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Geological interpretation of aeromagnetic data from Bou Chber area, Central Moroccan Massif

Interpretación geológica de los datos aeromagnéticos de la region de Bou Chber, Macizo Central de Marruecos

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ABSTRACT

This study concerns the geological interpretation of aeromagnetic data of Bou Chber region located in Central Morocco. Processed magnetic maps obtained through different standard methods known in aeromagntism were compared to field geological structures and ancient geological maps. We propose then a geological scheme of the Bou Chber non-mapped area based on the newly interpreted magnetic anomalies of this region.

Key-words: *Aeromagnetism, field geology, magnetic mapping, Central Morocco.*

RESUMEN

En este estudio se presenta una interpretación geológica de datos aeromagnéticos en la región de Bou Chber (Marruecos Central). Se han usado mapas aeromagnéticos procesados con métodos convencionales en aeromagnetismo, que se comparan con estructuras geológicas de campo y con mapas geológicos antiguos. Se propone un nuevo esquema geológico de la zona de Bou Chber según la interpretación de anomalías magnéticas aquí descrita.

Palabras clave: *Aeromagnetismo, geología del campo, cartografía magnética, Marruecos Central.*

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Introduction

Aeromagnetic data have been used recently in Morocco for geological mapping after its extensive use in the mining prospecting (Bouya *et al.*, 2013a, b; Bouya, 2014) and throughout the world mainly in regional geological studies (Galdeano, 1980; Blakely, 1995; Grauch *et al.*, 2001; Aspler *et al.*, 2003; Naba *et al.*, 2004; Aryamanesh, 2009; Groune *et al.*, 2009; Randrianasolo, 2009). Taking into account magnetic susceptibility, it allows highlighting different petrographic types at different map scales (Gleizes, 1992; Bouchez, 1997). However, it is always difficult to assign a magnetic anomaly to a specific geological facies (Henkel, 1991; Clark, 1997; Naba *et al.*, 2004; Naba, 2007; Randrianasolo, 2009). The data used in this study have been processed with the Oasis Montaj software.

The data were acquired during a program of measurements organized by Moroccan Ministry of Energy and Mines. In order to use these techniques, we have digitized data and built a database; so that we can compare numerical anomalies and geological maps of the region.

The aim of this work is twofold, first to process airborne magnetic data of the Bou Chber area, and then to define the geological significance of the detected magnetic anomalies.

Geological setting, data and methods

The study area corresponds to the Bou Chber region located at the Eastern part of the Central Moroccan Massif (Fig. 1). It is a segment of the famous Fourhal-Telt syncline trending NE-SW alike the whole Moroccan Meseta structures. Stratigraphic series correspond to alternate clays and sandstones attributed to the Visean-Namurian stage, which are overlain by Devonian-Visean allochthonous limestones. These series are NE-SW trend folded as the rest of Central Moroccan Meseta.

Aeromagnetic data used in this work were acquired from airborne geophysical survey in the Central Moroccan Massif, during April – June, 2000.

The acquisition was performed using a Eurocopter type AS350B3, equipped with a video recording system (PAL camera). These surveys were flown with a fixed-wing aircraft along NW-SE traverse lines spaced 500 m apart and 60 m altitude clearance, with NE-SW tie lines spaced 5 km. The magnetometer used was a Scintrex type cesium sensor of Geometrics, brought to a nominal altitude of 30 m with a sensitivity of 0.01 nT.

The values of the residual magnetic field obtained were interpolated to a 125 m cell-

