Acta Geodyn. Geomater., Vol. 21, No. 2 (214), 139–150, 2024
DOI: 10.13168/AGG.2024.0013
journal homepage: https://www.irsm.cas.cz/acta

ORIGINAL PAPER

INTEGRATED ANALYSIS ON GRAVITY, 2D SEISMIC AND WELL DATA OF THE ABU TUMAYAM TROUGH, WESTERN SIRT BASIN, LIBYA

Abdelhakim ESHANIBLI [1,2] *, Nur Azwin ISMAIL [1] *, Abdullatif DUGDUG [3], Hussin B. GHANUSH [2] and Abdussalam BUAZZA [3]

[1] *Geophysics Section, School of Physics, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia*
[2] *Department of Exploration Research, Petroleum Research Centre (PRC), 6431, Tripoli, Libya*
[3] *Waha Oil Company, Burj Boleila, El Shat Street, Tripoli, Libya*

**Corresponding author's e-mail:* a.eshanibli@prclibya.com; nurazwin@usm.my

ARTICLE INFO

Article history:
Received 16 February 2024
Accepted 3 May 2024
Available online 14 May 2024

Keywords:
Low-Pass
Gravity
2D Seismic
Well data
Depocenter

ABSTRACT

This study used gravity data and 2D seismic data to determine subsurface structures, including fault systems and the depth of the basement. The analysis of gravity data has been conducted using a low-pass filter, total horizontal gradient (THG), and source parameter imaging (SPI) techniques. In addition, a 2D seismic line and a well data were used in the study. The results indicate that the trough was influenced by many fault trends, including NW-SE, NNW-SSE, and NS. These fault patterns are suggestive of post-rift and syn-rift events that took place within the Sirt Basin. Based on the findings of the source parameter imaging (SPI), the depth of the basement at the depocenter exhibits a range of 5000 m to 5900 m. However, this range is not well captured by 2D seismic datasets. The depocenter is characterised by a significant accumulation of sediment, spanning from the Cambro-Ordovician to Oligocene periods, which provides evidence of the basin's filling and the evolutionary processes of Abu Tumayam.

1. INTRODUCTION

The study area is situated within the southwestern Sirt Basin, Libya (Fig. 1). It is precisely between the longitudes 18.20^{o} E and 19.20^{o} E, and the latitudes 26.7^{o} N and 27.7^{o} N. The Western Shelf borders the trough to the west; however, it is covered with Al Haruj al Aswad volcano lavas. The line of the Tibesti-Tripoli Arch overlaps with the Western Shelf in this location. The trough borders the Bayda Platform and Southern Shelf to the east, and the Tibesti Arch to the south. The Abu Tumayam Trough is comparable in size to the Zallah Trough, with a length of 220 km and a maximum width of 120 km, covering an area of around 16,000 km^2.

Several authors (e.g., Abdunaser, 2015; Eshanibli et al., 2020) have published studies on the tectonic history of the surrounding regions (such as the Zallah trough, Dur Ela Bid Trough and Zelten Platform), and they found that the areas have been affected by two types of tectonic movements, such as the compression movement during early Jurassic time and the extension movement during the early Cretaceous. However, certain locations still need more investigation, such as the study. The Abu Tumayam Trough is one of the most complicated troughs within the Sirt Basin due to several reasons, such as the closeness to Huge Volcanic Province (Al Haruj Volcanic), which may have formed some igneous intrusions that affected the sedimentary section beneath this trough by penetrating the layers (Saleem, 2019). Abu Tumayam Trough is one of these locations.

Good coverage of gravity data, one seismic line, and one well data were utilized to define the local beneath the study area. The current study applies geophysical approaches to the subsurface features of the Abu Tumayam Trough that have not been conducted previously in this location, thereby providing potential data for future in-depth field investigations. This study will contribute additional information about the study region to the information obtained by Saleem's (2015) study, which employed gravity, magnetic, seismic data and well data. The findings defined the subsurface structure of the region's faults and some of the existing igneous bodies, but they did not identify the depth or structural shape of the bedrock rocks. This study aims to determine the depth of the basement and the local fault system located beneath the trough.

2. GEOLOGICAL SETTING

The Abu Tumayam Trough extends to the south from the Zallah Trough, which it is isolated from by the Barrut and Hulayq spurs (Saleem, 2019). Due to the interplay of multiple converging structural features and the existence of two substantial faults, the

Cite this article as: Eshanibli A, Ismail NA, Dugdug A, Ghanush HB, Buazza A: Integrated analysis on gravity, 2D seismic, and well data of the Abu Tumayam Trough, Western Sirt Basin, Libya. Acta Geodyn. Geomater., 21, No. 2 (214), 139–150, 2024. DOI: 10.13168/AGG.2024.0013

connection between the Zallah Trough and the Gerad Graben is highly complicated (Hallett and Clark-Lowes, 2016). During the Paleozoic, the Sirt Basin was an arch that was called the Tibesti-Sirt Arch (Baird et al., 1996). Post-Hercynian structural reorganisation defined the main depo-centres until the Jurassic-Cretaceous breakup of Pangea (Klitzsch, 1996). Northern Tibesti-Sirt Arch collapsed into NW-SE horsts and grabens due to mid-Cretaceous sinistral shearing stresses that, followed by thermal sag, caused subsidence, and flooding the grabens (Hallett, 2002). Kingston et al. (1983) reported that the Sirt Basin is the result of a continental block's extensional movement. The basin's principal structural system is characterised by horsts and grabens trending mostly NW-SE. This trend roughly parallels the East African rift systems and the Red Sea. The incipient rifting started in the Triassic, and Syn-rift extension was restricted to the Upper Triassic and Lower Cretaceous (Finetti, 1985; Gras and Thusu, 1998).

Libya is on the northern edge of the African shield, between the relatively stable craton to the south and the active Mediterranean (formerly Tethys) area to the north. Although the late Mesozoic and Tertiary rifts in the eastern Mediterranean had an influence on Libya's geological formation, it is most closely related with the Paleozoic basins in the central Sahara (Dercourt et al, 1986; Klitzsch, 1996). The Pan-African orogeny occurred during the Proterozoic from about 650 to 540 My, and it was followed by a thermal event that remobilized large areas of existing crust (Hallett and Clark-Lowes, 2016). The fracturing of the north African craton was one of the most significant tectonic processes to affect Libya on a regional scale during the late Precambrian period, and at the same time, much of the eastern section of North Africa was eroding (Klitzsch and Squyres, 1990). The Sirt Arch originated during the late Paleozoic period when early Paleozoic tectonic features were inverted. Extreme erosion eroded the whole Paleozoic sequence (Hercynian unconformity) across the arch's crest (Hallet, 2002).

The collapse of the Sirt arch started during the early Mesozoic and formed a series of horsts and grabens, and Abu Tumayam is one of these grabens (Anketell and Ghellali, 1991). The northeast compressional movement during the Mid-Cretaceous affected the Abu Tumayam Trough, which was believed to have formed NNE-SSW trending faults in some parts of the trough (Saleem, 2015). Several authors have theorized that the NW-SE structures in Abu Tumayam Trough (Fig. 1) may have been caused by regional northeast-directed extension (dip-slip extensional tectonics) during basin formation in the Early Cretaceous (Bonnefous, 1972; Burke and Dewey, 1974). Late Cretaceous crustal expansion in

