IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 2, Issue 5 (Jul-Aug. 2014), PP 122-127
www.iosrjournals.org

Depth to basement analysis from gravity field over the Guelb Ahmer horst (Ghadames petroleum province, Southern Tunisia, North Africa)

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Abstract: *The Exploration complex geological structures like crystalline basement, significant to hydrocarbon exploration, is complicated in seismic interpretation. Gravity data were analyzed at a Guelb Ahmer horst situated to northern border of Ghadames basin (Southern Tunisia). The average radial spectrum from an area of 40x40 km of the gravity data grid reveals the deep and intermediate basement sources depths. 3D Euler deconvolution technique illustrates also the limits of the crystalline basement sources running essentially between 2000 and 3000 meter deep. The geometries of Mesozoic rocks, Paleozoic strata and Precambrian basement rocks are estimated by five 3D gravity models. These models give a significant support for the determination of potential structural traps related to the Guelb Ahmer horst.*
Keywords: *Basement, Depth, Ghadames, Gravity, Tunisia*

I. Introduction

The study area is situated to northern border of Ghadames basin (Southern Tunisia, North Africa) (Fig.1). The most important oil and gas fields in Ghadames basin are positioned on positive gravity anomalies, which are a signature of basement topography [1]. The study area of 40x40 km is associated with the Guelb Ahmer horst drilled by PGA petroleum well (Fig.1). This area reveals one of the most important positive gravity anomalies of southern Tunisia (Fig.2).

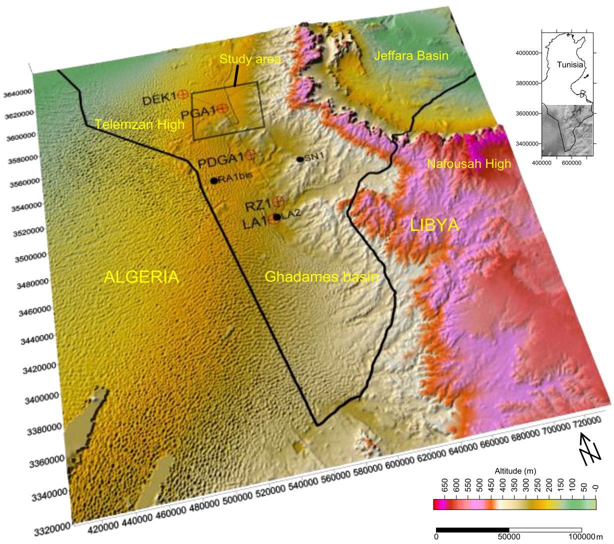

Fig.1 - DEM of the southern Tunisia and location of the study related to the northern border of Ghadames basin

The objective of this work is the imaging of Precambrian crystalline basement to provide support of the presence of sites for major structural traps. The crystalline type (granite) of the Precambrian basement was recognized in the study area by PGA 1 petroleum well at 2698 m depth (Fig.2) [2, 3]. After seismic study, the projected depth of the PGA 1 was 3600m to Precambrian basement. In this case, the basement top may not be perceptible in seismic reflection profiles. The PGA 1 well shows that the sediments immediately above crystalline basement can have the equivalent acoustic impedance due to weathering of the granite basement and the presence of consolidated Paleozoic sediments.

A Depth to basement analysis was obtained from the gravity field over the Guel Ahmer horst in southern Tunisia, revealing the pattern of faulting to enhance Precambrian crystalline basement topography.

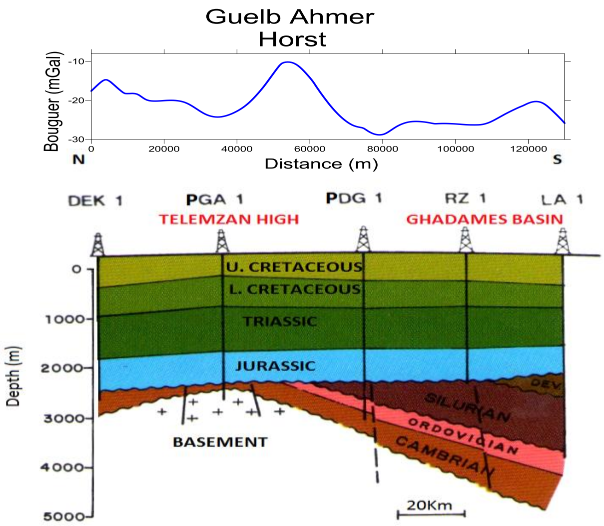

Fig.2 - Bouguer gravity variations along N-S geological cross-section [3] and location of the Guelb Ahmer horst associated with the most prominent positive gravity of southern Tunisia.

