Journal of African Earth Sciences 120 (2016) 125–133

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

New insights into the structure of Om Ali-Thelepte basin, central Tunisia, inferred from gravity data: Hydrogeological implications

Mongi Harchi [a,*], Hakim Gabtni [b], Hatem El Mejri [c], Lassaad Dassi [c], Abdallah Ben Mammou [a]

[a] Laboratoire des Ressources Minérales et Environnement, Code: LR01ES06, Département de géologie, Faculté des Sciences de Tunis, Université de Tunis El Manar, 2092 Tunis, Tunisia
[b] Laboratoire de Géoressources, Code: LR10CERTE01, Centre de Recherches et Technologies des Eaux, Technopole Borj-Cedria, B.P. 73, 8020 Soliman, Tunisia
[c] Laboratoire de recherche "Eau-Energie-Environnement", Code: LR99ES35, Ecole Nationale d'Ingénieurs de Sfax, Sfax 3038, Tunisia

A R T I C L E I N F O

Article history:
Received 23 January 2016
Received in revised form
28 April 2016
Accepted 6 May 2016
Available online 8 May 2016

Keywords:
Gravity data
Conductivity
Structural analysis
Hydrogeological implication
Om Ali- Thelepte basin
Central Tunisia

A B S T R A C T

This work presents new results from gravity data analyses and interpretation within the Om Ali-Thelepte (OAT) basin, central Tunisia. It focuses on the hydrogeological implication, using several qualitative and quantitative techniques such as horizontal gradient, upward continuation and Euler deconvolution on boreholes log data, seismic reflection data and electrical conductivity measurements. The structures highlighted using the filtering techniques suggest that the Miocene aquifer of OAT basin is cut by four major fault systems that trend E-W, NE-SW, NW-SE and NNE-SSW. In addition, a NW-SE gravity model established shows the geometry of the Miocene sandstone reservoir and the Upper Cretaceous limestone rocks. Moreover, the superimposition of the electrical conductivity and the structural maps indicates that the low conductivity values of sampled water from boreholes are located around main faults.

1. Introduction

Many geologic studies have discussed the tectonosedimentary evolution of central Tunisia (e.g. Pervinquière, 1903; Burollet, 1956; M'Rabet et al., 1979; M'Rabet, 1981; Dlala, 1984; Chihi, 1984, 1995; Zouari, 1984; Ben Ferjani et al., 1990; Boukadi, 1994; Ben Ayed, 1994; Zghal, 1994; Saidi, 1996; Zghal et al., 1997; Rabhi, 1999; Zouaghi et al., 2005a, 2011; Dhahri et al., 2015). However, only a few of these studies addressed the OAT basin, made up of grabens and subsiding troughs bordered by several Atlassic fold structures (Salloum, Kchem elkelb, Tamesmida, Douria and Elkbir) formed during the Atlassic orogeny (e.g. Richert, 1971; Dlala, 1984; Martinez et al., 1990; El Euchi, 1993; Zouaghi et al., 2005b; Zouaghi, 2008; Dhahri and Boukadi, 2010). This basin contains an aquifer system which constitutes the main water resources for agriculture and domestic uses in the region. The sustainable management of the water resources therefore requires an accurate knowledge of the geologic structures in the basin and their lateral continuity.

The structure of OAT aquifer system, made of the sandstones of Beglia Formation, is relatively unknown and the available information derived from few hydrogeologic borehole logs and preliminary electric data (Khanfir, 1980). Moreover, seismic data sets are few in the study area to provide complete information about the geometry and the lateral extension of the aquifer system. In fact, the structure of the deep aquifer level within the whole area is not yet well established as it is completely overlain by thick quaternary deposit. However, the analysis and the interpretation of new gravity data for the purpose of hydrogeological investigation of the OAT basin have not been carried out until now. Within this context and in view of the importance of geophysical surveys as a powerful tool for the geological mapping, the present work was initiated. Therefore, the aim of this study is to describe the structure and the geometry of the aquifer system of the OAT basin using gravity data. These techniques were performed by the integration of data extracted from borehole logs and seismic reflection profile in the OAT Miocene aquifer by showing different units and the spatial

* Corresponding author.
E-mail addresses: mongiherchi@yahoo.fr (M. Harchi), gabtni_hakim@yahoo.ca (H. Gabtni), hatemmejri@engineer.com (H. El Mejri), lassaad@geologist.com (L. Dassi), abdallah.benmammou@fst.rnu.tn (A.B. Mammou).

http://dx.doi.org/10.1016/j.jafrearsci.2016.05.004
1464-343X/

organization of the major tectonic structures.

2. Geological and hydrogeological setting

The OAT basin situated about 5 km to the north of Feriana city, within an E-W trough in central Tunisia covering an area of about 600 km^2 (Fig. 1). It is limited to the north by several highlands which include Dernaia (1203 m), Tamesmida (1233 m), Kchem elkalb (1112 m) mountains and the plateau of Kasserine, and to the east the basin is delimited by the Salloum mountains; to the south by the following mountains Douria (1105 m), Goubel (1003 m) and Elkbir (1150 m) mountains and to the west by international border with Algeria.

The OAT area is located in the central Atlas of Tunisia which is marked by NE-SW and E-W oriented anticlines separated by large synclinal structure basins. The fold structures resulted from the Miocene NW-SE compressive phase (Richert, 1971; Chihi, 1984, 1995; Dlala, 1984; El Euchi, 1993; Dlala and Rebai, 1994; Zouaghi, 2008; Rigane et al., 2010; Dhahri et al., 2015). Upper Cretaceous strata outcrop within the cores of several E-W and NE-SW anticlines around the study area are subdivided into two sub-basins; the Om Ali-Garaât Enaâm subbasin to the west and the Thelepte subbasin to the east.

The oldest outcropping stratigraphic units in the study area correspond to the Coniacian-Santonian bioclastic limestone of the Douleb Formation (Burollet, 1956; Trabelsi, 1989; El Euchi, 1993; Negra, 1994; Saidi, 1996). The Campanian-Maastrichtian series is known Abiod Formation made of white limestones. The Paleocene-Oligocene interval is not defined in the whole area suggesting hiatus during the Paleogene and a significant change in the depositional setting in the early Miocene (Fig. 2). The Miocene series (Beglia Formation), are mainly made of coarse to medium-grained, cross bedded yellow and white sandstone (Mannai-Tayech, 2005, 2009). This Formation outcrops in the southern limb of Elkbir anticline and in the west of the OAT basin (Fig. 1). However, the Pliocene series are represented by an alternation of marls and sands of the Segui Formation. The Beglia and the Abiod stratigraphic units are separated by an important sedimentary hiatus due to the emersion of the so-called Kasserine Island during the late Cretaceous and the Paleogene ages (Burollet, 1956; Burollet and Magnier, 1960; Marie et al., 1982; Marco et al., 2014; Kadri et al., 2015) (Fig. 2).

The Miocene deposits constitute an important aquifer made of 200 m thick sandstones which contain a 20 m-thick clay unit. The clays outcrop at the northern and the southern limbs of the Elkbir anticline and the western side of khchem elkalb mountain (Khanfir, 1980). The Miocene aquifer, which covers the OAT basin, represents the main groundwater reservoir in the region drilled by deep boreholes and occasionally by shallow wells.