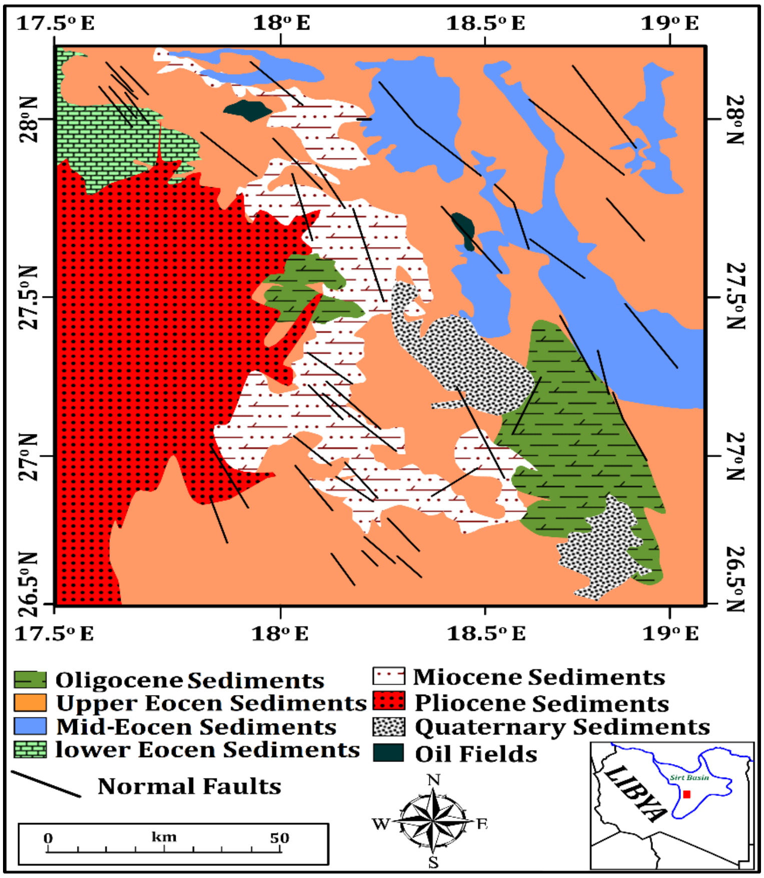

Fig. 1 Simplified surface geologic map of study area shows the exposed rock units, and oilfields compiled after Anketell and Gumati (1991).

the NE-SW direction caused NW-SE structural characteristics in the Sirt Basin (Shaaban and Ghoneimi, 2001). Sirt Basin's post-rift phase began in the upper Cretaceous with a graben fill structure produced by thermal subsidence and marginal sagging (Gumati and Nairn, 1991). Subsidence peaked in many troughs throughout the upper Eocene, including the Zallah Trough, the Ajdabiya Trough, and the Abu Tumayam Trough (Gumati and Kanes, 1985).

Kumati (1981) suggested that the western Sirt Basin Troughs, such as Zallah and Abu Tumayam Troughs, were formed as a result of sinistral strike or oblique-slip reactivation of deep-seated faults. Abdunaser (2015) reported that many main faults surrounding the major blocks were occasionally reactivated as vertical slip normal faults, which created accommodation space and impacted the stratigraphic section from the basement to the surface through thickness variations with slip movements. The overlaying Paleozoic rocks were removed as a result of the Hercynian orogeny and uplift, exposing the igneous and metamorphic rocks of the basement as well as Cambro-Ordovician quartzites as the trough's floor material (Hallett and El Ghoul, 1996; Hallett and Clark-Lowes, 2016). The unconformity is covered by uncalcified Nubian sands that date back to the time period before the Upper Cretaceous. These sands are, in turn, covered by marine rocks that date back to the Upper Cretaceous and were deposited in a fault-bounded trough that was sinking at the time (Hallett and Clark-Lowes, 2016). Post-rift trough infill sediments are dominated by subsequent cycles of Lower Paleocene transgression that were superimposed by a variation in sea level, which resulted in the production of a thick sequence of Eocene–Oligocene carbonate sediments. These sediments were deposited after the post-rift trough filled-in Figure 2. Early Eocene deposit depocenters (Gir Formation) were a consequence of severe tectonic events, subsidence, and fault regrowth throughout the Early Eocene period (Abugares, 1996).

According to Yanilmaz et al. (2008), it is possible that the Palaeogene deposits such as the Oligocene deposits were deposited in a basin that was

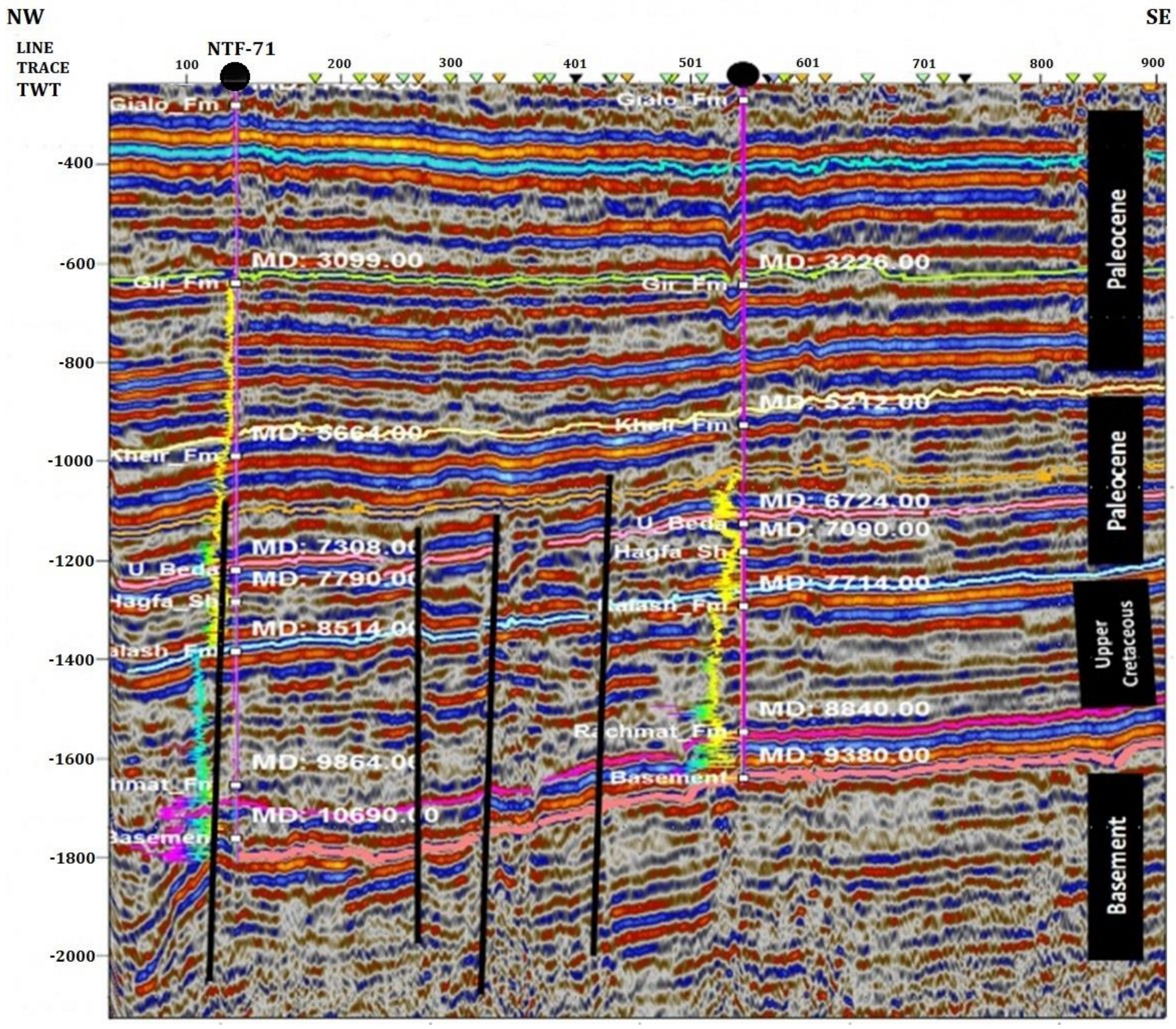

Fig. 2 2D Seismic Strick cross section shows the Cambro-Ordovician quartzite to Eocene Abu Tumayam Trough infill sedimentary sequences penetrated by the well NTF-71.

formerly at sea level (Tethys Sea) but has since been raised due to post-rift events. The surface within Abu Tumayam Trough is mostly covered by Oligocene sediments (Augila formation), with some early Eocene exposures in the trough's flanks (Van Der Meer and Cloetingh, 1993; Hallett and Clark-Lowes, 2016). Some faults are distinguished in seismic cross sections (Fig. 2) by distinct segments dependent on strike orientations. The segments imply a connected fault system, revealing a critical mechanism for fault development inside the trough (Cartwright et al., 1995).

