the Amazonas Basin, high-resolution magnetic data and a dense well network enabled more precise domain mapping and improved fault correlation, even with only 2D seismic. Additionally, 2D GM-SYS modeling with 200 m line spacing better constrained lateral variations in igneous intrusions thickness, clarifying ambiguous seismic features and reducing the risk of misinterpreting false highs. Although skepticism remains, this study shows that potential field methods gain significant value when resolution matches target scale and integration with other datasets is robust, especially for the sedimentary-igneous petroleum systems of the Brazilian Paleozoic basins.