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Moho depth derived from gravity and magnetic data in the Southern Atlas Flexure (Algeria)

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ABSTRACT

Existing aeromagnetic and gravity data were used to study the structure of the Southern Atlas Flexure (SAF) in Algeria. Forward and inverse numerical modelings were applied, giving access to the depth of the Moho and the Curie depth in this area. Our results suggest a maximum crustal thickness of about 48 km, and a Curie depth of about 20 km. We then discuss the implications of those results on the regional structure of the SAF, also using cross-sections built using 2D-geological modeling.

1. Introduction

The Southern Atlas Flexure (SAF) is a major geological feature of the Algerian Saharan Atlas Fig. 1. It was studied by many authors in the past (*e.g.* Laffitte (1939), Durand-Delga (1962), Guiraud (1973, 1977), Oudjida (1978)). One of the major issue concerning this structure concerns its multiple tectonic expression along its 2000 km of length ((Frizon de Lamotte et al., 2011; Habani and Kerai, 2011; Habani and Haddoum, 2006; Bettahar, 2009; Zazoun et al., 2015). Its geometry, kinematics and geodynamic evolution during the Meso-Cenozoic era and its influence on sedimentation were thus already investigated using morphological and geological data, but one should use geophysical data to perform a suitable modeling of the upper, middle and deep crust in this region. Local aeromagnetic, gravimetric, seismic and geoelectric surveys were conducted by mining or oil companies like Office National de Recherche et Exploration Pétrolière (ONAREP) and SONATRACH. Results of investigations based on potential field data were published by by Mickus and Jallouli (1999), Spakman (1986), and Asfirane and Galdeano (1995). Seismic and heat flow studies were conducted at larger scale during the European Geotraverse project (EGT; Morelli and Nicolich, 1990; Buness et al., 1992; Vedova et al., 1995). They provided more detailed information on the crustal and upper mantle structure in this area. Some of these potential field data were compiled in worldwide databases like the BGI (Bureau Gravimétrique International, http://bgi.omp.obs-mip.fr/), the World Digital Magnetic Anomaly Map WDMAM (Korhonen, 2007) or the EMAG2 magnetic field model (Maus et al., 2009). Part of the magnetic data set used in this work comes also from the Algerian airborne survey carried out between 1969 and 1976 by the North American company Aero Service Corporation over the whole territory (Asfirane and Galdeano, 1995).

In this study, we then use the potential field data to better describe and understand the geological structure of the SAF in Algeria. The Bouguer gravimetric field data are first considered to perform classical transformed distributions. We then derive the depth of the Moho using the method developed by Parker (1972) and Oldenburg (1974), via the Matlab code 3Dinver (Gómez-Ortiz and Agarwal, 2005). We also extract the pseudo-gravity from magnetic data to search for the maximum depth of the magnetic crust. Lastly we perform a 2D geological modeling along a profile crossing the SAF in order to investigate the structure of the middle and upper crust. All of these approaches allow us to discuss the geological structure of the SAF and its evolution.

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1.1. Geological settings

In Northern Africa, the transition zone between the Saharan platform to the south and the Alpine folded zone to the north extends over 2000 km from Agadir, Morocco, to Gabès, Tunisia (Aïssaoui, 1986). Its structure is oriented in various ways, the faults being grouped into system. It is known as the great “Southren Atlas event” (Bettahar, 2009). The transition from Saharan Atlas to the Sahara platform occurs through a flexural zone strongly affected by tectonics (Habani and Kerai, 2011). The SAF was first described by Savornin et al. (1931), Laffitte (1939), Durand-Delga (1962) and Guiraud (1973). Durand-Delga (1962) noticed that this flexure is well-marked in East Biskra, where it communicates with the recent sedimentary depressions. The detailed study of this flexure in its structural framework has been more recently conducted by Habani and Haddoum (2006) and Zazoun et al. (2015), for instance, but Guiraud (1973) already considered the flexure as a major deep fracture delimiting the stable and flat Saharan platform stable from the northern Maghrebides chain. These studies revealed that during the Mesozoic, nearly 10 km of continental and marine sediments were deposited unconformably on the Paleozoic basement (Habani and Kerai, 2011; Habani and Haddoum, 2006). These formations compose most of the outcrops in the studied area Fig. 2. Then the Alpine cycle occurred from the Tertiary to actual, inducing the reliefs of the Saharan Atlas and the activation of SAF (Habani and Kerai, 2011). While the Saharan Atlas underwent a topographic uplift, the South Auresian Trough underwent pulling down and received the products of the dismantling. These topographic variations stretched the plastics layers of the nearby structures (Durand-Delga, 1962). The SAF was then formed during the Tertiary era by these two tectonic phases at the transition between the Lutetian and Burdigalian stages.