3. Data and methodology

Gravity data was collected by the “Office National des Mines (ONM)” during 2011 comprising a total of 1244 ground gravity measurements over one station per km^2 using a Scintrex CG3 gravity-meter. The data sets were provided as two adjacent Bouguer anomaly maps (Feriana and Jebel Salloum 1/50000 sheets) with a reduction density of 2.34 g/cm^3 (ONM, 2011). This value results from the comparison of three methods; the direct measurement of densities done on samples from consolidated rocks within the outcropping formations, the Nettleton density profiling (Nettleton, 1939) and the triplet methods (Siegert, 1942). These data have been georeferenced and digitized in a single gravity map (Fig. 3). The Bouguer gravity anomaly data were gridded at 200 m spacing and contoured to produce a Bouguer gravity anomaly map. This map shows that the Bouguer anomaly data are affected by a slight regional gradient shown by northward increase of the values. A residual gravity map was established by subtracting this gradient (Fig. 4). The Bouguer anomaly map also contains information on the basement discontinuities, which can be delineated by analysing areas of gravity gradient. Hence, in order to highlight the geophysical lineaments such as faults, various filtering and complementary techniques were used. These techniques involve the horizontal gradient, the upward continuation and the Euler

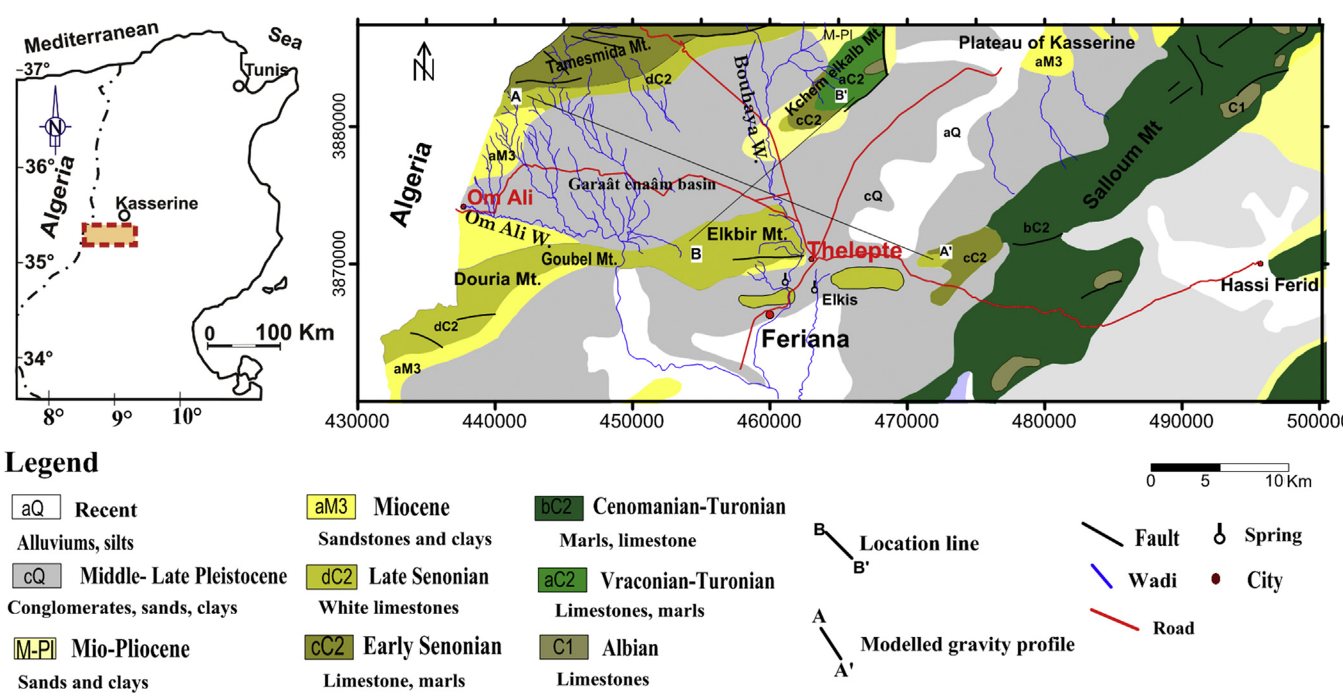

Fig. 1. Location and simplified geological map of the Om Ali-Thelepte basin.

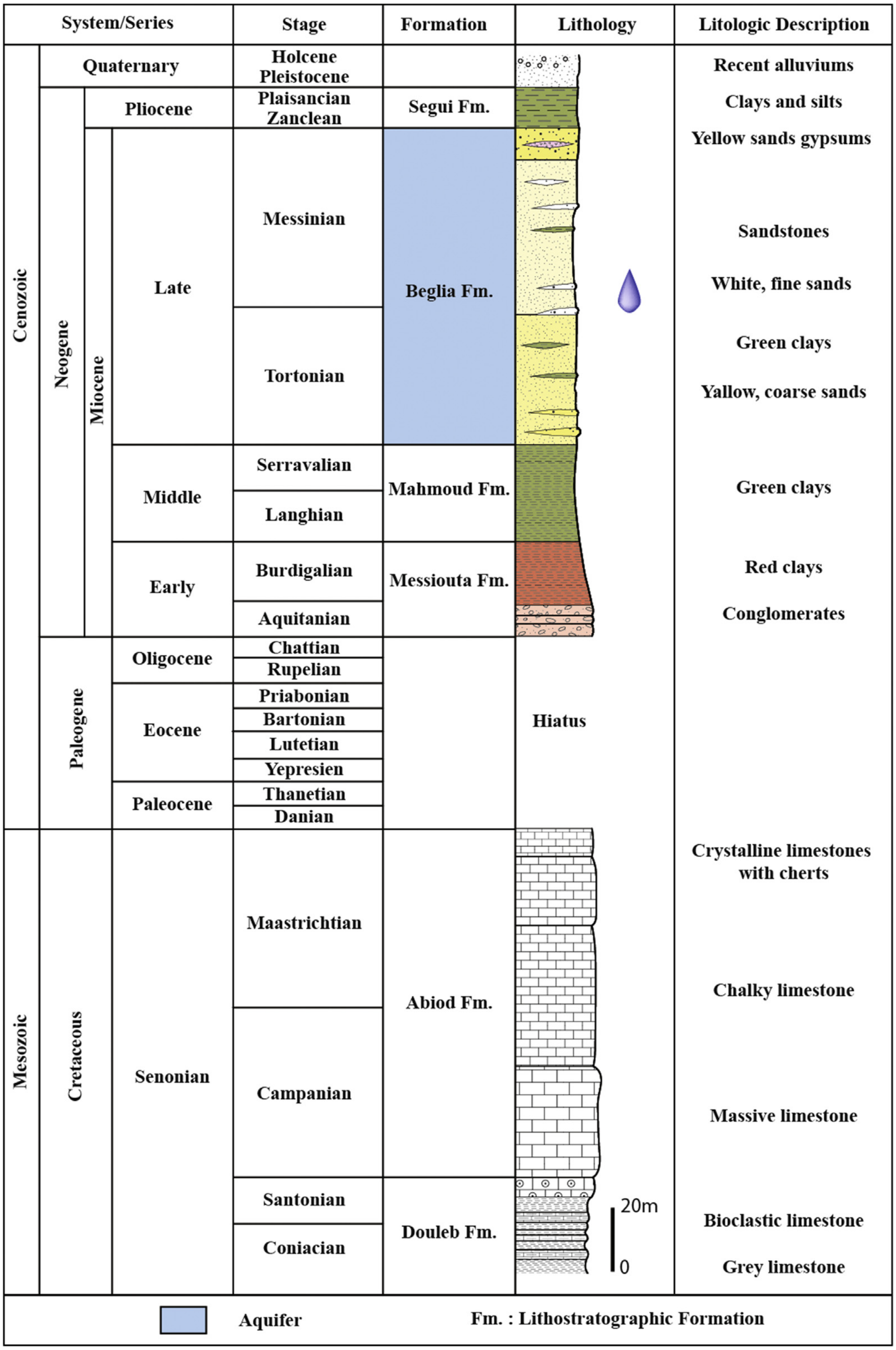

Fig. 2. Simplified lithostratigraphic column of the Om Ali-Thelepte basin (modified after Trabelsi, 1989).

deconvolution. The filtering of gravity data allows us to obtain additional information on the organization of the Miocene sandstone basement compared to those provided by the Bouguer anomaly map (Archibald et al., 1999; Everaerts and Mansy, 2001; Khattach et al., 2004; Vanié et al., 2005; El Gout et al., 2010; Gabtni et al., 2012; Ouerghi et al., 2013). First the horizontal gradient of the Bouguer anomaly map was computed and its maxima located using the automatic technique of Blakely and Simpson (1986) in order to highlight the geological contacts underlined by abrupt change of density. In fact, a vertical contact separating two formations with different densities generates an anomaly corresponding to a gravity level change from low values