3. MATERIALS AND METHODS

3.1. DATASETS

The Libyan Petroleum Institute (LPI) provided potential field data that was used in this study. The Libyan Gravity Project gathered and compiled the gravity data (Saleem, 2015; Eshanibli et al., 2021). The international formula and the Geodetic Reference System of 1980 (GRS 80) were used to figure out the free-air and Bouguer anomalies. The average density of the basement was lowered to 2.67 g/cm^3, which was then used in the analysis. LPI geophysicists made all improvements and corrections to the original gravity data. Harouge Oil Operations Company provided the seismic and well data. Different surveys collected the 2D seismic lines, whereas the well data was primarily utilised to guide the seismic interpretation and regulate the gravity modelling. The well's name is NTF-71. The density values of the formation tops have been derived from the density log and from previous studies such as Saleem (2015), and these values were utilized in this work. The data from one well was used Table 1.

3.2. DATA ANALYSIS AND FILTERING

Potential field data is analysed with Geosoft Oasis Montaj using various filtering and optimisation tools, as shown in Figure 3. After importing the X, Y, and Z columns gravity data, the Kriging interpolation method was used to grid the data and produce the Bouguer gravity grid as shown in Figure 4(a). In addition, the grid cell size that was utilised for the gridding was 100 metres, which was sufficient to depict the subsurface structures. We applied the low-pass Butterworth filter to gravity datasets to obtain the residual gravity anomaly grid. A low-pass Butterworth filter is used to eliminate high wavenumber noise from the gridded gravity data. The parameters that have been set for the low-pass filter were 80 for the filter function, and the cut-off wavelength value was 0.003 (cycles/metre), which means all wave numbers below this value are removed, as well as that value equivalating to a 5 km interval, which represents the residual gravity anomaly grid in Figure 4 (b).

The total horizontal gradient is the most common technique used to amplify the boundaries of geological structures. The Total Horizontal Gradient (THG) was used to analyse gravity data in order to identify density boundaries. This method effectively identifies locations with significant variations in gradient, such as faulted borders and shallow lineaments. The total horizontal gradient (THG) of the field (G) is mathematically represented by equation (1), as stated by Cordell and Grauch in 1985.

$$\mathrm{THG}(x, y) = x = \sqrt{\left(\frac{\partial G}{\partial x}\right)^2 + \left(\frac{\partial G}{\partial y}\right)^2} \qquad (1)$$

Where G represents the gravity anomaly, The strength of a total horizontal gradient at the specific location (x, y) is represented by THG(x, y). It is calculated based on the partial derivatives (∂G/∂x and ∂G/∂y) of the gravity anomaly towards x and y.

Source parameter imaging (SPI) is a method that uses an extension of the complex analytical signal to calculate subsurface depths such as the basement (Ekwok et al., 2019). Thurston and Smith (1997) developed this method. The method relies on the relationship between the depth of the source and the local wavenumber (k) of the measured field. This relationship may be computed for every place within a grid of data by analysing the horizontal and vertical gradients. The SPI Depth can be given in equation (2).

$$SPI\ Depth = \frac{1}{k_{max}} = \frac{1}{\left(\sqrt{(\partial Tilt/\partial x)^2 + (\partial Tilt/\partial y)^2}\right)_{max}} \qquad (2)$$

Where k represents the SPI structural index, $Tilt\partial x$ is the tilt derivative angle in X direction, and $Tilt\partial y$ tilt derivative angle in Y direction.

The gravity dataset was subjected to 2D forward modelling. The forward modelling used the technique

Table 1 Formation tops of well data used in this study.

Well NTF-71			
Formation Tops	**Density Value** /g/cm^3	**Depth/m**	**Age**
Augila Fm	2.423	375.91	Upper Eocene-Lower Oligocene
Gialo Fm	1.981	526.21	Lower to Middle Eocene
Gir-Anhydrite Fm	2.193	978.04	Lower Eocene
Upper Beda Fm	2.520	2228.04	Middel Paleocene
Upper Hugfa-Shale Fm	2.172	2375	Lower Paleocene
Upper Sirt-Shale Fm	2.342	2637.7	Upper Cretaceous (Maastrichtian)
Basement	2.743	---------	Paleozoic

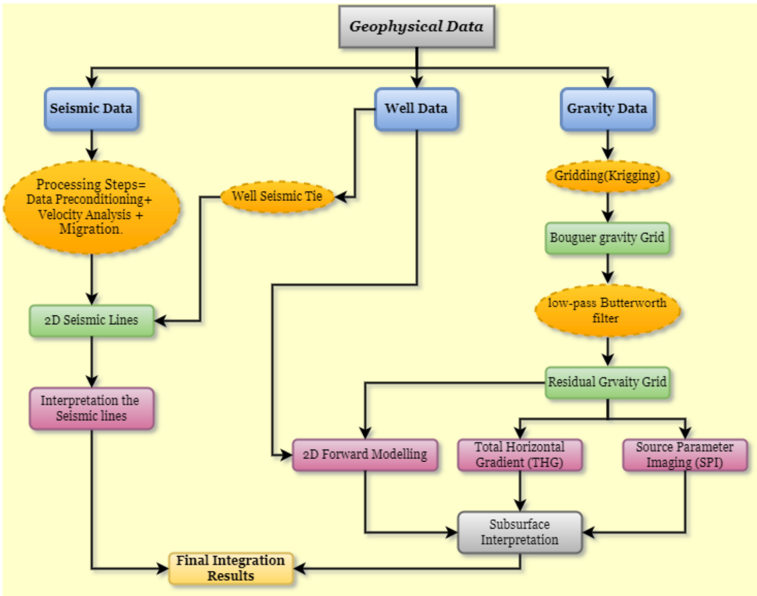

Fig. 3 A flow chart of the processing and analysis.