II. Geology

The study area is distinguished by gently dipping Paleozoic strata truncated by the Hercynian unconformity overlain by Triassic to Cretaceous rocks (Fig.3) [4, 5]. The study area located is characterized by Upper Cretaceous outcrops along the Dahar unit (Fig.2) [5]. The structural setting of the Ghadames basin was designed by four tectonic stages. These events include (1) Caledonian (Devonian), (2) Hercynian (Carboniferous), (3) Austrian (Early Cretaceous), and (4) Pyrenean (Late Cretaceous - Late Eocene) orogenies [6, 7, 8]

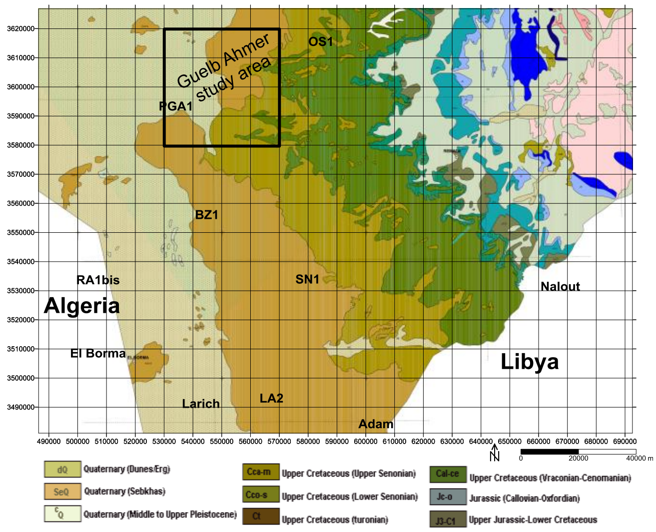

Fig.3 - Geological map of southern Tunisia [4] and location of the Guelb Ahmer study area

III. Gravity Analysis

The gravity data used for this study, with an average spacing of 2 km, were obtained from the Entreprise Tunisienne d'Activités Pétrolières (ETAP) (Fig. 4).

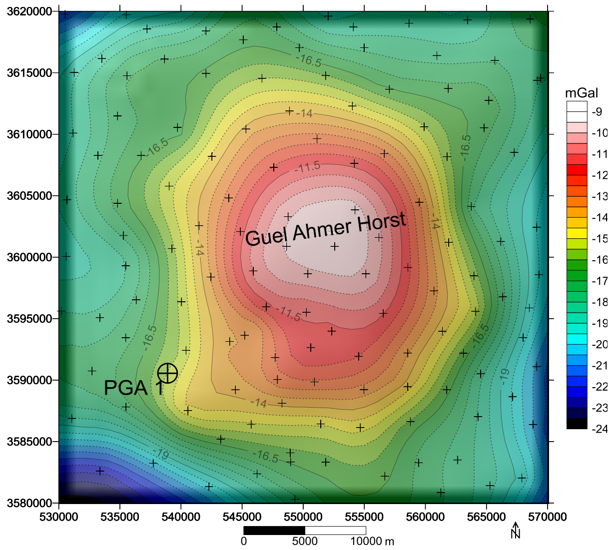

Fig.4 - Bouguer gravity map of the Guelb Ahmer study area

All the data were merged and reduced using the 1967 International Gravity formula [9]. Free Air and Bouguer gravity corrections were made using sea level as a datum and 2.67 g/cm^3 as a reduction density. The Bouguer gravity anomaly data were gridded at 1 km spacing and contoured to produce a Bouguer gravity anomaly map (Fig. 4).