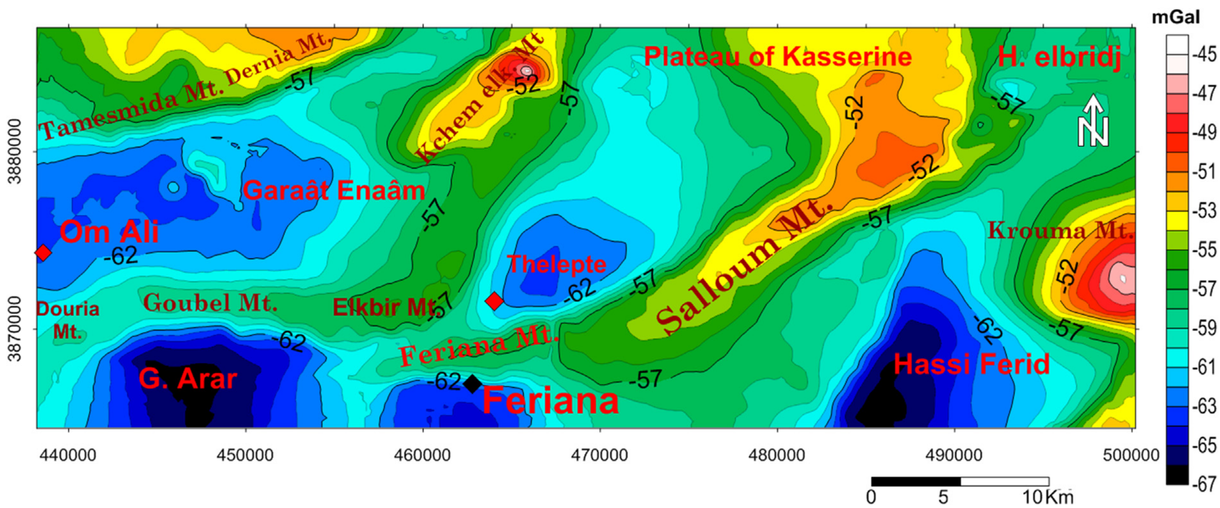

Fig. 3. Bouguer anomaly map of the Om Ali- Thelepte basin (Reduction density: 2.34 g/cm^3).

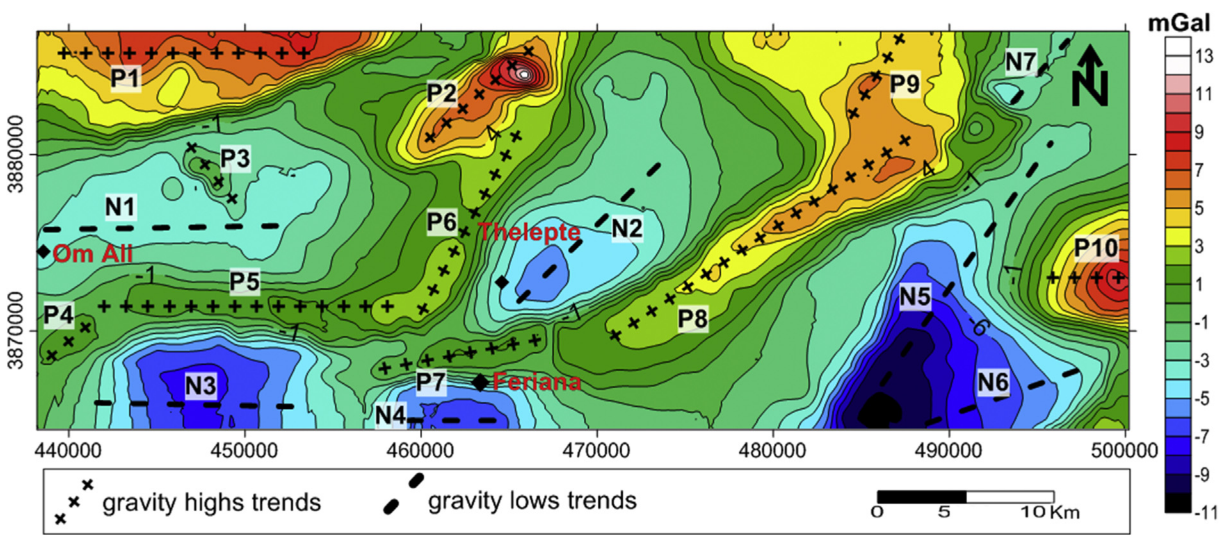

Fig. 4. Residual anomaly map of the study area (interval = 1 mGal).

on the rocks of low-density to higher values on the denser rocks. The inflection point which marks the transition between the two levels is located at the contact between the two types of rocks. This inflection point corresponds to maximum on the horizontal gradient map (Cordell and Grauch, 1982) (Fig. 5). Moreover, the evaluation of the directions of the contact dips is obtained through the upward of the Bouguer anomaly map at different altitudes (100, 200, 300, 400, 500, and 600 m) as well as the determination of the horizontal gradient maxima for each level (Fig. 6). The progressive migration of these maxima while the upward altitude is increased indicates the dip direction. The maxima overlap on a vertical contact (Archibald et al., 1999; Khattach et al., 2004; Jaffal et al., 2010).

The Euler deconvolution was applied to the gravity map in order to provide automatic estimations of source location and depth for the highlighted structures deducted previously (Fig. 7). The quality of depth estimation depends mainly on the choice of a structural index (SI) (Chenrai et al., 2010). Thus, the structural index used was awarded to zero which is considered as the more appropriate value for the successful application of the method (Thompson, 1982; Reid et al., 1990; Gabtni et al., 2012; Atawa et al., 2016). Furthermore, the compilation of the NE-SW seismic profile obtained from the “Entreprise Tunisienne des Activités Pétrolières (ETAP)” (Fig. 10) and the NW-SE gravity model constructed from residual gravity profile AA′ (Fig. 9) provides an understanding of the geometry of the Miocene aquifer. These techniques provide new insights into the structure of the OAT basin. Indeed, the conductivity and structural maps overlayed together point out the contribution of the used techniques in the hydrogeological research.

4. Results and discussion

4.1. Gravity data processing, modelling and interpretation

The Bouguer anomaly map of OAT basin shows a large number of strong variations and high gravity gradient zones which testify to the high density contrasts in the study area. The Bouguer anomaly values vary from −67 mGal to −45 mGal and underline several areas with ENE and E-W- trending axis. It seems that areas with high gravity values coincide with the uplifted terrains that match with the mountain ranges surrounding the study area (Fig. 3).

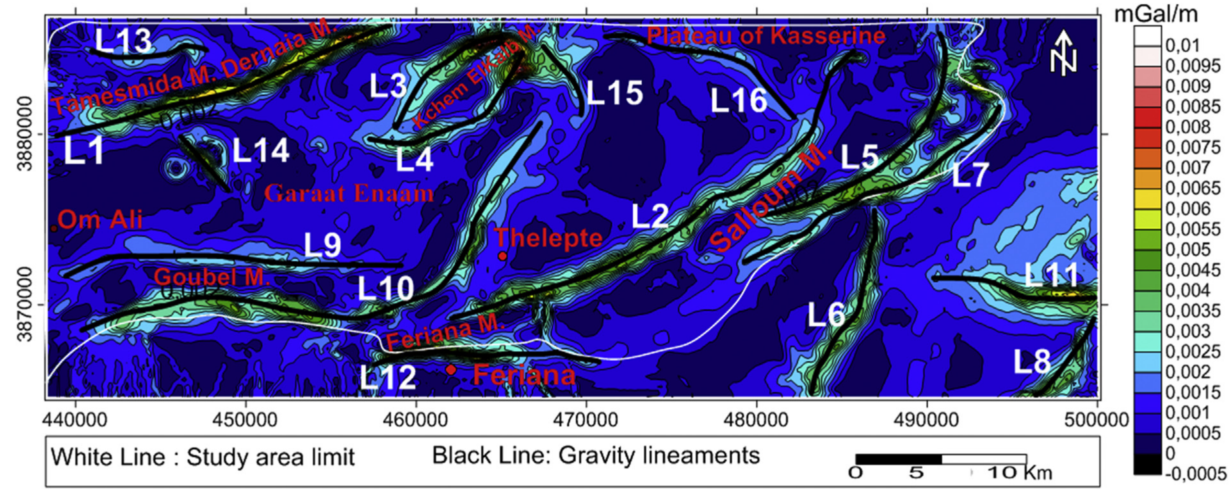

Fig. 5. Horizontal gradient map of the Bouguer anomaly.