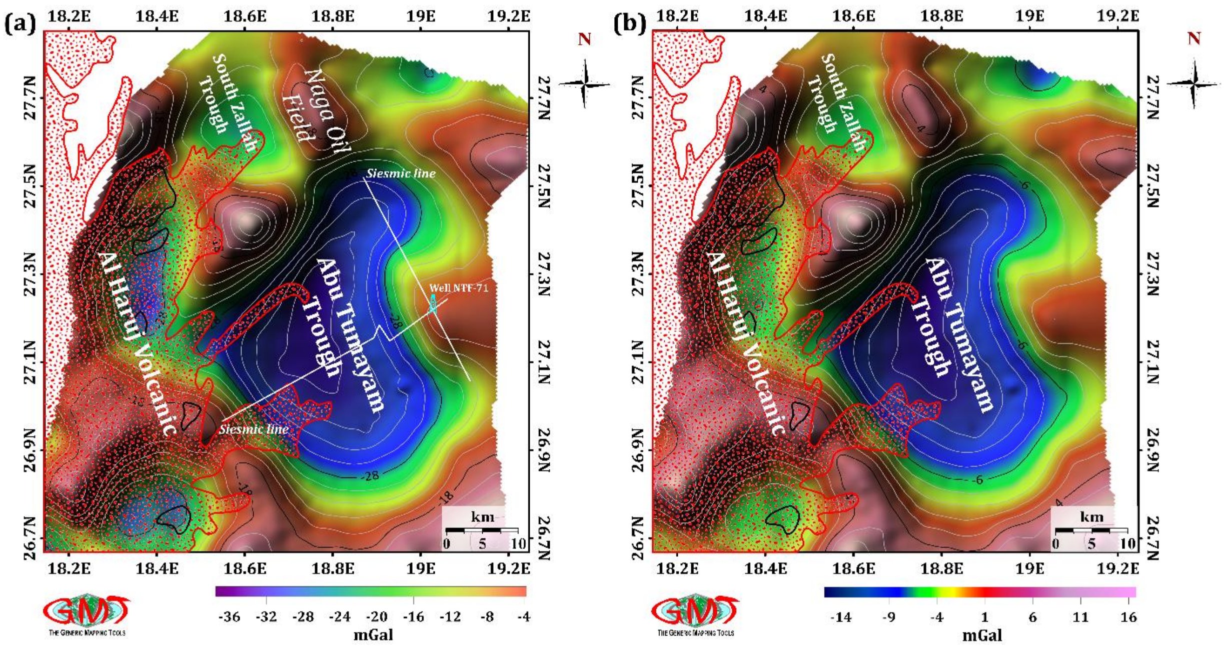

Fig. 4 The Gravity Data used in this study are **(a)** the Abu Tumayam Trough Bouguer gravity anomaly map and **(b)** the Abu Tumayam Trough Residual gravity anomaly map. The white line on the Bouguer map refers to the 2D profile model.

of Talwani et al. (1959), which revealed the real depth of the basement and the sedimentary section. The Harouge Oil Operations Company in Tripoli, Libya, gathered the data for the 2D seismic Line that was utilized for this study and provided it for this research. In a successful operation, the Seismic line was loaded onto the Petrel Software (version 2020). The interpretation began with a linkage between the well and the seismic data and then proceeded to choose the horizons of interest along the 2D profile. The 2D profile model was taken along with the seismic line. The two-way travel time (TWTT) of a seismic signal from its source to reflective components and back is measured in milliseconds (ms). The seismic approach requires seismic processing, which comprises a number of processing stages or sequences to obtain a final seismic picture.

4. RESULTS AND DISCUSSIONS

The Bouguer anomaly map in Figure 4(a) demonstrates that the majority of the anomalies are related to the long wavelength and produced by huge, deep structures, and also that the map is dominated by a substantial low anomaly range in the centre of the

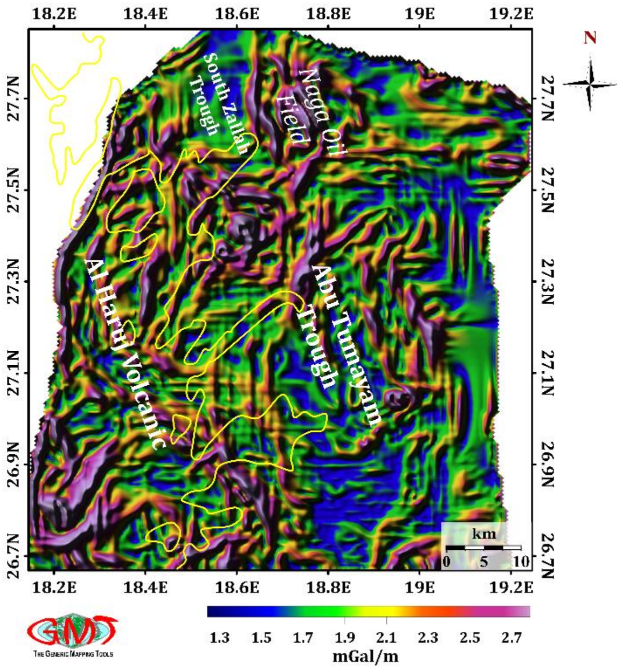

Fig. 5 Total horizontal gradient map of Abu Tumayam Trough.

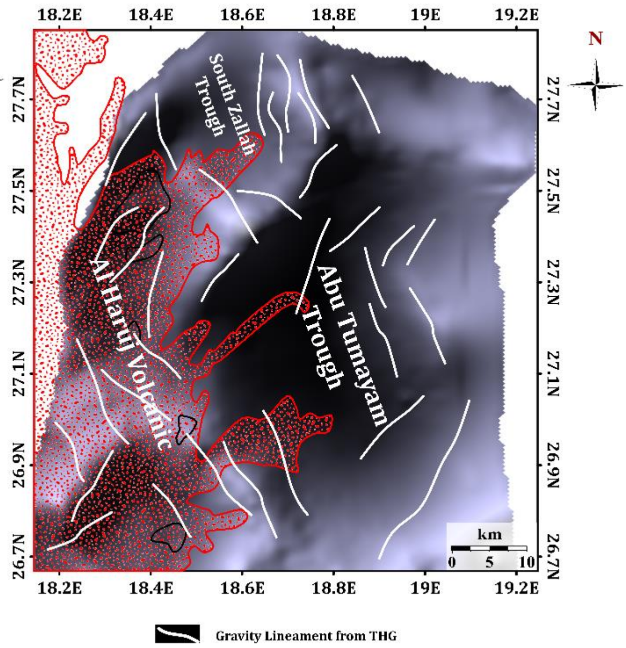

Fig. 6 Shaded residual gravity anomaly map superimposed by main lineaments deduced from THG map.

trough that ranges from -36 mGal to -24 mGal. This region is believed to represent a depocenter. The Abu Tumayam Trough is clearly obvious on the residual gravity anomaly map (Fig. 4(b)). The trough is bordered to the east by an extremely high gravity region, indicating that this high anomaly continues in depth, implying that this trough is geologically separated from the other troughs by this structure. A map showing the residuals is dominated by a collection of gravity trends that have high values (positive values), and these gravity trends are oriented in the following directions: NE-SW, NW-SE, NNW-SSE, and E-W. The creation of the Abu Tumayam Trough was influenced by a variety of tectonic events, which are collectively referred to as these numerous trends. The low gravity suggests a probable major sedimentary section of Cretaceous and Tertiary sediment infill beneath the centre portion of the Abu Tumayam Trough or as a result of fluctuations and changes in the sedimentary environment; however, they are only indicated by moderate-low values on the residual gravity anomaly map. In addition, it suggests the presence of deep basement rock. The residual map also reveals that the depocenter of the trough is located at a depth that is quite deep.

The total horizontal gradient map of the residual anomaly map (THG) (Fig. 5) depicts the elongated crest of the anomaly. The map reveals that the region is dominated by a network of faults; the bulk of these faults strike NW-SE, NE-SW, and NNW-SSE, while some faults are E-W, and the remaining faults are NE-SW. The NW-SE trending faults follow the Cretaceous trend in the Sirt Basin. The THG map shows the N-S trend fault, which may refer to the strike-slip faults that seem to cut the Cenozoic sediments. The NE-SW trend seems to be a basement fault with some intra-basement intrusive bodies. Some of the patterns in the whole horizontal gradient map correspond to the basement fault trend in the Abu Tumayam Trough. Paleozoic deformation in the Abu Tumayam Trough is controlled by structures from the Precambrian period, like faults that formed before the Mesozoic sedimentary sequences were deposited (Abadi, 2000; Baird et al., 1996). The THG map also emphasizes the patterns of exceptionally high gravity anomalies that spread between the designated low gravity anomalies and have distinct orientations. As a result of the distinct tectonic movement that occurred close to the southern shelf of the Sirt Basin, the THG map also reveals rather distinct differences in the structures that are located in the eastern portion of the study region. This movement This movement created the N-S and NNE-SSW trends.

The final structural map (Fig. 6), made from the total horizontal gradient of gravity anomalies, shows that the gravity low in the trough's depocenter is crossed by NW-SE lineaments, which are most likely faults. The southeast is cut by the main NE-SW Sirt faulting system, which shifts to the NNE-SSW in the southern part of the Abu Tumayam Trough. These faults indicate various tectonic activities, such as the Early Cretaceous faults that were produced by crustal extension. The other faults might be the result of the first rifting episode during the Early Paleozoic. Structural mapping shows relay ramps and overlapped faults in hanging walls along west-down throwing normal faults throughout the West and East Abu Tumayam Trough.

