

Tectonic framework and Basement configuration delineation through the Integration of Airborne Gravity Gradiometer, Magnetic and Seismic Data over Chirete area, Argentina

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Summary

The tectonic framework and basement configuration are delineated through the integrated interpretation of newly acquired airborne gravity gradient and magnetic data with the existing seismic data from the Chirete Block, onshore northern Argentina. The study area is comprised of approximately 3675 square km and covers approximately 35 km in an east-west direction and 105 km in north-south direction. The main project objective was to map the basement and associated major structural elements for the oil-and-gas prospect selection. The basement related faults/lineament maps were generated using several enhancements of gravity gradient and magnetic data. 2D seismic depth sections were used as initial constraints for 2.5D and 3D gravity and magnetic modeling. Well log densities and velocities are also constrained in this modeling process. The basement depth estimates are computed from the total magnetic intensity profile data. The Werner, Euler, and Peters half slope techniques are used in basement depth computations as well as the depths to the magnetic sources within the sedimentary section. This interpretation was then refined by utilizing the gravity gradient data and seismic data using 2.5 D and 3D modeling. Several of these depths are related to volcanic sources and were identified as igneous provinces and probably related to the rift and post rift periods. The basement depths show significant variation from south to north and ranging approximately 4-13.5 km below sea level. The enhanced potential field data yielded basement faults and structural framework of the area. The general basement faults trends are striking mostly in ENE-WSW direction. Two major East-West faults were identified as being the major bounding faults of the Lomas de Olmedo rift. There exists a remarkable correlation between these faults derived independently from seismic reflection data and enhanced Airborne Gravity Gradiometry data. A number of positive structural features were identified with the associated faulting may provide leads for oil & gas exploration

Introduction

Fugro Gravity and Magnetic Services (FGMS) was contracted by Petrobras to interpret airborne magnetic

and gravity gradiometer data in the Chirete Block area of Argentina. (Figure 1). These data were acquired with a flight line spacing of 145 m for magnetic data and 290 m for the gravity data. The survey production period was from February to June 2008. The survey area covers approximately 35 km in an east-west direction and 105 km from south to north. One must first understand the area's geological overview, including its tectonic framework, stratigraphic framework and petroleum systems.

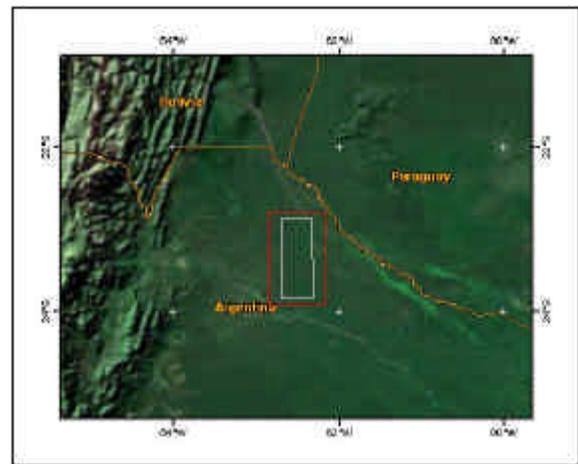


Figure 1: Study area location map

The tectonic framework has four events with the reactivation of pre-existing structures from the Late Precambrian to the Late Cretaceous periods. The result of the Pampean Orogeny was the closure of the Puncoviscan Ocean. Next, the Chanic Orogeny was related to the major South American subduction. Rifting and opening of the South Atlantic followed (Cominquez & Ramos, 1995, Jacques, 2003). Finally, the Andean Orogeny occurred, producing a retro-arc foreland basin along the eastern margin of the Andes.

Pre-rift, syn-rift and post-rift sedimentation characterized the stratigraphic framework from the Precambrian to the early Tertiary. (Cominquez & Ramos, 1995.) Pre-rifting deposited foreland basin clastics. During the rift, both siliciclastic and volcanic sedimentation occurred. A sag phase with a wide variety of lithologies and a good seismic marker characterizes the post-rift.

Both clastics and carbonates comprise the main petroleum system. These are sandstones, oolitic limestones and fractured limestone in the Yacoraité Formation in which are shown in a simplified stratigraphic section in Figure 2.

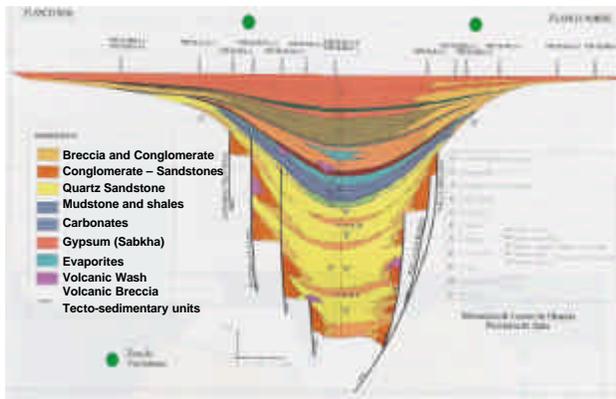


Figure 2: Stratigraphic section of the Lomas de Olmedo rift. (Modified from Hernández, Boll and Gómez Omil 1999).