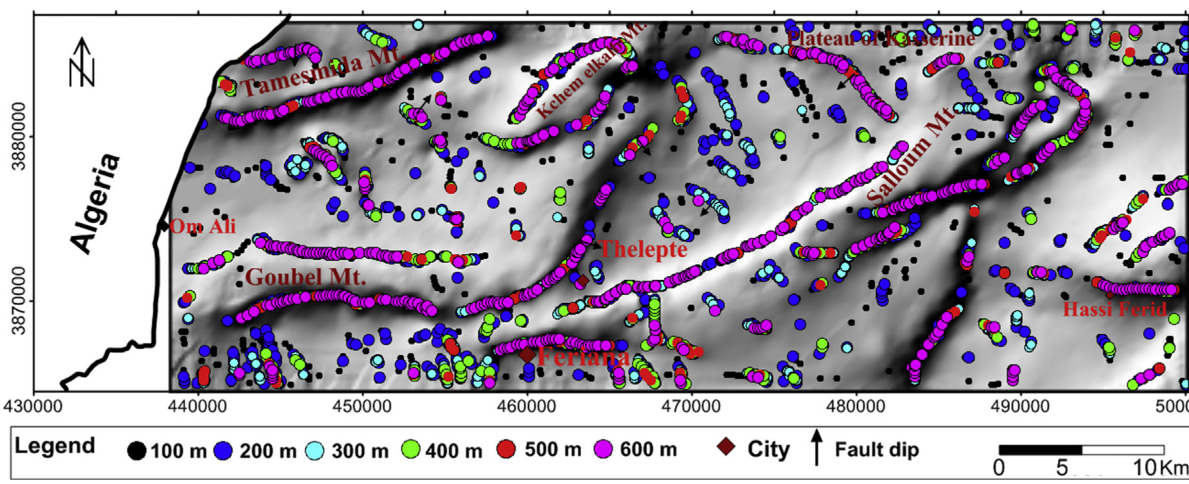

Fig. 6. Horizontal gradient maxima of the Bouguer anomaly and its upward continuations at different heights.

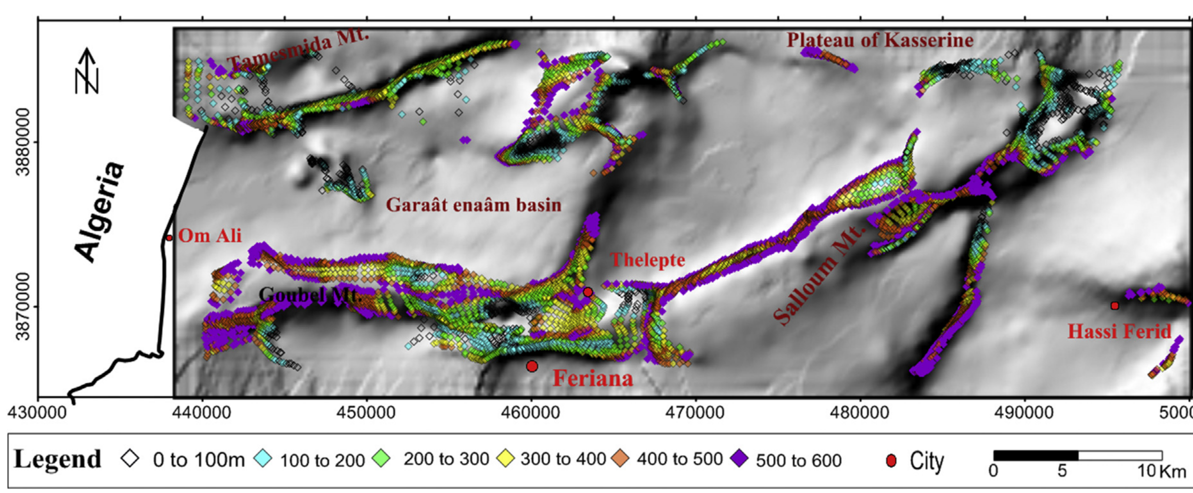

Fig. 7. Euler solution (structural index IS = 0, a 20 × 20 window and maximum relative error of 15%).

The gravity field includes effects from sources of local and shallow nature as well as regional and deep structures (Jallouli and Mickus, 2000). It is therefore essential to separate the regional and the residual anomalies originating from deep-seated and shallow sources respectively. The residual gravity anomalies were separated from the deep-seated sourced anomalies using a third-order

Table 1
Main gravity anomalies of the study area (see Fig. 3 for anomaly locations).

Anomalies	Directions	Locations	Causes
N1	E-W	Om Ali- Garaât Enaâm	Trough filled with Neogene sediments
N2	NE-SW	Thelepte	
N3	E-W	Garaât Arar	
N4	E-W	Feriana	
N5	NNE-SSW	Hassi Ferid	
N6	NEE-SWW	Hassi Ferid	
N7	NE-SW	Henchir elbridj	
P1	E-W	Tmesmida, Dernaia Mountains	Outcrop of Upper Cretaceous rocks
P2	NE-SW	Kchem elkalb Mountain	
P3	NW-SE	Garaât Enaâm	Basement uplift
P4	NE-SW	Douria Mountain	Outcrop of Upper Cretaceous rocks
P5	E-W	Goubel Mountain	
P6	NE-SW	Elkbir-Kchem elkalb Mountains	Basement uplift
P7	E-W	Feriana Mountain	Outcrop of Upper Cretaceous rocks
P8	NE-SW	Salloum Mountain	
P9	NE-SW	Salloum Mountain	
P10	E-W	Krouma Mountain	

polynomial surface to determine the regional gravity field. So, the residual anomaly was calculated in order to delineate shallow bodies (Fig. 4).

The examination of this map reveals several positive (P1 to P10) and negative (N1 to N7) gravity anomalies which reflect the lateral variations of the density in the basement related to geological structures. These anomalies correlate well with the structural features of the study area. In fact, positive anomalies (P1, P2, P4 to P9) that surround the OAT basin coincide with the high density rocks of the Upper Cretaceous series that outcrops within the Tamesmida, Kchem elkalb, Goubel, Elkbir, Feriana, and Salloum anticlinal structures (Fig. 1). The negative anomalies correspond to the thick Cenozoic deposits which infill the Om Ali, Garaât Enaâm and Thelepte sub-basins (Table 1). The various gravity anomalies are separated by high gradients zones indicative of discontinuities of density coinciding with the main faults in the area.

The application of the horizontal gradient maxima (HGM) together with upward continuation method allows the mapping of lateral rock boundaries, the localization of the limit of structural blocks and the determination of fault geometry and depth (Blakely, 1996; Archibald et al., 1999; Fedi and Florio, 2001; Khattach et al., 2004, 2006; Vanié et al., 2005, 2006; Chennouf et al., 2007, Najine et al., 2006; Jaffal et al., 2010; El Gout et al., 2010; Gabtni et al., 2012).

The application of Bouguer anomaly data allows the mapping of several lineaments corresponding to the maxima of the horizontal gradient. These lineaments are oriented NE, EW and NW (Fig. 5). The NE oriented lineaments underline the southeastern limbs of the Atlassic anticlinal structures and act as thrust faults (Zouari et al., 1990; Boukadi, 1994; Zitouni, 1997; Boutib and Zargouni, 1998; Bédir et al., 2001; Frizon De Lamotte et al., 2009). To the south of Om Ali basin, two main EW trending lineaments (L9, L10) underline the Goubel structure. However, lineament L10 is shifted to NE direction and appears to border the Kchem elkalb anomaly.