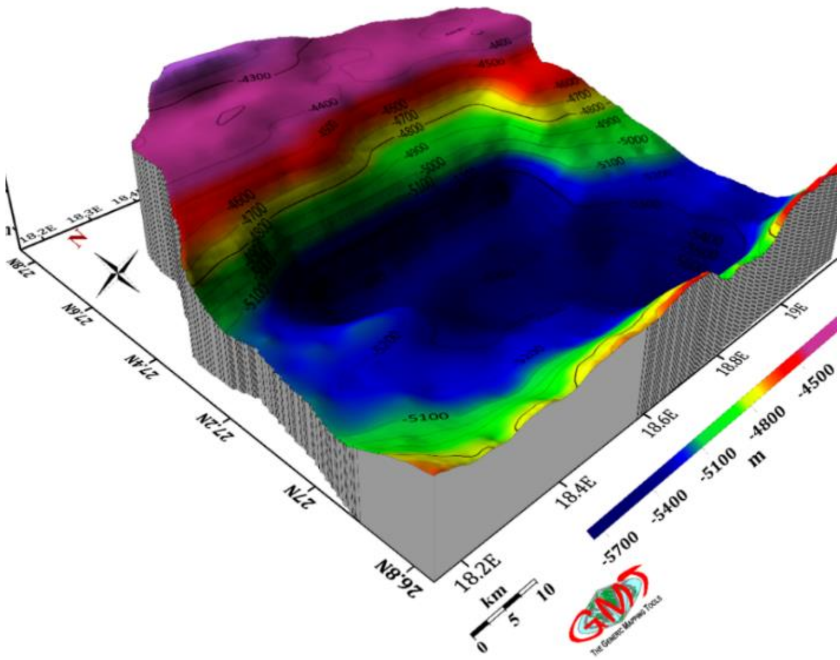

Fig. 7 The 3D basement map derived from SPI of residual gravity anomaly of Abu Tumayam Trough.

According to the findings of the 3D Source Parameter Imaging (SPI) Figure 7 the basement of the Abu Tumayam Trough is much deeper than the basements of the other nearby regions. The depth of the basement is an important aspect of information that must be determined in order to figure out how the basement is laid out. The gravity basements extend down to depths that may range anywhere from 5,200 metres all the way up to 5,900 meters. The statistics demonstrate, in addition, that the depth of the sedimentary succession differs from one location to another.

The 2D gravity model demonstrates that we have obtained our best-match model for the gravity anomaly that has been detected in the Abu Tumayam Trough. To explain the positive anomaly, it is required to assume a higher density at depth in the centre of the trough. These vertical densities, however, were calculated using density logs and changed with the strata's composition. The Abu Tumayam Trough seems to be reflected in the gravity anomalies overall. However, the profile, on the other hand, shows that the geological formations and gravity are all compatible with one another. The model demonstrates that there is an increase in depth as one travels further into the centre of the trough, as can be seen in the central part of the trough (the depocenter). In addition, the depth of the basement varies anywhere from 5200 to 5700 metres, as can be seen in Figure 7.

However, the analysis of the gravity model (Fig. 8) and the seismic line NC-1 in Figure 9 reveals a deep basement within the trough's depocenter. The thin layer of sediments near the edge of the trough might be because of the uplift caused by the rift event in the Mesozoic. This was followed by thermal subsidence and thickening towards the centre of the trough (Abadi et al., 2008). Changes in sea level since the Tertiary have had an effect on the sedimentary sequences, causing stratigraphic stages to get bigger and troughs to sink. Furthermore, the analysis of the 2D seismic line indicates that the Lower to Mid Eocene strata (specifically the Gilao and Augila Formations) were deposited beneath a shallow marine environment throughout the Abu Tumayam Trough. This deposition was influenced by the abrupt closure of the Tethys Ocean, which occurred due to the NE movement of Africa. As a result, stretching and rifting processes took place in the northern regions of Africa (Boote et al., 1998; Hallett, 2002). The study region has excellently preserved sequence stratigraphy, especially within the depocenter of the trough, despite the limited resolution of the 2D seismic line at this particular level. We propose that the regressive sediments created most of the Cenozoic sedimentary section, resulting in a broad progradation stacking vertical pattern on the 2D seismic line.

In the context of the 2D gravity model, which has been taken as a kinked line to cover the most part of the Abu Tumayam Trough, such as the depocenter of the trough, and show most of the subsurface structures, the analysis was conducted on the central portion of the trough depicted in Figure 10 along the seismic line NC-2 illustrated in Figure 11. Furthermore, the seismic data we obtained did not accurately cover the

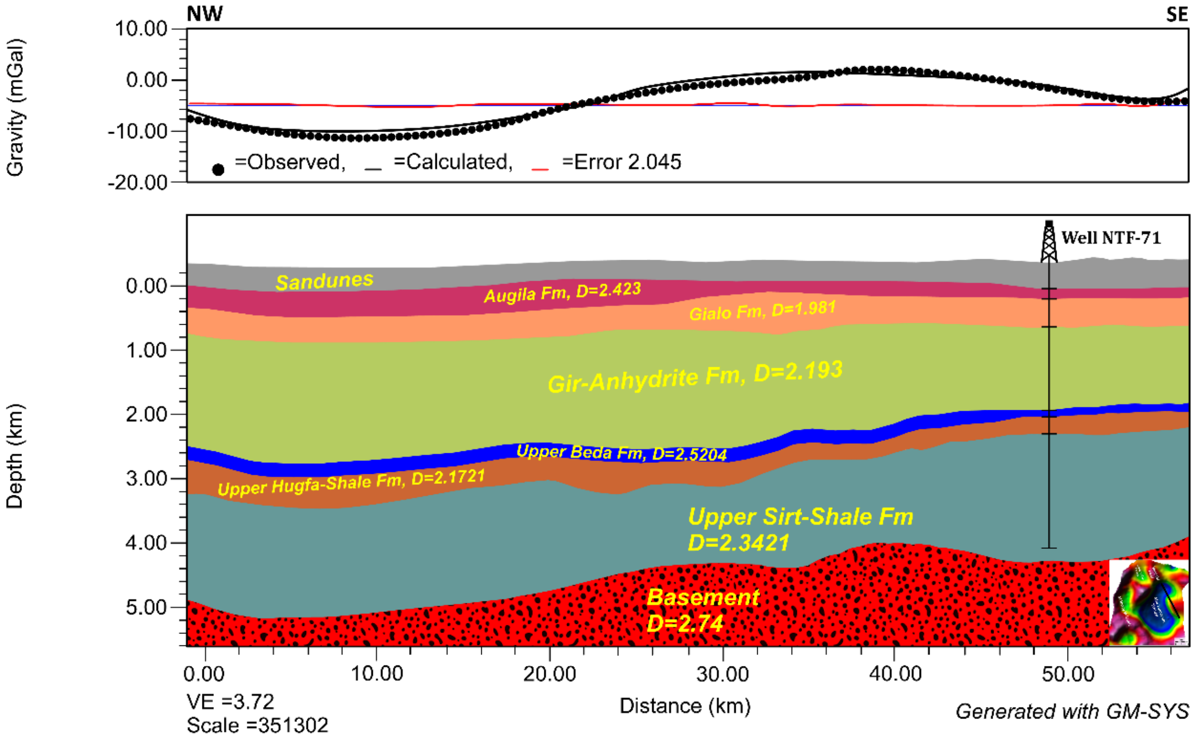

Fig. 8 The NW-SE 2D gravity model shows the depositional strata, with the main features dominating the area and basement morphology.

central portion of the trough. However, kinked lines provide significant theoretical and practical difficulties, particularly due to their deviation from the intrinsic 2D assumption in their application. Furthermore, the existence of abrupt bends within these lines might result in inaccuracies, especially in close proximity to the bend itself. An attempt was made to provide an interpretation of the extensive gravity low observed over the Abu Tumayam Trough. This was carried out by proposing a hypothesis that suggests the presence of thick sediments containing certain sedimentary facies characterised by a low-density value, which may have had limited effects.

