8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-276

FALCON Airborne Gravity Gradiometer, Aeromagnetic and Seismic Data Integrated Interpretation for the basement and structural configuration over Chirete area, Argentina

Marcela Lidia Fernandez, *Petrobras Energia S.A.,* ***Julio Cesar Soares de Oliveira Lyrio,*** *Petrobras S.A.,*
S. V. (Rao) Yalamanchili*, Luiz Braga, and Alan Morgan, *Fugro Gravity and Magnetic Services, Houston, Texas*

Summary

FALCON airborne gravity gradient and aeromagnetic data are recently acquired over Chirete Block, onshore northern Argentina. These two data sets are integrated with the existing 2D seismic data to unravel the geogical targets for hydrocarbon exploration. The main project objective was to map the basement and associated major structural elements for the oil-and-gas prospect selection. 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. Several gravity and magnetic data enhancements were generated and used for mapping of tectonic framework. 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 2.5D and 3D modeling. 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 was contracted by Petrobras to interpret Airborne Gravity Gradient and magnetic 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 gradiometry data. The flight line orientation is in north-south and the tie lines are in east-west direction. 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.

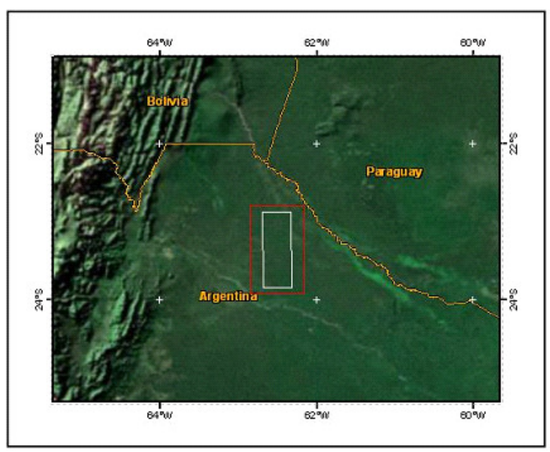

Figure 1: Study area location map

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 (Cominguez & 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 (Cominguez & 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 Yacoraite Formation in which are shown in a simplified stratigraphic section in Figure 2.

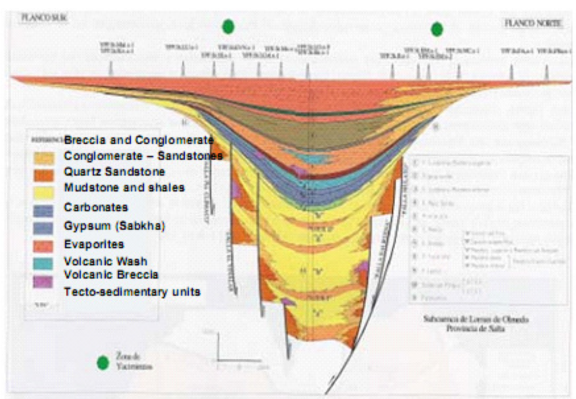

Figure 2: Stratigraphic section of the Lomas de Olmedo rift. (Modified from Hernández, Boll and Gómez Omil 1999).

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 conjuction 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).

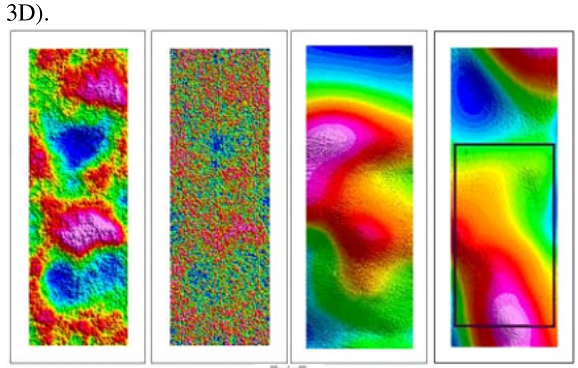

Figure 3A-D (Left to Right): Red colors indicate high values while blue colors indicate low values A) Bouguer gravity anomaly (g_D). B) Vertical gravity gradient (G_{DD}). C) Total Magnetic Intensity (TMI) anomaly. D) Reduced to Pole (RTP) magnetic anomaly. A box on Figure 3D shows the outline of Figure 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 indicate a change in the crustal thickness beneath the Lomas de Olmedo rift.