The structuring of southern Tunisia by against better elucidated (Zargouni, 1985). The structural configuration seems induced activities structural discontinuities of the substratum. Thus the part Southern Atlas, between Gafsa and Tozeur is considered a segment of the Atlas Southern flexure, the region where the continental crust of the Saharan platform was stable from the Upper Precambrian, becomes unstable during Paleozoic and Meso-Cenozoic (Zargouni, 1985).

2. Data compilation

2.1. Gravity data

Gravimetric data are particularly useful as a reconnaissance tool for the deep structure of a large tectonic region. In this study (Telford et al., 1990), the used gravity data come from the BGI. The data are not raw gravity field measurements but usually processed Bouguer anomaly. We also used the Earth Gravitational Model (EGM2008) from Pavlis et al. (2008) who combine gravitational information from GRACE with the information contained within a global gravity anomaly database of $5' \times 5'$ resolution, and expanded the gravity field up to spherical harmonic maximum degree and order 2160. Some terms up to degree 2190 and order 2160 were added to the expansion. It is difficult to assess the errors contaminating the data, but we assume them as uncorrelated errors (Pavlis et al., 2008). Fig. 3 shows the Bouguer anomaly map over the SAF with 5 mgal contour interval. The major negative anomalies have a NE-SW direction and a minimum intensity of -125 mgal along the flexure.

2.2. Magnetic data

During the period ranging from 1969 to 1974, an aeromagnetic survey covering the whole territory of Algeria was conducted by the North American company Aero Service Corporation. Parts of these data were gridded and published in the EMAG2 model (Maus et al., 2009) and the WDMAM (Korhonen, 2007). The resolution of EMAG2 has been improved from 3 arc min (about 5.5 km) to 2 arc min corresponding to about 3.7 km in the study area. Correspondingly, the altitude has been decreased from 5 km to 4 km above geoid. Additional adjacent grids and track line data sets have been incorporated in order to improve the data coverage over land and ocean areas for subsequent interpolation. Fig. 4 thus shows the interpolated aeromagnetic anomaly map over our target area. To correct this map for angular distortion, we reduced it to the pole Fig. 5 using normal core field ($I = 47.67°$ and $D = 355.82°$) parameters at the center of the area. We assume that the magnetization is completely induced.

According to Figs. 4 and 5, the magnetic anomaly distribution trends in the NE-SW direction with a negative anomaly in the southeastern part, similar to the general trend of the topography, geology and gravimetric signal. According to Fig. 5, a minimum

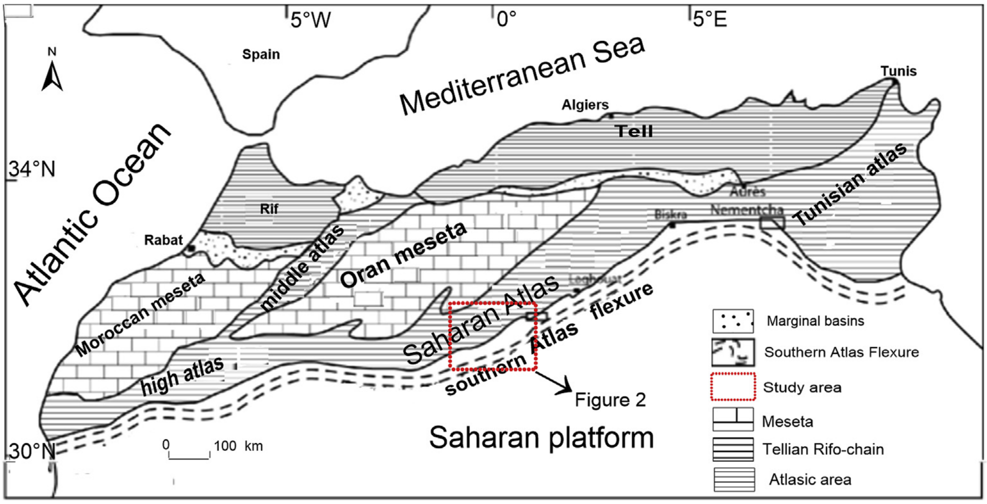

Fig. 1. Geological framework of the Maghreb (Pique et al., 1998).