Objectives

The primary objective was to map the magnetic basement and associated major structural elements. This was for the purpose of evaluating potential prospects for oil-and-gas exploration. A secondary objective included the identification of igneous features within the sedimentary section.

Data Processing and Enhancements

Gravity, magnetic, elevation, seismic and wire-line data were incorporated in the interpretation. Airborne gravity gradiometry (AGG) in conjunction with high-resolution aeromagnetic (HRAM) data were acquired and processed. Seismic data provided structural modeling constraints while the wire-line data constrained densities.

The processing included standard leveling and corrections for gravity and magnetics. Bouguer and terrain corrections were made for gravity data (g_D and G_{DD}). (Figures 3A and 3B) After leveling of the total magnetic intensity (TMI) anomaly (Figure 3C), reduction to the magnetic pole (RTP) transformation was applied for the magnetic data (Figure 3D).

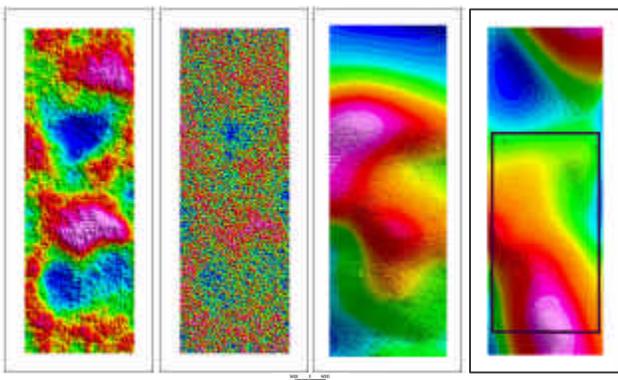


Figure 3A-D (Left to Right). Red colors in the grid images indicate higher values while blue colors indicate lower values. A) Bouguer gravity anomaly (g_D). B) Vertical

gravity gradient (G_{DD}). C) Total Magnetic Intensity (TMI) anomaly. D) Reduced to Pole (RTP) magnetic anomaly. A box on Figure 3D shows the outline of Figure 5A-D

Werner deconvolution, Euler deconvolution and Peters half slope methods were applied to the magnetic data for magnetic basement depth estimation. Every line of the data was interpreted and the depths to the magnetic basement were checked for the consistency from line to line data before contouring the basement surface. The estimation resulted in depths between 4 km and 13.5 km below sea level with major East-West bounding faults. Igneous structures were inferred from enhancements of the RTP data.

Enhancements were made to the gravity and magnetic data including band-pass, derivatives with one or more transformations. The enhanced AGG data critically supplemented enhanced magnetic data for the identification of linear anomalies arising from shallow sedimentary sources as well as from deeper basement sources

2D, 2.5D and 3D Modeling

Seven 2D/2.5D magnetic and gravity models supported and adjusted the interpretation of the seismic sections. One model, along seismic section 1270 crosses one of the major bounding faults of the Lomas de Olmedo rift (Figure 4). The wide range of densities (2.67 to 2.87 g/cm^3) and magnetic susceptibilities (500 to 5000 micro-cgs units) in the basement support a change in the crustal type from felsic to mafic lithologies.

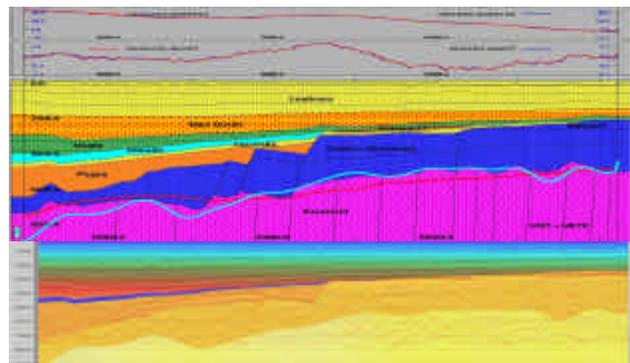


Figure 4. 2D model line 1270 (Top) and seismic section 1270 (Bottom). This NNW-SSE oriented line transects the southern-most bounding fault of the Lomas de Olmedo rift. Color shading over the seismic image reflects density values from the 3D model.

3D gravity modeling was performed and was initially constrained by formations from well tops, seismic-interpreted horizons, magnetic depth estimates and logged density or velocity measurements from wells.