The Bouguer gravity anomaly map (Fig. 4) shows a positive gravity anomaly over the Guelb Ahmer horst. The source for this strong positive gravity is possibly the topography of crystalline Precambrain basement drilled by W1 well at 2698 m depth. For the 3D gravity modeling, the second order polynomial regression of the gravity field [10] was performed to produce the residual gravity field.

Depth to basement is imperative for the purpose of districts where there may be hydrocarbons. To obtain a good approximation of the Precambrian basement depths, we analyzed the Radial Power Spectrum, the Euler Deconvolution solutions and the 3D gravity modeling along five NE-SW profiles.

The estimation of the mean depth of the geological interfaces (for example the Top of Crystalline basement) can be determined by the analysis of the Radial Power Spectrum of gravity field [11]. The Fig.5 represents the log of Radial Power Spectrum of gravity field as a function of wave number/frequency [12].

By measuring the slope of the Radial Power Spectrum of gravity field, the sources depth was estimated using the equation 1:

$$\text{Log } E(K) = 4\pi hk \quad (1)$$

Where h is the depth in Km; k is the wave number in cycles/Km.

After the analysis of the graph (Fig.5) represented the radial average of the energy spectrum versus the radial frequency, we can determine three major segments with diverse slopes. The energy spectrum illustrates three linear reflecting depths: 1) the deep basement sources depths about 3Km; 2) the intermediate basement sources depths about 2Km; 3) the shallow sedimentary sources depths about 1Km.

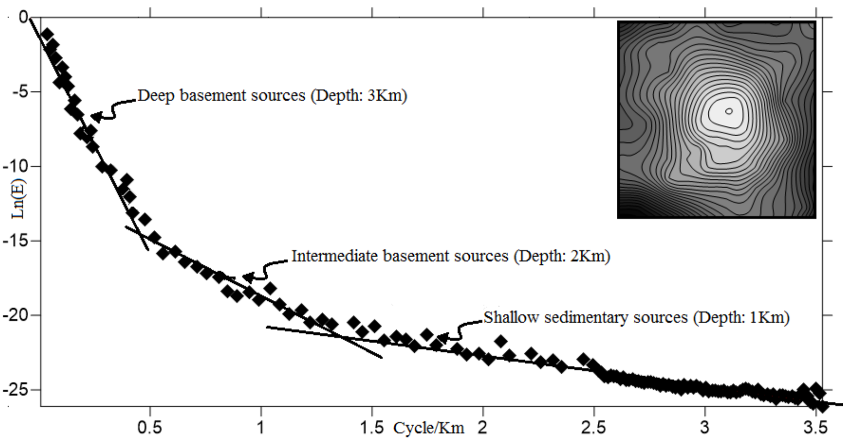

Fig.5 - Radial average of the energy spectrum versus the radial frequency of the Guelb Ahmer study area (40Km*40Km)

The Euler deconvolution technique [13] was successfully applied to 3D gridded data by [14]. The solutions considered with the Euler deconvolution technique corresponded with sectors with strong gravity gradients. The result is a series of aligned points at diverse depths.
3D form of Euler's equation can be defined [14] as equation: (2)

$$x\frac{\partial g}{\partial x} + y\frac{\partial g}{\partial y} + z\frac{\partial g}{\partial z} + \eta g = x0\frac{\partial g}{\partial x} + y0\frac{\partial g}{\partial y} + z0\frac{\partial g}{\partial z} + \eta b \quad (2)$$

Where $\frac{\partial g}{\partial x}, \frac{\partial g}{\partial y}$ and $\frac{\partial g}{\partial z}$ are the derivatives of the field in the x, y and z directions,

η is the structural index value that needs to be chosen according to a prior knowledge of the source geometry. By considering four or more neighboring observations at a time, source location (x0, y0, and z0) and b can be calculated by solving a linear system generated from equation (2).

