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Subsurface structure of Teboursouk and El Krib plains (dome zone, northern Tunisia) by gravity analysis

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ABSTRACT

Gravity data was used to investigate sub-surface structure of the Teboursouk and El Krib plains belonging to the dome zone in the Northwest of Tunisia. Analysis of the gravity data included the computation of the Bouguer anomaly, the horizontal and vertical gravity gradients, the upward continuations, Euler deconvolution and analytic signal of high-resolution. The Bouguer anomaly map (d = 2.4 g cm^{-3}) has provided information on the variation of the underground density and shown contrasting anomalous zones. The treatments applied to the Bouguer anomaly map have detected new deep faults and provided details on their dips and depths (exceeding 1500 m per places).

Statistical analysis of the gravity data filtering shows that the study area is divided by four major faults with NW–SE, NE–SW, E–W and N–S trends. These faults have contributed to the structuring of the area.

The results provide confirmation of some faults already recognized or inferred from the previous structural studies, and specify their depths and dips. While large number of new faults that remained undetected until now, have been highlighted.

1. Introduction

The study area is located in the northern Tunisian Atlas, so-called the dome zone, which is characterized by Triassic outcrops, elongated NE–SW and generally is in tectonic contact with the series from the Lower Cretaceous to the Miocene (Dali, 1995; Perthuisot, 1979). This region is known by its economic interest, especially in:

- The mining domain represented by potential Pb–Zn concentrations (National Office of Mines, 1989) closely related to the Triassic-Cretaceous contacts (Hammami et al., 1997; Perthuisot, 1979). Some of these mines have been exploited (i. e. Jebel Bou khill, Jebel Fej Lahdoum and Jebel Lakhouet);
- The petroleum domain represented by the exploration of the AK1 drilling (ETAP, 1955), in the Jebel Aksabe, and the establishment of TEB1 drilling for recognition in the Dougga region (Chaari, 2006).
- The hydrogeological domain is characterized by an over-exploitation of groundwater available in the study area. They are the unique resources of drinking and irrigation waters (Balti et al., 2013; DGRE, 2006).

The better exploitation and/or management of these resources depend on an accurate knowledge of the regional structure. The previous authors (Chikhaoui, 2002; Hammami et al., 1997; Perthuisot, 1978) have emphasized the important role of diapirs and their associated fractures that are prominent in characterizing the regional structure of the study area. Moreover, the diapirs have an important role on the richness in the mineral deposits index. They have also given rise to many multidisciplinary studies (Bolze, 1950; Chikhaoui, 2002; Dali, 1979; Hammami et al., 1997; Jallouli et al., 2005; Perthuisot, 1972, 1975; Villa, 1997) including the geophysical methods counting the seismic reflection survey (Balti, 2015; Balti et al., 2013; Benassi, 2011). Indeed, the seismic data are available in Teboursouk-El Krib study area, but unfortunately the quality is poor due to the intense fracturing of the region (dome zone). The seismic lines have already been interpreted by Balti (2015). The result of seismic data has given a different interpretation compared to those of the previous authors (Hammami, 1999). In fact, previously, many authors adopted the theory of

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layer thinning around the diapir structures. However, recently, Balti in 2015 showed, from the seismic data interpretation, that the layers thicken around the diapir (rim-syncline). The complexity of the study area conducted us to use another geophysical survey. Moreover, a very contrasted density of materials characterizes the study area belonging to the dome zone. Therefore, we consider that the gravity method is the best tool in this study.

The main objective is that gravity method provides additional clarifications through a density contrast analysis by recognizing gravity anomalies, establishing the horizontal and vertical derivative maps, and by correlating the obtained results with the known surface geology. The application of the upward continuation and the analytic signal of high-resolution techniques, and the use of the Euler deconvolution method can provide new insights into the structure of the study area.

2. Geological setting

The study area belongs to the Atlassic domain (Fig. 1) and consists of the most important domes: Jebel Ech Cheid, Jebel Bou Khill, Ain Jemmala and the southeastern Thibar complexes (Jebel Aiadi). The Triassic rocks consist of chaotic mass of gypsum, clays, sands, marls, limestones and dolostones. These series are mentioned by tectonic contacts with set of series beginning from the Lower Cretaceous to the Miocene. The Cretaceous strata are composed by clay and limestone. While the Cenozoic series are represented mainly by limestone, sand and sandstone. Jurassic units are lacking in the study area (Perthuisot, 1979).

The dome ascent in the region has been occurred into two major periods: the Aptian (Chikhaoui, 2002; Perthuisot, 1978; Villa, 1997) and the middle Eocene that is the probable period of surface piercing and the definitive establishing of the actual Triassic structures (Perthuisot, 1978).

Some authors (Jauzein, 1967; Perthuisot, 1978) emphasize a NE-SW major alignment formed by regional faults disposed in relay (the major Teboursouk overthrust) (Perthuisot, 1978; Zargouni, 1975). Later, Adil (1993) considers that this fault trending is the tectonic heritage responsible for the Tethys opening. The tectonic faults are reactivated in strike-slip with conjugated structures in push-up and pull-apart. This fault system has facilitated the uplift of the Triassic material and the establishment of the Triassic piercing into the Mesozoic and Cenozoic coverage.