Moreover, the eastern edge of Kchem Elkalb Mountain and the plateau of Kasserine reveal two NW directed lineaments i.e. L15 and L16, respectively. Three NW-oriented lineaments appear in Om Ali-Garaat Enaam (L14), eastern Kchem Elkalb (L15) and in the plateau of Kasserine (L16). The lineaments correlate with the NW-Oriented faults bordering the graben structures of central Tunsia (Richert, 1971; Ben Ayed, 1980; Dlala, 1984, 1995; Rabhi, 1999; Boukadi, 1994; Chihi, 1995; Zouaghi, 2008; Dhahri and Boukadi, 2010).

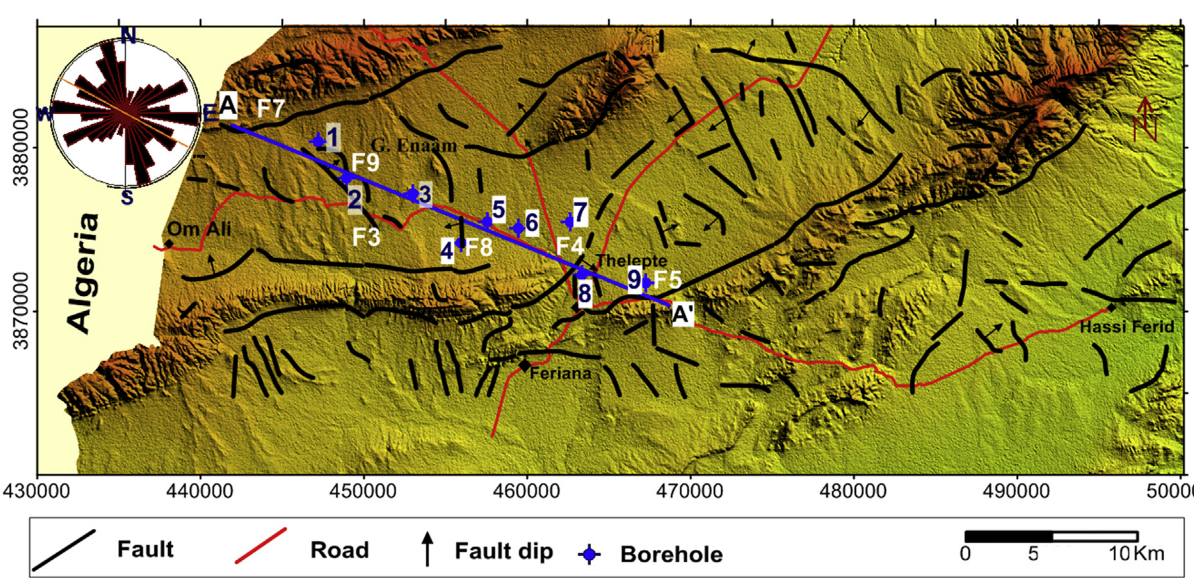

Fig. 8. Digital model elevation of the study area after the Shuttle Radar Topography Mission with structural interpretation of gravity data and rose diagram of faults. AA′ indicates the location of the gravity model.

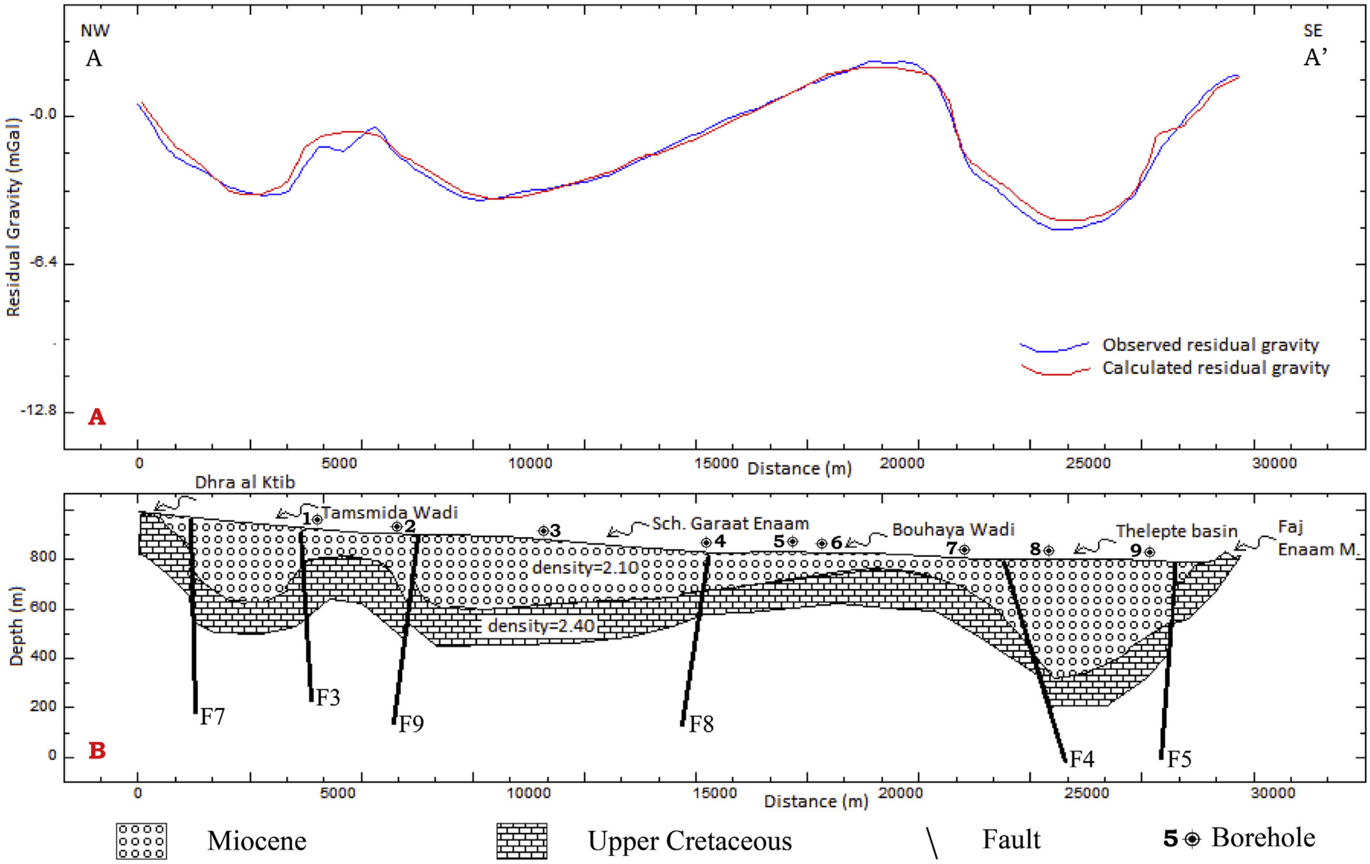

Fig. 9. Residual gravity model along NW-SE section in the Om Ali-Thelepte basin constructed after calibration of hydraulic boreholes and gravity data. A; Residual anomaly profile. B; NW-SE gravity model along the profile AA′ (see Fig. 8 for location).

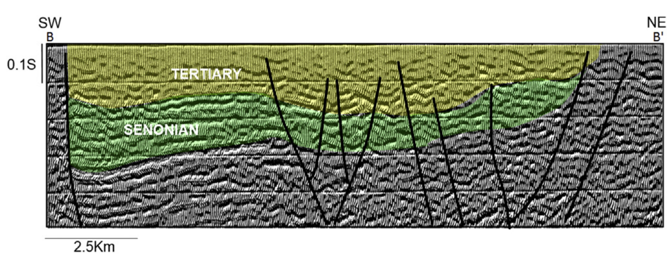

Fig. 10. Interpreted seismic line BB′ (see Fig. 1 for location), showing the geometry distribution of the Senonian and Tertiary series.