To enhance the estimation of the depth to basement solutions, 3D Euler deconvolution technique was perform on the Bouguer data in an attempt to find depth to basement of lineaments (Fig.6) with a window size of 10 grid cells, a depth tolerance of 15% and a structure index 0. In a gravity field, a contact (like fault) has a structural index of 0. We identified basement blocks faults using index 0. We can identify the limits of the crystalline basement sources running essentially between 2000 and 3000 meter deep (Fig.6).

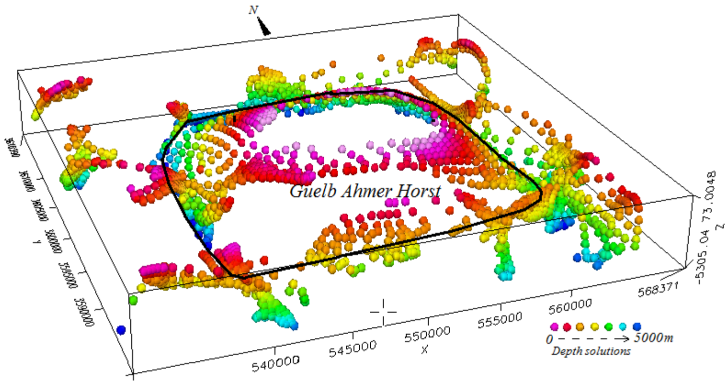

Fig.6 - 3D Euler deconvolution solutions og Guel Ahmer area using a window size of 10 grid cells, a depth tolerance of 15% and a structure index 0.

Forward gravity modeling of basement topography implies calculating the theoretical signature of the geometry of geological units (Fig.7). Five models were constructed along NE-SW residual gravity profiles (Fig.7).

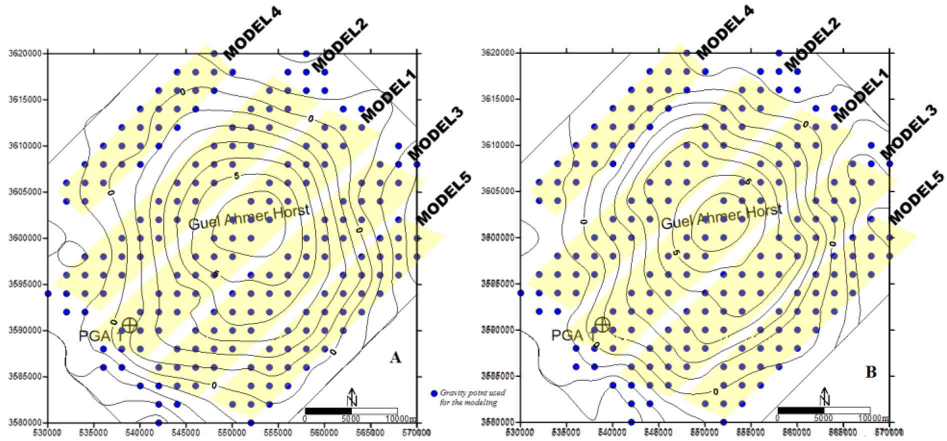

Fig.7 - A. Observed residual gravity map and B. calculating the theoretical signature of the geometry of bodies related to models

The density of Mesozoic rocks, Paleozoic strata and Precambrian basement rocks are estimated by well logging and are respectively 2.6gm/cc 2.62gm/cc and 2.76gm/cc. Each model (Fig.8 and 9) has three principal bodies. These models give new informations about the geometry of the Guelb Ahmer horst.