Furthermore, the 2D gravity model is clearly visible beneath the trough's centre, indicating the absence of Paleozoic sediments under the Cenozoic and Mesozoic layers (pre-Upper Cretaceous). Two major faults have been detected by the gravity model, which cut the Cenozoic and Mesozoic layers. These faults are oriented in opposing directions, forming a small graben in the trough's centre. In the trough, Figures 5-10-11 show faults that cut through the Gialo Formation and end in the Early Paleocene. These faults are younger than the mid-Eocene. Other faults end in the upper Cretaceous because they are cut off by opposing faults.

A 2D dip composite seismic line NC-2 (Fig. 11) oriented in an east-west direction has been constructed, spanning from the southern rim of the Sirt Basin to the Abu Tumayam Trough. This seismic line provides valuable insights into the geological evolution of the region, particularly in relation to the deposition of over 5,000 metres of sediment. These sediments range in age from the Cambrian-Ordovician period to the Oligocene. Continued rifting in the Sirt Basin's western part, such as the Abu Tumayam Troughs, results in faults, as illustrated in dip seismic line NC-2 (Fig. 11). This might have resulted in a significant increase in the subsidence of the Abu Tumayam Trough depocenter. The estimated depth from both 2D gravity models matches those in the seismic lines, indicating that the depth rises near the trough's depocenter.

5. CONCLUSIONS

This study focused on the Abu Tumayam Trough, which is located in the southwestern Sirt Basin. This paper deals with gravity, seismic, and well data were used in this study in order to determine the depth of the basement and the subsurface fault system. The Bouguer and residual gravity maps both show that the Abu Tumayam Trough is dominated by a number of high anomaly structures on the edges. The maps also show what indicates that the depocenter predominates by a low anomaly in the middle section of the trough. In addition to this, it revealed a large fault that trends from NW-SE. The total horizontal gradient map (THG) illustrated many trend faults extending in the directions NW-SE, NE-SW, N-S, and E-W in addition to NNW-SSE. These faults provide evidence of a variety of tectonic mechanisms, such as the extension movement that took place during the Mesozoic era. The interpretation of the gravity maps

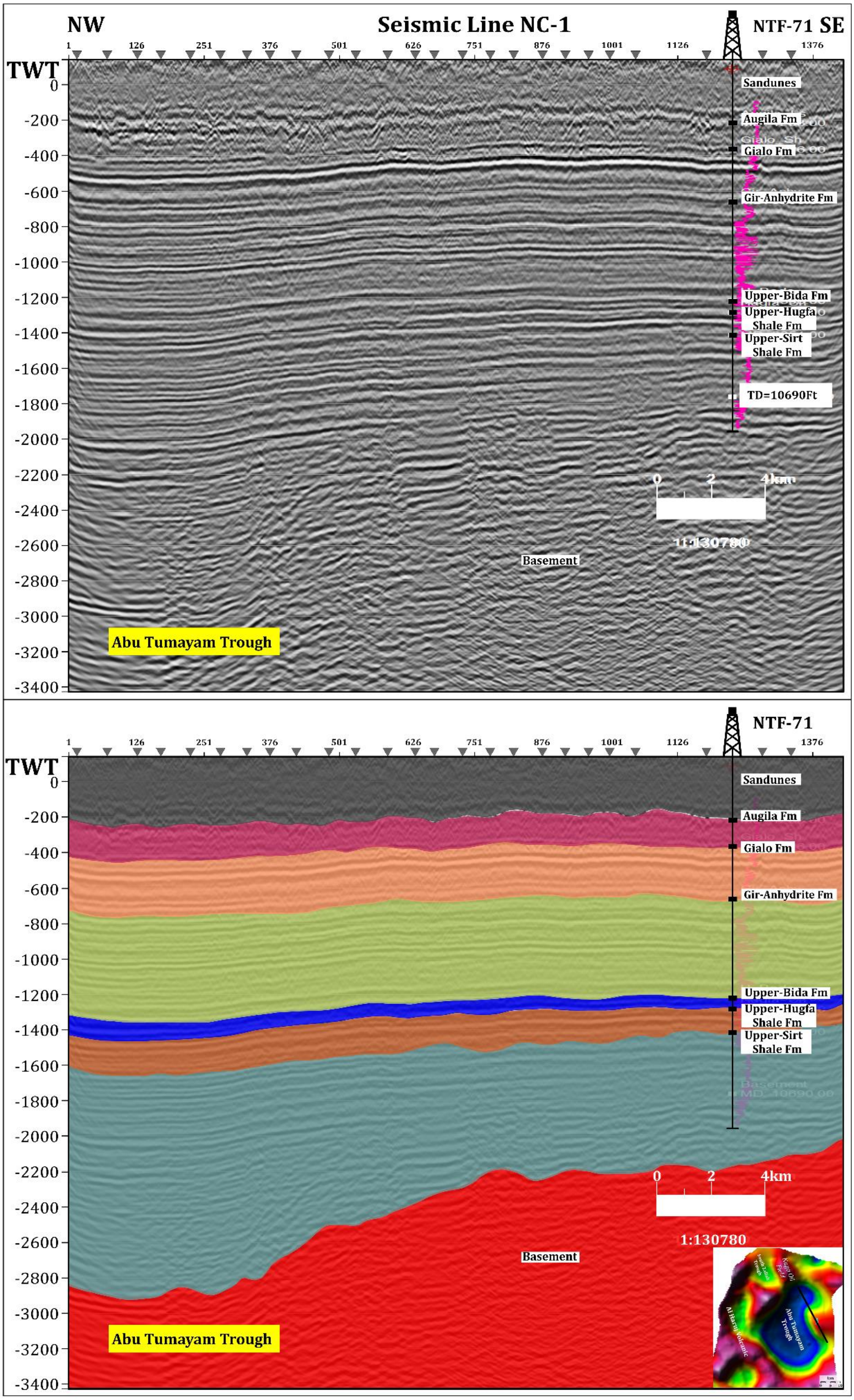

Fig. 9 The NW-SE, 2D Strick seismic line NC-1 across the Abu Tumayam Trough.