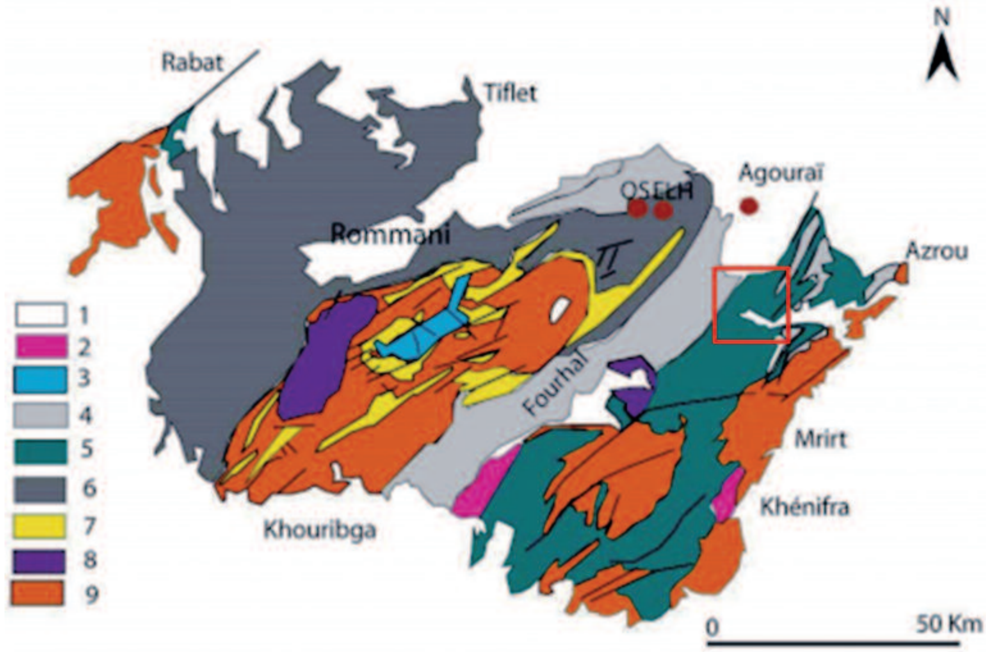

Fig. 1.- Geological map of central Moroccan Massif and location of the study area (square). 1) post-paleozoic; 2) Permian; 3) Namurian-westphalian; 4) Lower Namurian; 5) Visean; 6) Devonian-Dinantian; 7) Silurian; 8) Tardi-hercynian granite; 9) Lower Palaeozoic (Cambrian- Silurian). Colour version on the web.

Fig. 1.- Mapa geológico del macizo central de Marruecos y ubicación del área de estudio (recuadrado). 1) Post-paleozoico; 2) Pérmico; 3) Namuriense-Westfaliense; 4) Namuriense inferior; 5) Viseense; 6) Devónico-Dinantiense; 7) Silúrico; 8) granito Tardi-Hercinico; 9) Paleozoico inferior (Cámbrico-Silúrico). Versión en color de la figura en la web.

size grid. The method was to digitize all the intersection points between flight lines and isovalue curves available onto map (9950 points were digitized) and later the processing was done by Oasis Montaj program.

Once the database is compiled in ArcGis, it is exported onto Oasis Montaj to undergo standard procedures used in such studies.

Results

It is known that magnetic anomalies could be induced either by crystalline rocks metamorphic basement or can be generated by linear tectonic contacts (Grauch *et al.*, 2006). The first obtained processed map is the residual magnetic anomaly map that we use to apply different conventional filters used in aeromagnetism. The reduction-to-pole (RTP) technique applied to the residual magnetic field permits to obtain the RTP map (Fig. 2A), in order to eliminate distortions caused by the tilt of the Earth's magnetic field vector. The RTP map will be used as the base map for applying diverse mathematical filters.

So the RTP map or pseudogravity map allows finding different geological contours as well as major geological structures that characterize this region.

The obtained maps permit distinguishing areas of strong anomalies and others of relatively low response. On these maps, the presence of four areas that show strong magnetic anomalies (1 to 4, Fig. 2C) is depicted. The north end of the map coincides with the edge of the plateau of Agourai. A strong anomaly E-W oriented in the east-central part of the map is related to the Oued Ifrane. And finally, two strong anomalies in the southern part of the map are also represented (Fig. 2C). Moreover, the application of the Euler deconvolution to the magnetic data in the region of Bou Chber, with a structural index of 0 and 3, allow us to obtain the maps presented in Fig. 2D. So that, many geological contacts are observed, two semicircular contacts occurring in the southern part of the map, others NE-SW oriented in the NW area and finally N-S linear contacts observed in the eastern part of the map. Euler map of structural index (SI=3) confirms the aforementioned structures and highlights a semicircular structure in the southern part of the map that could be caused by a deeper magnetic source.

Geological interpretation and conclusions

The studied mapped magnetic anomalies of different scales can be caused either by magnetic sources of different depths or induced by the magnetic bodies of different dimensions (Fig. 4). The first strong anomaly, substantially elongated E-W, detected in the northern part of the map at the boundary with the Agourai plateau, obviously corresponds to the Triassic outcrops bordering this Mesozoic plateau (Figs. 3 and 4). The second strong circular anomaly detected, a few km south, corresponds to Carboniferous basalts, which have been studied by Driouch *et al*. (2010). These are basic rocks interbedded within Visean-Namurian flysch of the Fourhal - Telt Synclinorium. The strong magnetic signature of these outcrops corresponds to their mineralogical composition and geochemical characteristics of basic and ultrabasic rocks (Thomas *et al.*, 2002). The third strong magnetic anomaly occurring at the central part of the map, with a remarkably elongated E-W trend, coincides with a Quaternary basalt flow, which emphasizes the bedding of the Oued Ifrane, close to Amghasse town (Fig. 3). These different Carboniferous, Triassic and Quaternary basaltic bodies have been mapped and interpreted in the geological sheet (1/100.000) of Aguelmous (Figs. 3 and 4). The Middle Atlas and the Eastern part of Central Moroccan massif is characterized by the presence of basaltic Plio-Quaternary volcanism which is a magnetic marker of this