Therefore, tectonics has a very important role and a major control on the Triassic ascension, which has been reported as induced inversion under the influence of the density contrast in strata coverage (Chikhaoui, 2002; Perthuisot, 1978). Consequently, the regional structural evolution and the basin geodynamic tied to the activation and reactivation of several tectonic structures, which were motivated by the existence of deep and old faults. Several structural and geophysical studies have been performed and confirmed their deepening and rootedness. In fact, the presence and/or the injection of Triassic outcrops along the faults, the deformation of echelon folds and the presence of inversed series are some of this evidence (Ben Ayed, 1994; Chikhaoui, 2002; El Ouardi, 2001; Perthuisot and Jauzein, 1972). This fact has been supported by the seismic data interpretations (Balti, 2015).

3. Gravity data analysis

High-resolution gravity data of the Teboursouk and El Krib plains was obtained from the National Office of Mines (ONM) of Tunisia. Acquisition was carried out in 1997 by the Val Dor Sagax Company. Gravity data cover the 1/50 000 scale map of Teboursouk and Gaafour. A total of 834 stations covering an area of 868 km^2 have been measured. The approximate mean density is one observation per square km. A Lambert North projection using the Clark ellipsoid 1880 and Carthage datum has been adopted. Free-air and Bouguer gravity corrections have been performed using sea level datum and a reduction density of 2.4 g/cm^3. This value results from the comparison of several methods: direct measurement of densities over several samples and the indirect method using Nettleton profiles (ONM, 2000). Bouguer and terrain corrections have been automatically calculated using a Digital Elevation Model (DEM). Taking into account the quality of the gravity and measurement locations, the underlined tolerances are of 0.02 mGal for gravimetric measurements and 0.1 m for the positioning of the stations (ONM, 2000).

4. The Bouguer anomaly

The Bouguer anomaly map indicates the density variation in the subsurface. The gravity response depends upon the parameters source as shape, size, contrast density, and position of the source. Therefore, this technique is an effective tool, especially in the close neighboring area. In fact, it has been used for better understanding the deep structures arrangement (Hachani et al., 2014) and it is an appropriate structural modeling of the subsurface (Benassi, 2009; Hamdi et al., 2010).

Gridding using the minimum curvature technique (Briggs, 1974) has been established in this study. The Bouguer anomalies values range from −24 mGal to 7 mGal (Fig. 2). Positive anomalies (from 0 to 7 mGal) coincide with: [1] Triassic outcrops of the Jebel Thibar; [2] Cretaceous outcrops of the Tabet Ech Cherif syncline.

Negative anomalies, having a positive axis, correspond to the: [3], [4], [5] Triassic outcrops of Jebel Ech Cheid, Jebel Bou khill and Ain Jemmala, respectively; [6] Turonian and Santonian outcrops of Oued Aarkou anticline; [7] Turonian outcrops of Jebel Lakhouet; [8] Cretaceous outcrops of Jebel Aksabe. Negative anomalies, having a negative axis, correspond to the Quaternary outcrops of the: [9] Gaafour-El Aaroussa syncline; [10] Teboursouk-El Krib plains; [11] Ain El Hamra- Dougga syncline; [12] Oued Harmoucha syncline and [13] Bled El Ghorfa El Gueblia syncline.

5. The residual anomaly

The subtraction of the regional component of the field leads to the establishment of the residual anomaly map. This map helps to understand the responses of superficial structures. The obtained residual anomaly map of the study area (Fig. 3) shows an amplitude of 25 mGal (−13 mGal to 12 mGal) expressing a difference of 6 mGal compared to that of the Bouguer anomaly.

Positive anomalies (from 0 to 12 mGal) coincide with Triassic outcrops of [P1] Jebel Ech Cheid, [P2] Ain Jemmala, [P3] Jebel Thibar, [P4] Jebel Bou Khill, and Cretaceous outcrops of [P5] Tabet Ech Cherif syncline, [P6] Oued Aarkou anticline, [P7] Jebel Lakhouet, [P8] Jebel Aksabe.

Negative anomalies correspond to the Mio-Plio-Quaternary outcrops of [N1] El Aaroussa-Gaafour syncline, [N2] Teboursouk and El Krib plains, [N3] Ain El Hamra- Dougga syncline, [N4] Oued Harmoucha syncline and [N5] Bled El Ghorfa El Gueblia syncline.

6. Treatment of the gravity map and cartography of fractures

To understand the spatial organization of the study area, locate the block boundaries of different densities and get closer to the sources, the treatment of the Bouguer anomaly map has proved useful. Indeed, the horizontal gradient (Grauch and Cordell, 1987), the vertical gradient (Marson and Klingele, 1993), superimposed maxima (Blakely and Simpson, 1986; Cordell and Grauch, 1985) and the analytic signal of high-resolution (Roest et al., 1992) are