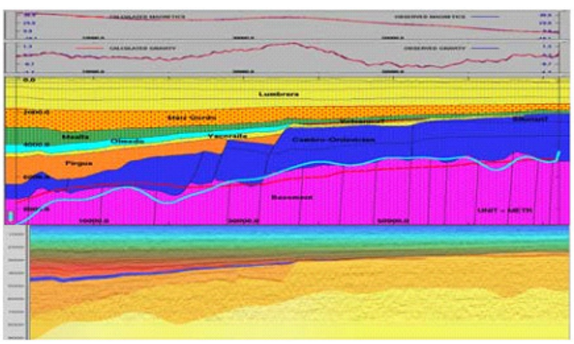

Figure 4. 2D model line 1270 (Top) and seismic section 1270 (Bottom). This NNW-SSE oriented line transects the southernmost bounding fault of the Lomas de Olmedo rift. Color shading over the seismic image reflects density values from the 3D model.

3D gravity modeling was performed and was initially constrained by formations from well tops, seismicinterpreted 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 5-30km 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 final phase of modeling used the unfiltered Bouguer gravity (2.0g/cm^3) anomaly (G_{DD}) to invert for depth of the basement. The 3D potential field interpretation resembles the acoustic in structural shape and location, but is somewhat deeper (Figures 5C and 5D).

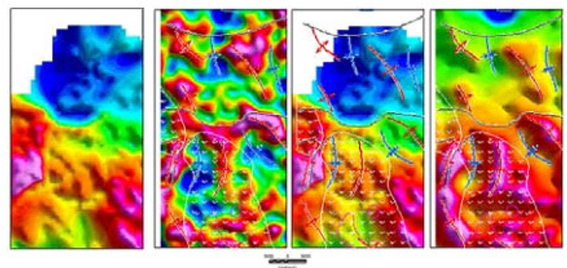

Figure 5A-D (Left to Right): Red colors in the grid images indicate shallower depths while blue colors indicate deeper depths. A) Acoustic basement depth from seismic reflection data (depth range 3.2 to 5.8km). B) 5-30 km band-pass of the G_{DD} Bouguer gravity anomaly. C) Acoustic basement depth showing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

Conclusions

FALCON Airborne Gravity Gradiometry (AGG) results helped 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 thickness under the center of Lomas de Olmedo rift. 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.

Acknowledgements

The authors are very much thankful to Marcos Amaral de Almeida for his guidance during the progress of this AGG Falcon project. The management of Petrobras and Fugro Gravity and Magnetic Services Inc. were acknowledged for granting permission to publish this abstract.

References

Cominguez, A. H. and Ramos, V. A., 1995. Geometry and Seismic Expression of the Cretaceous Salta Rift System, Northwestern Argentina. In: *Tankard A. J., Suárez R. S. and Welsink, H. J. (eds.)* Petroleum basins of South America, AAPG Memoir, **62**, 325–340.

Del Papa, C. E. and Salfity, J. A., 1999. Non-marine Paleogene sequences, Salta Group, Northwest Argentina. Acta Geologica Hispanica, **34** (2-3), 105-121.

Hernández, R., Disalvo, A., Boll, A. y Gómez Omil, R. 1999. Estratigrafía secuencial del Grupo Salta, con énfasis en las subcuencas de Metán-Alemania, Noroeste Argentino. En: González Bonorino, Omarini y Viramonte (Eds.): Geología del Noroeste Argentino, Relatorio 14º Congreso Geológico Argentino, **1**:263-283. Salta

Jacques, J. M., 2003. A tectonostratigraphic synthesis of the Sub-Andean basins: Implications for the geotectonic segmentation of the Andean Belt. Journal of the Geological Society, London, **160**, 687-701.

Kley, J., Rossello, E. A., Monaldi, C. R. and Habighorst, B., 2005. Seismic and field evidence for selective inversion of Cretaceous normal faults, Salta rift, northwest Argentina. Tectonophysics, **399**, 155– 172.

Li, X., 2003, On the use of different methods for estimating magnetic depth: The Leading Edge, **11**, 1090-1099.

Marquilllas, R. , C. del Papa, and I. Sabino. 2005. Sedimentary aspects and paleoenvironmental evolution of a rift basin: Salta Group (Cretaceous–Paleogene), northwestern Argentina. International Journal of Earth Sciences **94**:94–113.

Ramos, V. A., 2008. The Basement of the Central Andes: The Arequipa and Related Terranes. Annual Review, Earth and Planetary Sciences, **36**, 289–324.

Rapela, C. W., Pankhurst, R. J., Casquet, C., Baldo, E., Saavedra, J. and Galindo, C. 1998. Early evolution of the Proto-Andean margin of South America.Geology, **26** (8), 707-710.