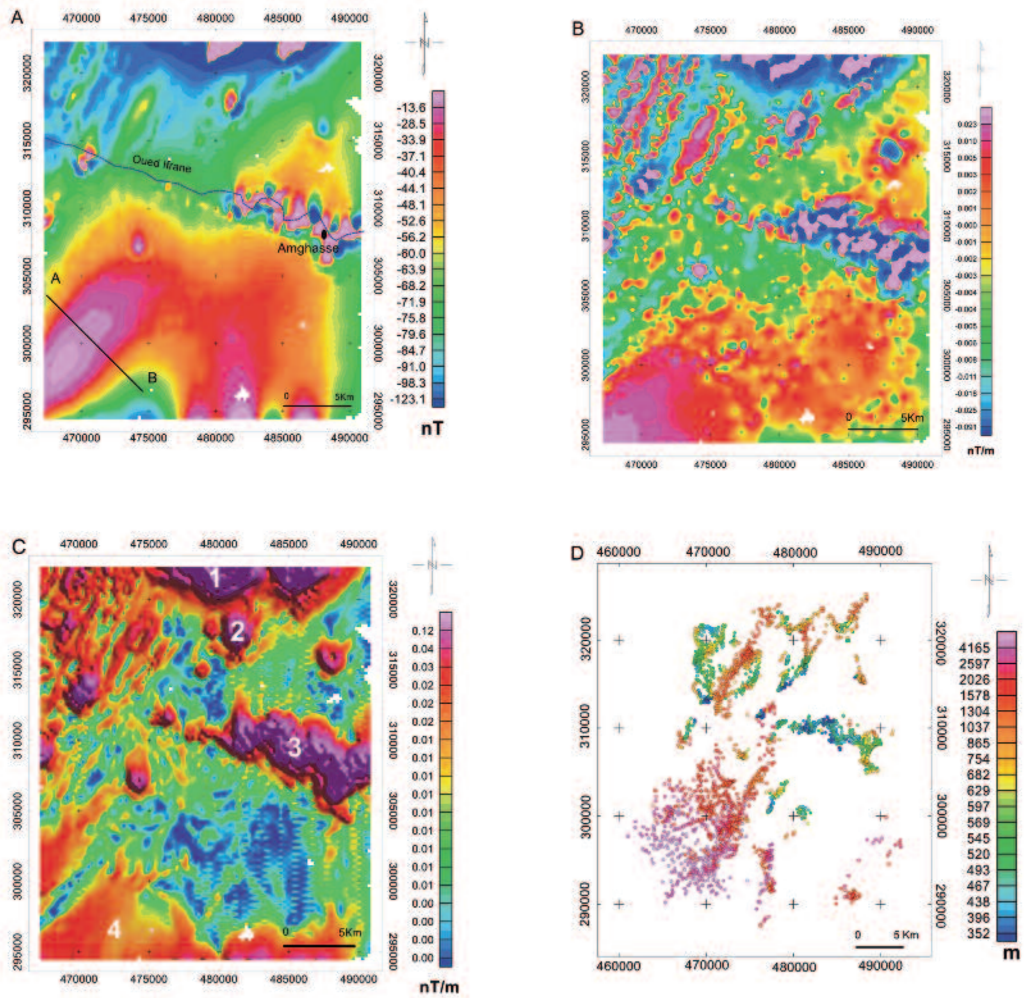

Fig. 2.- Processed magnetic maps of Bou Chber area (colour version on the web). A) RTP map; B) Vertical gradient map; C) Horizontal gradient map; D) Euler deconvolution (SI=3) map.

Fig. 2.- Mapas magnéticos procesados del área Bou Chber (figura en color en la web). A) Mapa RTP; B) Mapa de gradiente vertical; C) Mapa de gradiente horizontal; D. Mapa de deconvolución de Euler (SI=3).

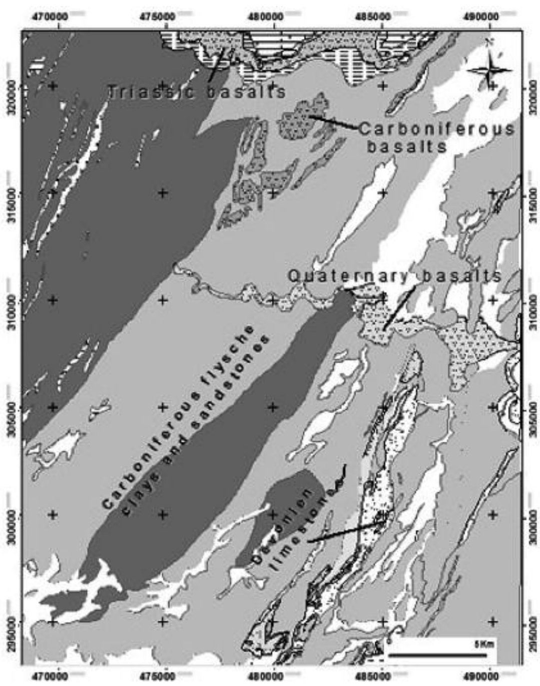

Fig. 3.- Geological map of the Bou Chber area (extracted from the geological map of Morocco 1/1000000). Colour version on the web.