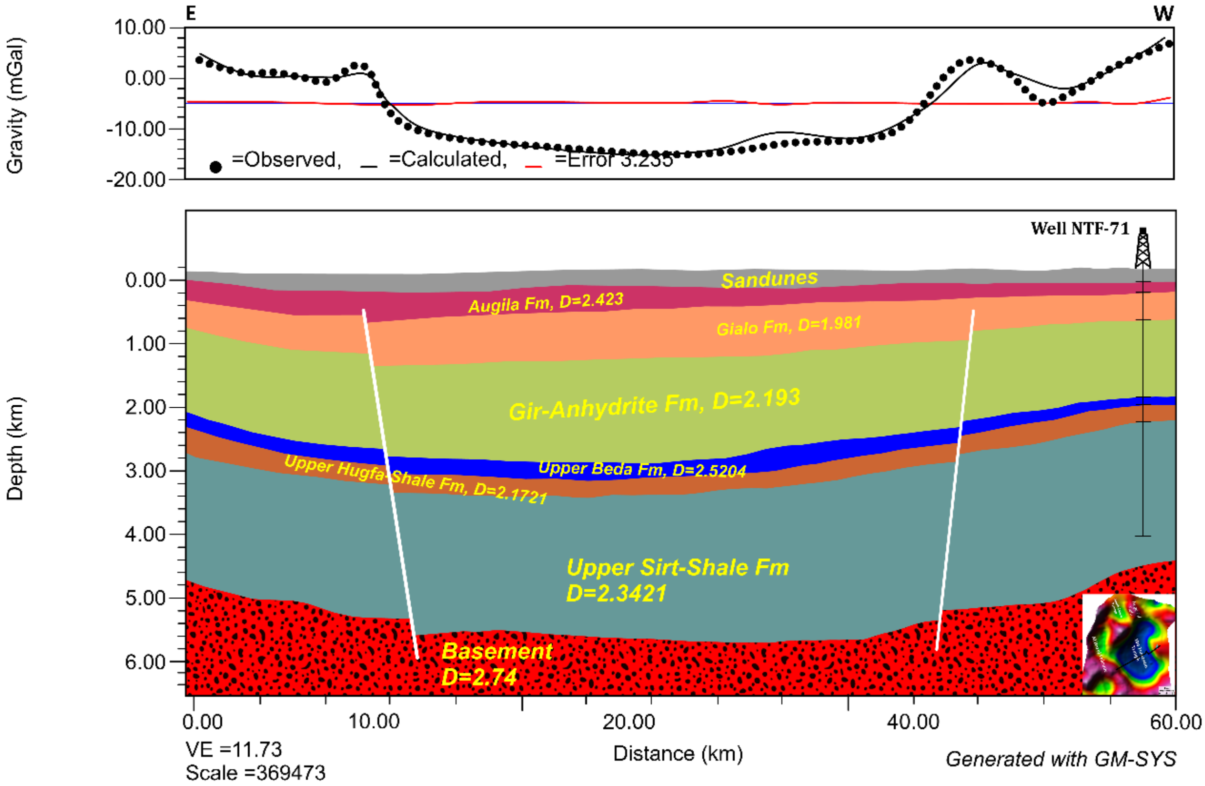

Fig. 10 The E-W 2D gravity model shows a general thickening of the sedimentary sequence of the central part of the Abu Tumayam Trough. The model shows variations in sediments thickness which matches the seismic profile.

reveals the presence of three prominent elevations in the northern region, while a large basin extends in a northeast-southwest direction in the southern part. The top of these structures is situated at depths ranging from approximately 1300 metres to 5000 metres, with further extensions below. Furthermore, the map highlighted the NE-SW basement faults very clearly. The 3D SPI map shows the depth of the basement, which varies from 5200 to 5900 meters. The bedrock that resides under the troughs is rather deep, reaching 5.9 km, as shown by the 2D gravity model. In contrast, the basement that is beneath the positive anomalies only reaches 5.2 km. The seismic interpretation reveals that a few faults crossed the trough, and these faults formed a small graben at the depocenter and cut the sedimentary section.

ACKNOWLEDGEMENTS

The authors would like to thank the Petroleum Research Centre (PRC) and the National Oil Corporation (NOC) for providing data for use in this study. Universiti Sains Malaysia's facilities were also useful in this research.

MATERIALS AVAILABILITY

Data will be available upon request.

FUNDING

This study was funded by the Authors.

REFERENCES

Abadi, A.M.: 2002, Tectonics of the Sirt Basin. Inferences from tectonic subsidence analysis, stress inversion and gravity modelling. Ph.D Thesis, Vrije Universiteit Amsterdam, 187 pp.

Abadi, A.M., Van Wees, J.-D., Van Dijk, P.M. and Cloetingh, S.A.: 2008, Tectonics and subsidence evolution of the Sirt Basin, Libya. Bull. Am. Assoc. Petrol. Geol., 92, 993–1027. DOI: 10.1306/03310806070

Abdunaser, K.: 2015, Satellite imagery for structural geological interpretation in Western Sirt Basin, Libya: Implication for petroleum exploration. Geosciences, 5, 8–25. DOI: 10.5923/j.geo.20150501.02

Abugares, Y.I., 1996, Sedimentology and hydrocarbon potential of the Gir Formation, Sirt Basin, Libya. In: Salem, M.J., El-Hawat, A.S. and Sbeta, A.M. (eds.), The geology of Sirt Basin: Amsterdam, Elsevier, 2, 45–64.

Anketell, J.: 1996, Structural history of the Sirt Basin and its relationship to the Sabratah Basin and Cyrenaica platform, northern Libya. In: Salem, M.J., Busrewil, M.T., Misallati, A.A. and Sola, M.A. (eds.), The Geology of Sirt Basin, 3, Elsevier Sciences, Amsterdam, 57–89.

Anketell, J.M. and Ghellali, S.M.: 1991, A palaeogeographic map of the pre-Tertiary surface in the region of the Jifarah plain and its implication to the structural history of northern Libya. In: Salem, M.J., Sbeta, A.M., Bakbak, M.R. (eds.), The Geology of Libya. Elsevier Sciences, 2407–2416.

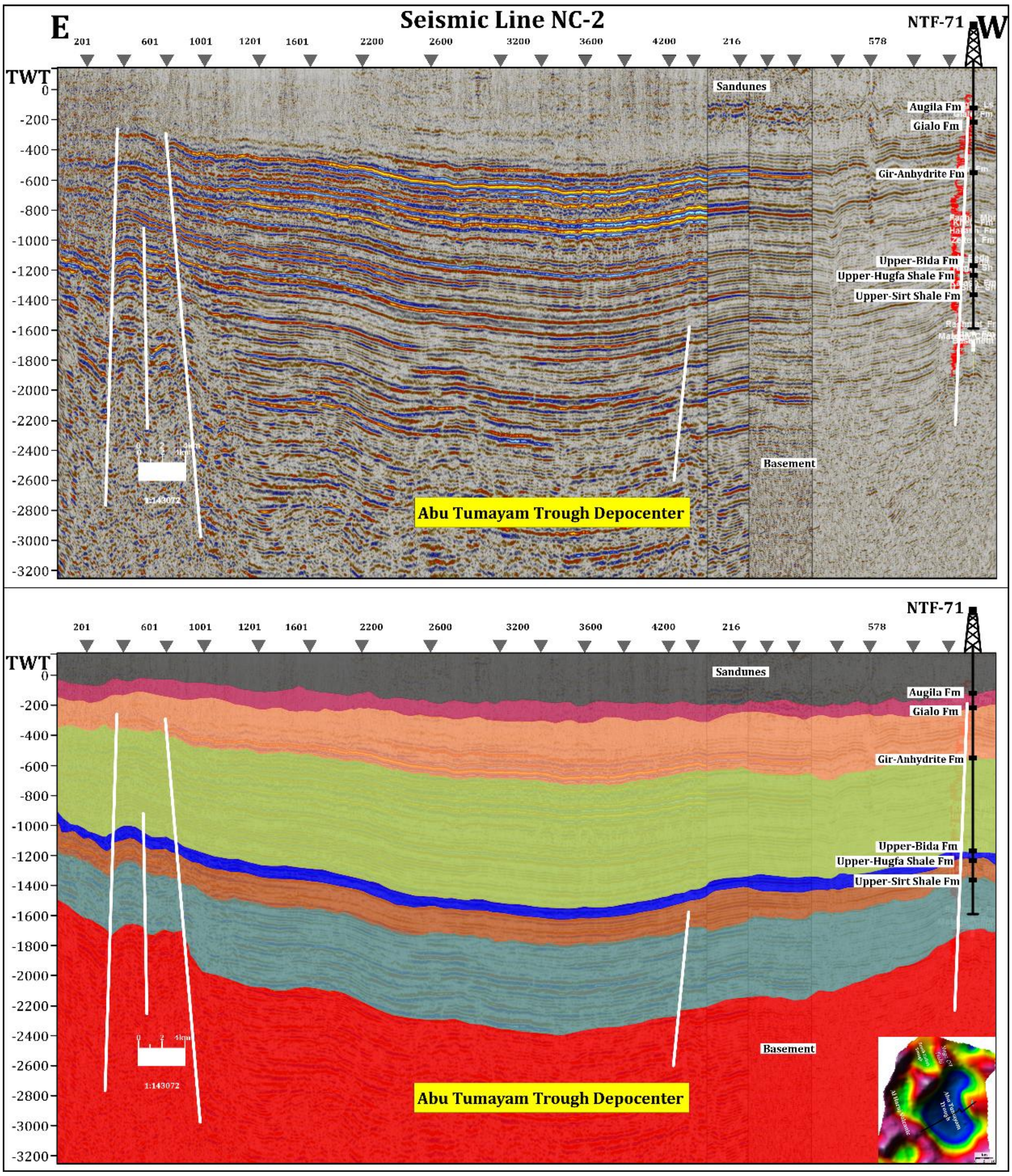

Fig. 11 The E-W, 2D dip composite seismic line NC-2 across the central part of Abu Tumayam Trough.