One particular enhancement of the AGG data stands out when compared to the geometry of the acoustic basement from seismic reflection data. When a band-pass of 5 to 30km was applied to the AGG vertical

derivative of the gravity gradient (G_{DD}), a striking correlation was made with the shape of the enhanced data and the acoustic basement surface from seismic reflection data (Figures 5A and 5B).

3D modeling occurred in three stages designed to emulate effect of a 5-30 km band-pass of the Bouguer gravity data (g_D) by inverting short-wavelength to the density variation in the shallow sedimentary section and long wavelength to the density variation within the basement. The 3D potential field interpretation resembles the acoustic in structural shape and location, but is somewhat deeper (Figures 5C and 5D).

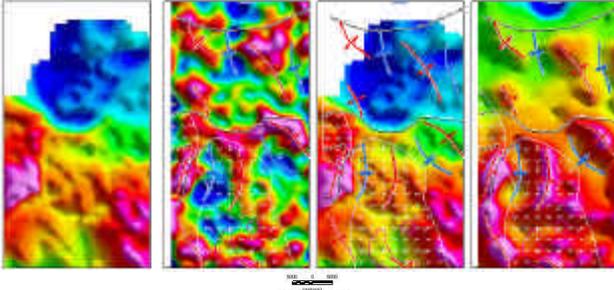


Figure 5A-D (Left to Right). A) Acoustic basement depth from seismic reflection data (depth range 3.2 to 5.8km). B) 5-30 km band-pass of the G_{DD} Bouguer gravity anomaly. C) Acoustic basement depth showing interpreted structural elements. D) Basement resulting from 3D inversion showing interpreted structural elements. Red colors in the grid images indicate shallower depths while blue colors indicate deeper depths.

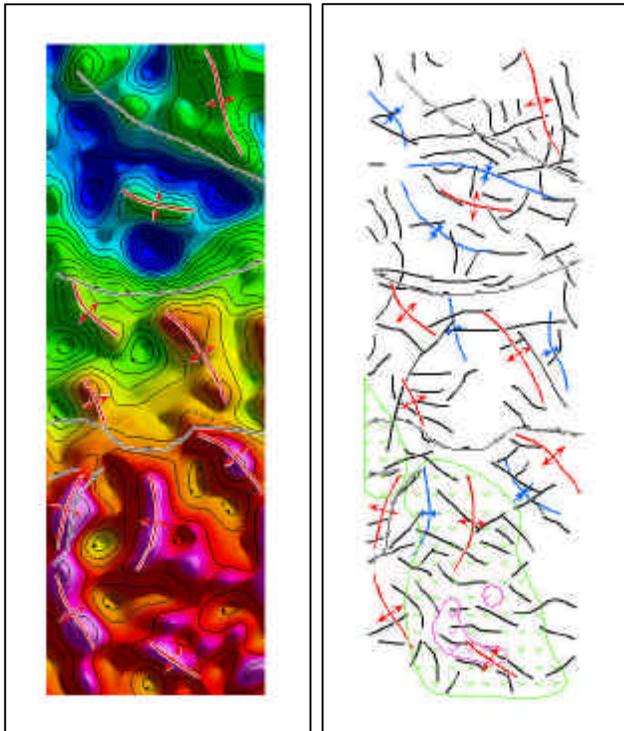


Figure 6A-B (left to right): A) Depth to the basement with major structural elements overlay. The contours are with 500 meters interval. B) Tectonic elements map derived from several enhancements of gravity gradient and magnetic data.

The depth to the basement and tectonic elements are shown in Figures 6A and 6B. The primary structural trends are of ENE-WSW and NNW-SSE orientations. These trends are intersected by faults, which were in perpendicular orientation at several locations, and displacements along strike are apparent. The dominant basement related faults are approximately following east-west trends where as faults within the sedimentary section exhibit north northwest and north northeast trends.

Several significant basement structural lows and structural highs are identified. Magnetic sources within the sedimentary section are also identified, and these are mapped as volcanic zones. These zones are shown with green and pink colors in Figure 6B.

Conclusions

Airborne Gravity Gradiometry (AGG) results improved upon those of Bouguer gravity for the delineation of basement faults as well as structural fabric in the sedimentary section. The density and susceptibility variations of the basement from the modeling studies indicate that the change of crustal type from felsic to mafic lithologies. The high frequency component of the gravity gradient data is most likely related to the density variations within the upper sedimentary section, which would contribute for the velocity analysis of seismic data. Interpreted basement depths ranged from about 4 km in the south to about 13.5 km in the deepest part of the Lomas de Olmedo rift. The high resolution aeromagnetic and airborne gravity gradient data played an important role in corroborating with the seismic data for the mapping of the basement and to decipher the structural geometry.

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