Further analysis of the gravity defined contacts was performed by computing horizontal gradient maxima of upward continuation of the Bouguer anomaly at different depths up 600 m by steps of 100 m. This method yielded a large number of linear features interpreted as faults. Several faults are known from the previous geological studies and new ones are highlighted here for the first time (Fig. 8).

The rose diagram plotted as Fig. 8 shows fault segments within the study area oriented NE-SW, E-W, NW-SE and NNW-SSE (Fig. 8). Statistically, the NNW-SSE oriented lineaments dominate compared to NE-SW and E-W orientations, but they are relatively the shortest lineaments in the whole area. The NW and E-W segments coincide with grabens and troughs formed during the Miocene (Richert, 1971; Chihi, 1984, 1995; Dlala, 1984; El Euchi, 1993; Zouaghi, 2008; Zouaghi et al., 2011). Hydrogeologically, these faults have a significant role in the recharge and infiltration of surface water and groundwater flow.

To improve the interpretation of the structures affecting the OAT basin, the Euler deconvolution method was applied to the gravity data. This method permits the determination of the source depths and the localization of faults. Furthermore, faults are distinguished by the Euler deconvolution method on the gravity data using a structural index of 0 (SI = 0) (Gabtni et al., 2012; Atawa et al., 2016) (Fig. 7). The Euler method generates many solutions with different degrees of clustering and different depths in areas of pronounced changes in crustal and basement rocks (Shannon et al., 2001; Tašárová et al., 2006). However, preliminary results confirm the main faults previously deducted from horizontal gradient and upward continuation method. The shallow faults and small scale contacts are not identifiable through this method.

In order to accurately delineate the top of the Abiod Formation a NW-SE oriented gravity model was constructed and calibrated with four boreholes (5, 6, 7 and 8) that reach the Abiod Formation. Within this model the bodies of the theoretical responses of the Upper Cretaceous carbonates and the Miocene sediments were computed. Their densities estimated from seismic P wave velocities and boreholes data are 2.4 g/cm^3 and 2.1 g/cm^3, respectively. The density contrast (0.3 g/cm^3) between these bodies provides a good opportunity to produce a significant gravity model. The gravity model was constructed along a NW-SE transect (Figs. 1 and 9) based on the information from several boreholes logs and the seismic reflection profile BB' (Figs. 1 and 10). The model reveals that the Miocene aquifer is affected by six major faults (F7, F3, F9, F8, F4 and F5) which control the architecture of Om Ali, Garaât Enaâm and Thelepte basins (Fig. 9). These faults act a subsurface barrier contributing to the hydraulic discontinuity of the Miocene aquifer. Furthermore, the NE-SW seismic profile (BB′) (Fig. 10) illustrates

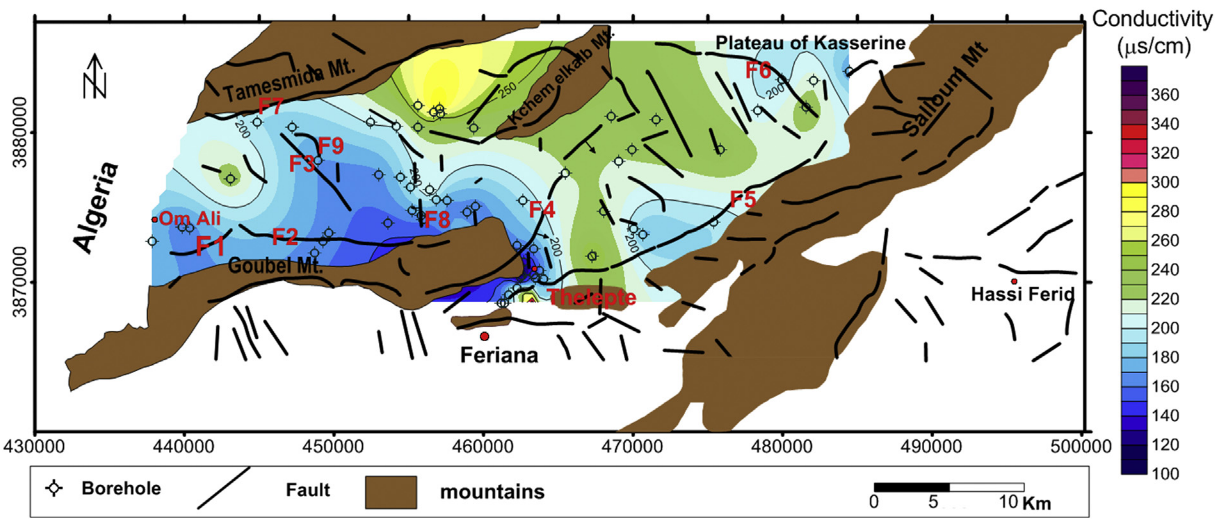

Fig. 11. Groundwater electrical conductivity map within the main structural features of the study area.

the lateral changes of the geometry of the basin particularly at the base. The profile also provides a good control on the geometry of Senonian series covered by the Tertiary sequence. The geometry is controlled by deep flower system faults. There is a high correlation between the master faults shown on the seismic section and those delineated within the gravity model. Regarding Figs. 8–10, the NE-trending Kchem El Kalb fault as well as the EW- trending Goubel -Elkebir fault, have significant throw and were highlighted within the seismic section and the gravity model. Moreover, seismic profile indicates clearly the thickening of the Miocene deposits at the Garaât Enaâm basin which correlate with confirms the middle part of the NW-SE gravity model.

4.2. Hydrogeological implication

Given that there is no piezometric map established for the Miocene aquifer, we mapped the electrical conductivity along the study area based on in situ measurement at each borehole (Fig. 11). Fig. 11 shows that the lower conductivity values are located around the major faults (F1, F2, F3, F4, F5 and F6) in the western and eastern parts of the study area which may enhance the aquifer recharge at this area. Whereas, most of the water samples having higher electrical conductivity values are located northern Thelepte and around Kchem ElKalb mountain where the conductivities values exceed 220 µs cm^{-1}. In this area, the Miocene series are relatively thick and overlain by a thick marly layer (Khanfir, 1980). Moreover, some faults delineated using the Euler solutions are shallow and seem not to affect the Miocene aquifer (Fig. 7). High conductivity zones may be due to insufficient recharge of the aquifer by the freshwater along contacts above the Miocene aquifer, reflecting the negligible mixing of the deep aquifer with the shallow water. In this area, the hydrodynamic functioning of the aquifer seems to be controlled by a Piston flow circulation model, where mixing is negligible (Robertson and Cherry, 1989; Maas, 1994). The water resides during longer periods of time and its mineralisation tends to increase. Besides, the groundwater flow occurs generally from west to east (Khanfir, 1980).

5. Conclusion

The interpretation of the gravity data permits clarification of the structure of the basement of the OAT basin, by highlighting two depressions (Garaat Enaâm and Thelepte) delimited by faults. The structural maps show several faults organized into four main orientations E-W, NE-SW, NW-SE and NNE-SSW. From a hydrogeological point of view, this study confirms the thickening of Miocene aquifer in the Thelepte, Garaât Enaâm and Om Ali basins towards international border with Algeria. Borehole logs, seismic profile and filtered gravity data allowed the building up of a gravity model for the Miocene aquifer. The structural maps provide useful information for the planning of further hydrogeological research and the sustainable management of groundwater in the area.

Acknowledgements

The authors are grateful to the “Office National des Mines (ONM)” and the “Entreprise Tunisienne d’Activités Pétrolières (ETAP)” for providing geophysical data. We would like to express our gratitude to the reviewers for their helpful comments and suggestions that improved this manuscript.

References

Archibald, N., Gow, P., Bochetti, P.F., 1999. Multiscale edge analysis of potential field data. Explor. Geophys. 30, 38–44.

Atawa, M., Zouaghi, T., Souei, A., 2016. Gravity constraints on the underground structural framework and associated volcanism of the Maghrebian allochthonous domain: the Sejnene numidian flysch, Tunisian Tell. J. Afr. Earth Sci. http://dx.doi.org/10.10/J.jafrearsci.2016.01.008.