Anketell, J.M. and Ghellali, S.M.: 1991, A palaeogeologic map of the pre-Tertiary surface in the region of the Jifarah plain and its implication to the structural history of Northern Libya. In: Salem, M.J., Busrewil, M.T. and Ben Ashour, A.M. (eds.), Geology of Libya, 7, Elsevier, Amsterdam, 2681–2687.

Baird, D.W., Aburawi, R.M. and Bailey, N.J.L.: 1996, Geohistory and petroleum in the Central Sirt Basin. In: Salem, M.J., El-Hawat, A.S. and Sbeta, A.M. (eds.), The geology of the Sirt Basin. Elsevier, Amsterdam, 3–56.

Bonnefous, J.: 1972, Geology of the quartzitic Gargaf Formation in the Sirte Basin, Libya. Bull. Centr. Rech. Pau, SNPA, 6, 225–261.

Boote, D.R., Clark-Lowes, D.D. and Traut, M.W.: 1998, Palaeozoic petroleum systems of North Africa. Geol. Soc. Spec. Publ., 132, 7–68. DOI: 10.1144/GSL.SP.1998.132.01.02

Burke, K. and, Dewey, J.F.: 1974, Two plates in Africa during the Cretaceous? Nature, 249, 313–316. DOI: 10.1038/249313a0

Cartwright, J., Bouroullec, R., James, D. and Johnson, H.: 1998, Polycyclic motion history of some Gulf Coast growth faults from high-resolution displacement analysis. J. Geol., 26, 819–822. DOI: 10.1130/0091-7613(1998)

Cordell, L. and Grauch, V.: 1985, Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico. In: Hinze, W.J. (ed.), The utility of regional gravity and magnetic anomaly maps. Society of Exploration Geophysicists, USA, 181–197.
Dercourt, J., Zonenshain, L., Ricou, L.-E., Kazmin, V., Le Pichon, X., Knipper, A., Grandjacquet, C., Sbortshikov, I., Geyssant, J. and Lepvrier, C.: 1986, Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Lias. Tectonophysics, 123, 241–315. DOI:10.1016/0040-1951(86)90199-X
Ekwok, S.E., Akpan, A.E. and Ebong, E.D.: 2019, Enhancement and modelling of aeromagnetic data of some inland basins, southeastern Nigeria. J. Afr. Earth Sci., 155, 43–53. DOI: 10.1016/j.jafrearsci.2019.02.030
Eshanibli, A., Khalil, A., Younis, A. and Ghanoush, H.: 2020, Structural framework of the Zelten platform, south Sirt Basin, Libya using potential fields modelling. Acta Geodyn. Geomater., 17, 2, 230–236. DOI: 10.13168/AGG.2020.0017
Eshanibli, A.S., Osagie, A.U., Ismail, N.A. and Ghanush, H.B.: 2021, Analysis of gravity and aeromagnetic data to determine structural trend and basement depth beneath the Ajdabiya Trough in northeastern Libya. SN Appl. Sci., 3, 228. DOI: 10.1007/s42452-021-04263-7
Finetti, I.: 1985, Structure and evolution of the central Mediterranean (Pelagian and Ionian Seas). In: Stanley, D. and Wezel, F. (eds), Geological evolution of the Mediterranean Basin. Springer, New York, 215-230.
Gras, R. and Thusu, B.: 1998, Trap architecture of the Early Cretaceous Sarir sandstone in the eastern Sirt Basin, Libya. Geol. Soc. Spec. Publ., 132, 317–334. DOI: 10.1144/GSL.SP.1998.132.01.1
Gumati, Y. and Nairn, A.: 1991, Tectonic subsidence of the Sirte Basin, Libya. J. Petrol. Geol., 14, 93-102. DOI: 10.1111/j.1747-5457.1991.tb00301.x
Gumati, Y.D. and Kanes, W.H.: 1985, Early tertiary subsidence and sedimentary facies-Northern Sirte Basin, Libya. Bull. Am. Assoc. Petrol. Geol., 69, 39–52. DOI: 10.1306/AD461B83-16F7-11D7-8645000102C1865D
Hallett, D.: 2002, The structure geology. In: Selley, R. and Tull, S. (eds), Petroleum Geology of Libya. Elsevier Science, Amsterdam, 235 pp.
Hallett, D. and Clark-Lowes, D.: 2016, Petroleum geology of Libya. Elsevier Sciences, Amsterdam, 391 pp.
Hallett, D. and El Ghoul, A.: 1996, Oil and gas potential of the deep trough areas in the Sirt Basin, Libya. In: Salem, M.J.A., El-Hawat, S. and Sbeta, A.M. (eds.), The geology of Sirt Basin. Elsevier Science, Amsterdam, 455–484.
Kingston, D.R., Dishroon, C. and Williams, P.: 1983, Global basin classification system. Bull. Am. Assoc. Petrol. Geol., 67, 2175–2193. DOI: 10.1306/AD460936-16F7-11D7-8645000102C1865D
Klitzsch, E.: 1996, Geological observations from Nubia and their structural interpretation. In: Salem, M.J., Mouzughi, A.J. and Hammuda, S. (eds), The geology of Sirt Basin. Elsevier Science, Amsterdam, 101–106.
Klitzsch, E. and Squyres, C.: 1990, Paleozoic and Mesozoic geological history of northeastern Africa based upon new interpretation of Nubian strata. Bull. Am. Assoc. Petrol. Geol., 74, 1203–1211. DOI: 10.1306/0C9B2457-1710-11D7-8645000102C1865D
Kumati, S.: 1981, The geology of the Hofra region, Sirte Basin, Libya (SPLAJ). Ph.D Thesis, Universty of Manchester, 231 pp.
Saleem, M.A.A.: 2015, Tectonic evolution and structural analysis of south-western Sirte Basin, Central Libya. Ph.D Thesis, University of Birmingham.
Saleem, M.A.A.: 2019, Structural and tectonic subsidence history study of south-western Sirt Basin, Libya. Int. J. Sci. Res., 8, 19 pp. DOI: 10.21275/ART20194711
Shaaban, F. and Ghoneimi, A.: 2001, Implication of seismic and borehole data for the structure, petrophysics and oil entrapment of Cretaceous-Palaeocene reservoirs, northern Sirt Basin, Libya. J. Afr. Earth Sci., 33, 103–133. DOI: 10.1016/S0899-5362(01)90093-4
Talwani, M., Worzel, J.L. and Landisman, M.: 1959, Rapid gravity computations for two- dimensional bodies with application to the Mendocino submarine fracture zone. J. Geophys. Res., 64, 49–59. DOI: 10.1029/JZ064i001p00049
Thurston, J.B. and Smith, R.S.: 1997, Automatic conversion of magnetic data to depth, dip, and susceptibility contrast using the SPI (TM) method. Geophysics, 62, 807–813. DOI: 10.1190/1.1444190
Van Der Meer, F. and Cloetingh, S.: 1993, Intraplate stresses and the subsidence history of the Sirte Basin (Libya). Tectonophysics, 226, 37–58. DOI: 10.1016/0040-1951(93)90109-W
Yanilmaz, E., Huffman, D., Martin, M. and Gutteridge, P.: 2008, Facies analysis and depositional systems of defined sedimentary sequences from Precambrian to Late Miocene in NE Libya. In: Salem, M.J. and El-Hawat, A.S. (eds.), Geology of East Libya. Earth Science Society of Libya, Tripoli, 3–84