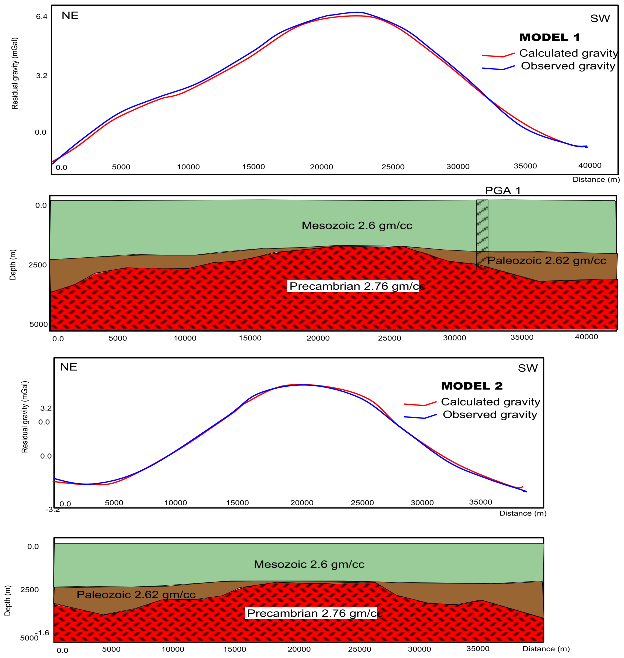

Fig. 8 **-** 3D Gravity models 1 and 2 along NW-SE profiles crossing Gueb Ahmer Precambrian Horst

The model 1 is calibrated by the PGA 1 well (Fig.8). This model has enhanced understanding about the topography of Precambiran crystalline basement and proposes that the flanks of the Guel Ahmer horst are associated with a Paleozoic strata thinning. This thinning can be explained by the erosion related to Caledonian (Devonian) and Hercynian (Carboniferous) orogenies [6, 7, 8]. The models 2, 3, 4 and 5 (Fig.8 and 9) update also the geometry of the Guel Ahmer horst and provide new detailed image for the possible hydrocarbon accumulation.

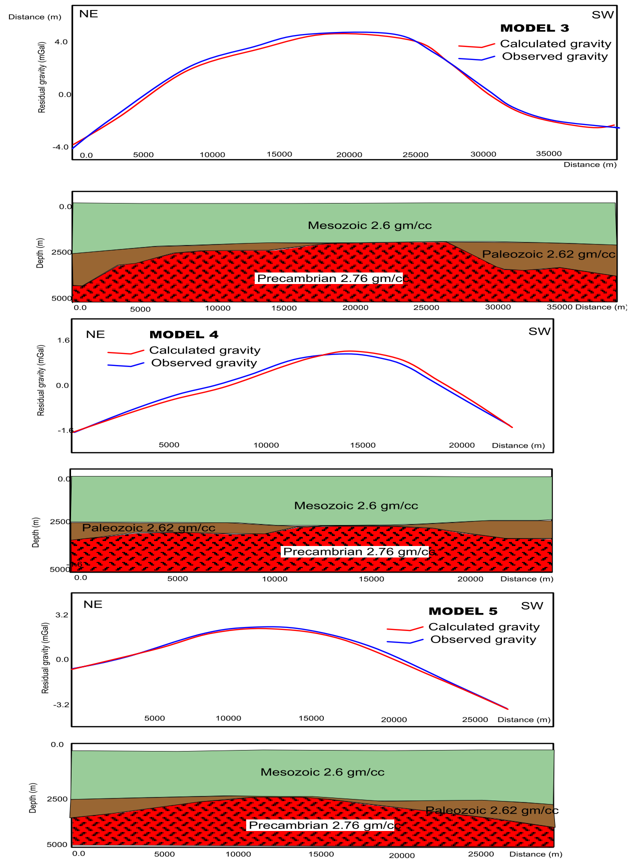

Fig. 9 **-** 3D Gravity models 3, 4 and 5 along NW-SE profiles crossing Gueb Ahmer Precambrian Horst

IV. Conclusion

The interpretation of the crystalline basement geometry associated with the Guelb Ahmer horst (Ghadames basin) after classic seismic reflection method is complex. The imaging of Precambrian crystalline basement topography using depth to basement analysis of gravity field provides an important support for the determination of potential structural traps.

Based on the result of gravity analysis using the Radial Power Spectrum, the Euler Deconvolution solutions and the 3D gravity modeling along five NE-SW profiles, the Guelb Ahmer horst is imaged as undulated basement after hercynian erosion with deep basement sources depths about 3Km and intermediate basement sources depths about 2Km.

Acknowledgements

This research was supported by CERTE. We are very grateful to ETAP Company for the scientific support.

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