Bédir, M., Boukadi, N., Tlig, S., Ben Timzal, F., Zitouni, L., Alouani, R., Slimane, F., Bobier, C., Zargouni, F., 2001. Subsurface Mesozoic Basins in the Central Atlas of Tunisia, tectonics, sequence deposit distribution and hydrocarbon potential. A. A. P. G. Bull. 85, 885–907.

Ben Ayed, N., 1980. Le rôle des décrochements E-W dans l’évolution structurale de l’Atlas Tunisien. C.R. Somm. Soc. Géol. Fr. 29–32.

Ben Ayed, N., 1994. Les décrochements-chevauchements EW et NS convergents de la Tunisie septentrionale: géométrie et essai de reconstitution des conditions de déformation. Entreprise Tunisienne d’Activités Pétrolières, Tunis, Tunisia. Memoir 7.

Ben Ferjani, A., Burollet, P.F., Mejri, F., 1990. Petroleum Geology of Tunisia. Entreprise Tunisienne d’Activités Pétrolières, Tunis.

Burollet, P.F., 1956. Contribution à l’étude stratigraphique de la Tunisie centrale. Ann. mines la géologie, 345pp.

Burollet, P.F., Magnier, P., 1960. Copenhague. Remarques sur la limite Crétacé-Tertiaire en Tunisie et en Libye. 21th Int. Geol. congr, 5, pp. 136–144.

Boukadi, N., 1994. Structuration de l’Atlas de Tunisie : signification géométrique et cinématique des nœuds et des zones d’interférences structurales au contact de grands couloirs tectoniques (Unpublished thesis). Doctorat d’Etat, Université de Tunis II, Tunisia, 249 pp.

Blakely, R.J., Simpson, R.W., 1986. Approximating edges of sources bodies from magnetic or gravity anomalies. Geophysics 51 (7), 1494–1498. http://dx.doi.org/10.1190/1.1442197.

Blakely, R.J., 1996. Potential Theory in Gravity and Magnetic Applications. Cambr. Univ. Press, p. 461.

Boutib, L., Zargouni, F., 1998. Disposition et géométrie des plis de l’Atlas centroméridional de Tunisie. Découpage et cisaillement en lanières tectoniques.