Fig. 3.- Mapa geológico de la région de Bou Chber (extraído del mapa geológico de Marruecos 1/1000000). Figura en color en la web.

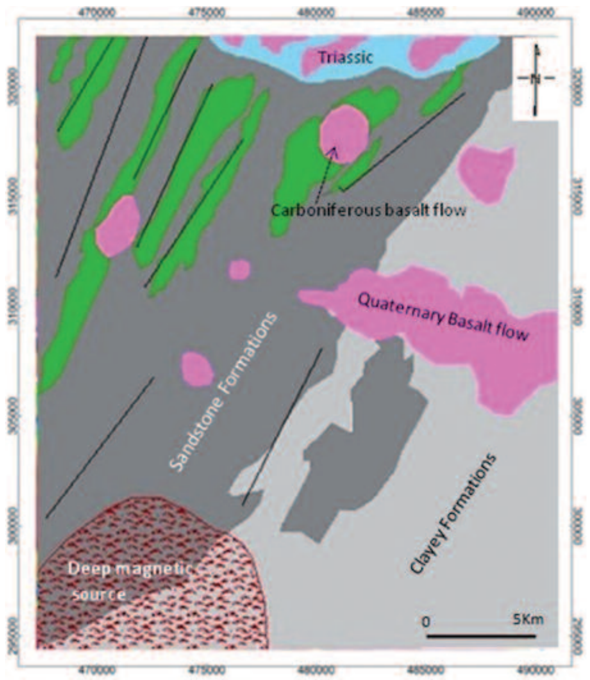

Fig. 4.- Geological scheme of Bou Chber area and interpretation of the main magnetic anomalies. Colour version on the web.

Fig. 4.- Esquema geológico de la región de Bou Chber y de las principales anomalías magnéticas. Figura en color en la web.

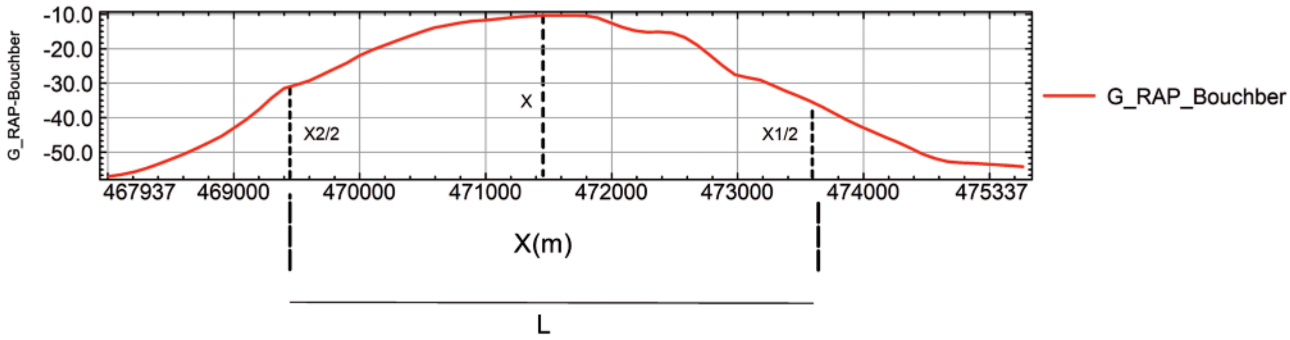

Fig. 5.- Depth estimation of magnetic source from the magnetic signal (see location in Fig. 2A).

Fig. 5.- Estimación de profundidad del cuerpo magnético (localización en Fig. 2A).

magmatic province (El Azzab and El Wartiti, 1998; El Azzab *et al*., 2001). Finally, the fourth strong anomaly was highlighted in the southern part of the map. This anomaly may be caused by a deep magnetic source. From the intensity of the magnetic signal, we can assume that this deep source may correspond to buried basic magmatic rocks analogous to basic flows exposed in the northern region of Bou Chber. The estimated depth of this magnetic source from Euler deconvolution and the analysis of the magnetic signal is about 2100 m deep (Figs. 4 and 5). Geological field data permit to confirm the presence of many basaltic dykes and sills in this area hosted in the Carboniferous flysch.

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