C. R. Acad. Sci. Fr. 326, 261–265.
Chihi, L., 1984. Etude tectonique et microtectonique du graben de Kasserine (Tunisie centrale) et des structures voisines Jbel Salloum et Jbel Maargaba (Unpiplushed thesis). Doctorat 3eme cycle, Paris-Sud, Centre d'Orsay, France, 116pp.
Chihi, L., 1995. Les fossés néogènes à quaternaires de la Tunisie et de la mer pélagienne : leur signification dans le cadre géodynamique de la méditerranée centrale (Unpiblushed thesis). Doctorat d'état, Université Tunis II, Tunisia, 324pp.
Cordell, L., Grauch, V.J.S., 1982. Dallas. The san Juan basin, New Mexico. In: Mapping Basement Magnetization Zones from Aeromagnetic Data. in: 52nd Ann. Int. Meet. Soc. Explor. Geophys, pp. 246–247. Abstracts biographies.
Chennouf, T., Khattach, D., Milhi, A., Andrieux, P., Keating, P., 2007. Principales lignes structurales du Maroc. C.R. Geosci. 339, 383–395.
Chenrai, P., Meyers, J., Charusiri, P., 2010. Euler deconvolution technique for gravity survey. J. Appl. Sci. Res. 6 (11), 1891–1897.
Dhahri, F., Boukadi, N., 2010. The evolution of pre-existing structures during the tectonic inversion process of the Atlas chain of Tunisia. J. Afr. Earth Sci. 56, 139–149.
Dhahri, F., Tanfous, D., Gabtni, H., Boukadi, N., 2015. Structural and geodynamic study in central Tunisia using field and geophysical data: new structural interpretation of the N–S axis and associated Atlassic structures. Int. J. Earth Sci. http://dx.doi.org/10.1007/s00531-015-1159-1. Geol Rundsch.
Dlala, M., 1984. Etude tectonique et microtectonique de la région de Kasserine (Tunisie centrale) (Unpiblushed thesis). Doctorat 3 ème cycle, CNRS, Université Montpellier, France, 138pp.
Dlala, M., Rebai, S., 1994. Relation compression-extension Miocène supérieur à Quaternaire en Tunisie: implication sismotectonique. C. R. Acad. Sci. Paris (série II) 319, 945–950.
Dlala, M., 1995. Evolution géodynamique et tectonique superposées en Tunisie: implications sur la tectonique récente et la sismicité. Thèse d'Etat. Université de Tunis II, Tunis, Tunisia.
Everaerts, M., Mansy, J.L., 2001. Le filtrage des anomalies gravimétriques, une clé pour la compréhension des structures tectoniques du Boulonnais et de l'Artois (France). Bull. Soc. Géol. Fr. 172 (3), 267–274.
El Euchi, H., 1993. La Tunisie du centre-Ouest de l'Aptien à l'Actuel : tectonique coulissante, dynamique sédimentaire associée et essai de caractérisation des séquences de dépôt. Unpiblushed thesis, Doctorat 3 ème cycle. Université Tunis II, Tunisia, 263pp.
El Gout, R., Kattach, D., Houari, M.R., Kaufmann, O., Aqil, H., 2010. Main structural lineaments of north- eastern Morocco derived from gravity and aeromagnetic data. J. Afr. Earth Sci. 58 (2), 255–271.
Fedi, M., Florio, G., 2001. Detection of potential fields source boundaries by enhanced horizontal derivative method. Geophy. Prosp 49, 40–58.
Frizon De Lamotte, D., Leturmy, P., Missenard, Y., Khomsi, S., Ruiz, G., Saddiqi, O., Guillocheau, F., Michard, A., 2009. Mesozoic and Cenozoic vertical movements in the Atlas system (Algeria, Morocco, Tunisia): an overview. Tectonophysics 475, 9–28.
Gabtni, H., Alyahyaoui, S., Jallouli, C., Hasni, W., Mickus, K.L., 2012. Gravity and seismic reflection imaging of a deep aquifer in an arid region: Case history from the Jeffara basin, Southeastern Tunisia. J. Afr. Earth Sci. 66–67, 85–97.
Jallouli, C., Mickus, K., 2000. Regional Gravity analysis of the crustal structure of Tunisia. J. Afr. Earth Sci. 30 (1), 63–78.
Jaffal, M., El Goumi, N., Kchikach, A., Aifa, T., Khattach, D., Manar, A., 2010. Gravity and magnetic investigations in the Houaz basin Morocco, Interpretation and mining implications. J. Afr. Earth Sci. 58, 331–340.
Kadri, A., Essid, E.M., Merzeraud, G., 2015. "Kasserine Island" boundaries variations during the Upper Cretaceous-Eocene (Central Tunisia). J. Afr. Earth Sci. 111, 244–257.
Khanfir, R., 1980. Contribution à l'étude hydrogéologique de la région d'Om Ali-Thelepte (Ksserine). These de 3eme cycle. Univ. Pierre et Marie Curie, Paris, 6 ; 76pp.
Khattach, D., Keating, P., Mili, E.M., Chennouf, T., Andrieux, P., Milhi, A., 2004. Apport de la gravimétrie à l'étude de la structure du bassin des Triffa (Maroc nord-oriental) : implications hydrogéologiques. C. R. Geosci. 336, 1427–1432.
Khattach, D., Mraoui, H., Sbibih, D., Chennouf, T., 2006. Analyse multi échelles par ondelettes des contacts géologiques : application à la carte gravimétrique du Maroc nord- oriental. C.R. Geosci. 338, 521–526.
Mannai-Tayech, B., 2005. Un nouveau gisement miocène à ichthyfaune au sud de la chaine des chotts (Tunisie méridionale). Paléoenviron. Paléobigéogr. C. R. Palevol 4, 405–412.
Mannai-Tayech, B., 2009. The lithostratigraphy of Miocene series from Tunisia, revisited. J. Afr. Earth Sci. 54, 53–61.
Marco, I., Dhahri, F., Hajji, T., Boukadi, N., 2014. The Aptian–Albian transition in central Tunisia: tectonosedimentary and paleogeo-graphic records. J. Earth. Sci. 25 (5). ISSN 1674–487X.
Marie, J., Trouvé, P., Desforges, G., Dufaure, P., 1982. Nouveaux éléments de paléogéographie du Crétacé de Tunisie. Cretac. Res. 3, 167–170.
Martinez, C., Turki, M.M., Truillet, R., 1990. La signification des plis d'orientation méridienne dans l'Atlas tunisien centro-méridional. Bull. Soc. Géol. Fr. 8, 843–852.
Maas, C., 1994. On Convolution Processes and Dispersive Groundwater Flow. Ph.D. Thesis. Delft University of Technology, The Netherlands, 157pp.
M'Rabet, A., Dufaure, P., Burollet, P.F., 1979. Nouvelles données biostratigraphiques, sédimentologiques et paléogéographiques sur l'Aptien de la Tunisie central. Géobios (Lyon, France). Mémoire spécial 3, 213–229.
M'Rabet, A., 1981. Stratigraphie, sédimentation et diagenèse carbonatée des séries du crétacé inférieur de Tunisie centrale. Thèse, Doct. Es Sciences, Orsay, 41 pl., IV tabl., 87 fig., 540 pp..
Najine, A., Jaffal, M., El Khammari, K., Aïfa, T., Khattach, D., Himi, M., Casas, A., Badrane, S., Aqil, H., 2006. Contribution de la gravimétrie à l'étude de la structure du bassin de Tadla (Maroc): Implications hydrogéologiques. C. R. Geosci. 338, 676–682.
Negra, M.E.H., 1994. Les dépôts de plate forme à bassin du crétacé supérieur en Tunisie centro-septentrional (Formation Abiod et Faciès associés), stratigraphie, sédimentation diagenèse et intérêt pétrolier. Unpublished Thesis, Doctorat d'état. Université Tunis II, Tunisia, 649pp.
Nettleton, L.L., 1939. Determination of density for reduction of gravimeter observations. Geophysics 4, 176–183.
ONM, 2011. Campagne gravimétrique CG9. Coupures 1/50000 de Feriana et J. Salloum.
Ouerghi, S., Rebai, N., Gabtni, H., Farhat, B., Bouaziz, S., 2013. Apport de la gravimétrie à l'étude des structures effondrées du Nord Est de la Tunisie, implications hydrologiques. hydrol. Sci. J. 58 (6), 1–13.
Pervinquière, L., 1903. Published thesis. In: Rudeval, F.R. (Ed.), Etude géologique de la Tunisie centrale. Dir. Trav. Pub. Carte Géol. Tunisie, Paris, 360 pp.
Rabhi, M., 1999. Contribution à l'étude stratigraphique et analyse de l'évolution géodynamique de l'axe Nord-Sud et des structures avoisinantes (Tunisie centrale). University of Tunis II. Fact. Sc. Tunis, 206 pp.
Reid, A.B., Allsop, J.M., Granser, H., Millet, A.J., Somerton, I.W., 1990. Magnetic interpretation in three dimensions using Euler deconvolution. Geophysics 55, 80–91.
Richert, J.P., 1971. Mise en évidence de quatre phases tectoniques successives en Tunisie. Notes Serv. géologique Tunis. 34, 115–125.
Rigane, A., Feki, M., Gourmelen, C., Montacer, M., 2010. The "Aptian Crisis" of the South-Tethyan margin: new tectonic data in Tunisia. J. Afr. Earth Sci. 57, 360–366.
Robertson, W.D., Cherry, J.A., 1989. Large-scale dispersion in a sandy aquifer: simulation of subsurface transport of environ-mental tritium. Water Resour. Res. 32, 3253–3266.
Saidi, F., 1996. Sédimentologie stratigraphie séquentielle et diagenèse carbonatée des faciès du crétacé supérieur de la région de Kasserine- Tamesmida (Tunisie centrale). Unpublished thesis. Université Tunis II, Tunisia, 347pp.
Shannon, P.M., Haughton, R.D.W., Corcoran, D.V. (Eds.), 2001. The Petroleum Exploration of Ireland's Offshore Basins, 188. Geological Society, London, Special Publications, pp. 393–399.
Siegert, A.J.F., 1942. Determination of the Bouguer correction constant. Geophysics 7, 29–34.
Tašárová, Z., Götze, H.-J., El-Kelani, R., Ebbing, J., Hassouneh, M., 2006. Small-scale gravity modeling of upper crustal structures in the Araba Valley along the Dead Sea Transform. Geochem. Geophys. Geosyst. 7, 9. http://dx.doi.org/10.1029/2005GC001229.
Thompson, D.T., 1982. EULDPH: A new technique for making computer-assisted depth from magnetic data. Geophysics 47, 31–37.
Trabelsi, H., 1989. Les matériaux utiles de la région de Feriana (Tunisie centrale). Université de Nice, France, 249pp.
Vanié, L.T.A., Khattach, D., Houari, M.R., 2005. Apport des filtrages des anomalies gravimétriques à l'étude des structures profondes du Maroc oriental. Bull. Inst. Sci. Rabat, Sect. Sc. Terre 27, 29–40.
Vanié, L.T.A., Khattach, D., Houari, M.R., Chourak, M., Corchete, V., 2006. In: Apport des filtrages des anomalies gravimétriques dans la détermination des accidents tectoniques majeurs de l'Anti-Atlas (Maroc). Actes du 3[ème] Colloque Maghrébien de Géophysique Appliquée, pp. 23–30. Oujda, 11-13 Mai 2006.
Zghal, I., 1994. Etude biostratigraphique du Crétacé inférieur de la Tunisie du centre ouest (Région de Kasserine-Sbeitla et de Tajerouine). Thèse de 3ième cycle. Univ. Tunis II. Tunis, Tunisia, 382pp.
Zghal, I., Ben Haj Alia, N., Razghallah, S., Razgallah, S., Bismuth, H., 1997. Foraminifères et Ostracodes de l'Aptien-Albien du Jebel Hameima (région de Tadjerouine, Tunisie): biostratigraphie, paléoécologie. Afr. Geosci. Rev. 4, 361–372.
Zouaghi, T., Bédir, M., Inoubli, M.H., 2005a. Structuration profonde des dépôts de l'Albien-Maastrichtien en Tunisie centrale: nouvelle limite de l'archipel de Kasserine et implications géodynamiques. C. R. Geosci. 337, 685–693.
Zouaghi, T., Bédir, M., Inoubli, M.H., 2005b. 2D seismic interpretation of strike-slip faulting, salt tectonics, and Cretaceous unconformities, Atlas Mountains, central Tunisia. J. Afr. Earth Sci. 43, 464–486.
Zouaghi, T., 2008. Distribution des séquences de dépôt du crétacé (Aptien- Maastrichtien) en subsurface: déformation tectonique, halocinése, évolution géodynamique (Atlas central de Tunisie). Unpublished thesis. Université Tunis El Manar, Tunisia, 367 pp.
Zouaghi, T., Ferhi, I., Bédir, M., Ben Youssef, M., Gasmi, M., Inoubli, M.H., 2011. Analysis of cretaceous (Aptian) strata in central Tunisia, using 2D seismic Data and well logs. J. Afr. Earth Sci. 61, 38–61.
Zouari, H., 1984. Etude structurale de jebel Chaambi (Tunisie Centrale), relation entre minéralisation et structure. Unpublished thesis, Doctorat 3ème cycle. Université Franche-Comté- besançon, France, 93 pp.
Zouari, H., Turki, M.M., Delteil, J., 1990. Nouvelles données sur l'évolution tectonique de la chaîne de Gafsa. Bull. Soc. Géol. Fr. 8, 621–628.
Zitouni, L., 1997. Evolution géodynamique des bassins mésozoïques de subsurface des régions de Sidi Aïch-Majoura (Tunisie centrale): Sismostratigraphie, sismotectonique et implications pétrolières. Unpublished thesis. Université Tunis II, Tunisia, 335 pp.