



# Seismo-stratigraphic Mapping Guided by Magnetic Anomalies Stripes: Assessing Opening Models for the Eastern Algerian Oceanic Domain

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## Abstract

The Eastern Algerian basin (EAB) occupies a key position at the eastern tip of the Western Mediterranean. Although clear triangular-shaped magnetic anomalies (MA) are well identified since long, the way seafloor spreading occurred during the middle Miocene is still debated. In this work, a new seismo-stratigraphic interpretation of deep penetration seismic data correlated to reduced to the pole MA was used in order to specify the distribution of the oldest sedimentary deposits in the oceanic domain, and thus to assess the best opening models matching the MA fan-shaped pattern. According to this pattern, our results reveal that the seafloor spreading of EAB has occurred along an NW–SE-oriented accretion system giving birth to six magnetic inversions spanning ca. 2 Myr in Langhian Serravallian times. The oldest units overlying the oceanic floor are of Langhian, i.e., younger than the syn-rift deposits identified on the stretched continental crust further south. We discussed the implications of our findings on the current opening models of the Western Mediterranean Sea.

## Keywords

East Algerian oceanic basin • Magnetic anomalies • Seismic interpretation • Opening model

## 1 Introduction

A multi-phase evolutionary scheme was proposed for the tectonics history since the Oligocene for the Western Mediterranean basin and gave rise to several basins (Fig. 1) (Alboran Sea, Algerian basin, Liguro-Provençal Basin, Tyrrhenian Sea and Valencia Trough). The Algerian basin is an Oligo-Miocene oceanic domain formed by back-arc extension induced by rollback of the Tethyan slab south of the European forearc (Frizon de Lamotte et al. 2000). It is suspected that its western and central oceanic domains are younger than the eastern ones, implying the formation of two different types of margins: transform-type to the west and rifted-type to the east. Moreover, the Lesser Kabylia (LK) block displays (1) a collision zone (south) and (2) a passive-type margin (north) bearing the oldest sedimentary units identified off Algeria, supporting an SE-ward drift of the block (Arab 2016). However, from the initial stage of the migration of LK (upper Oligocene) until its final collision with Africa (>17 Ma, Abbassene 2016), the published kinematic models fail to accurately explain both the geophysical data offshore and geological evidence on land, favoring either N–S or E–W dominant directions of opening (Cohen 1980; Driussi 2015; Martin 2006; Schettino and Turco 2006), even within the well-identified sphenochasm-shaped area to the east (Fig. 1). In this work, we addressed this issue by correlating MA with the first seismo-stratigraphic units deposited on the seafloor.

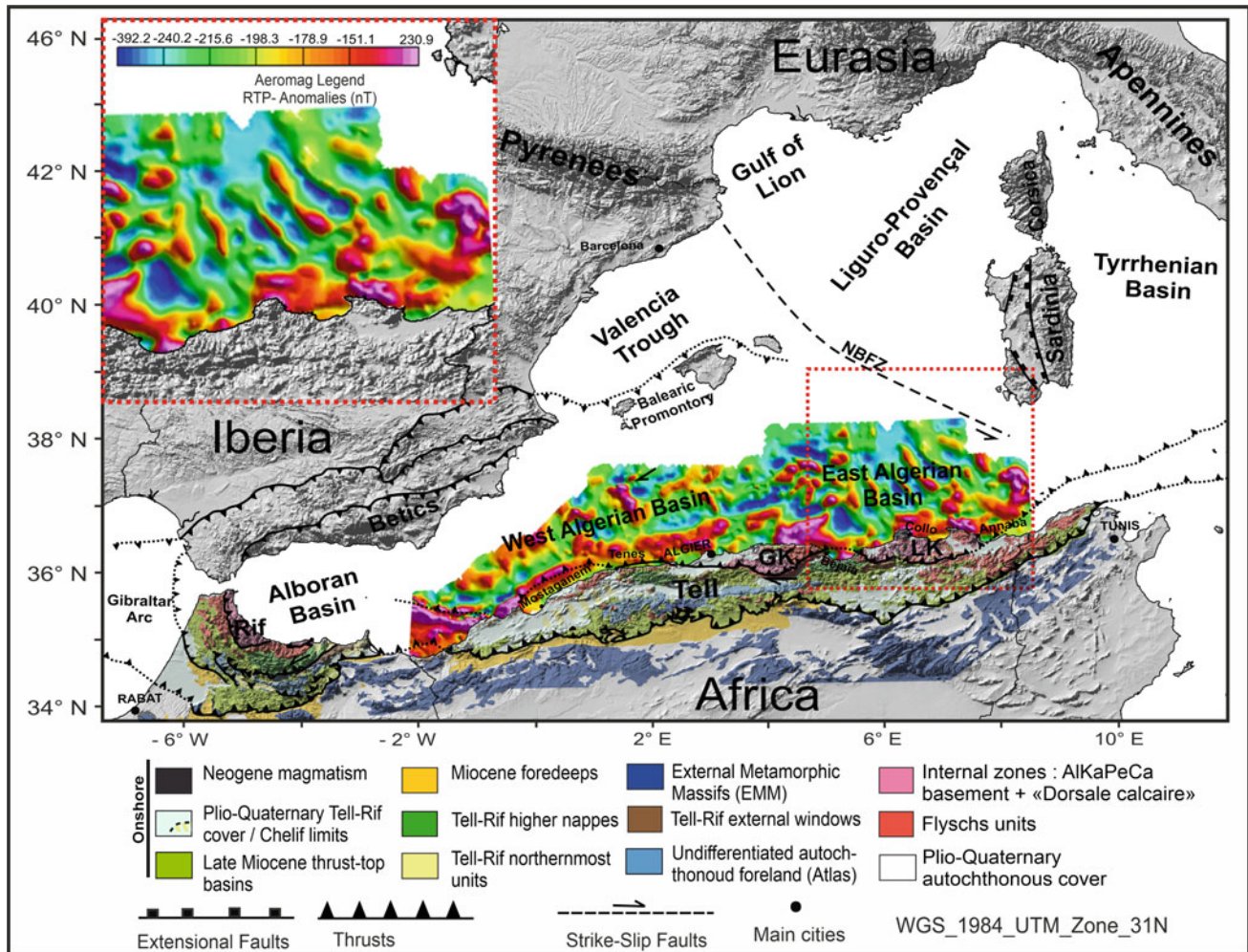
## 2 Correlation of Seismo-acoustic Units with MA

The MA data interpretation was attempted for the first time in this region thanks to a reduced to the pole (RTP) processing (Fig. 2). RTP processing allows us to convert magnetic anomaly to a symmetrical pattern corresponding to a vertical magnetization (e.g. Cooper & Cowan, 2005).

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**Fig. 1** Map of the Western Mediterranean region with the main basins superimposed on the reduced to the pole (RTP) magnetic anomaly map (values in nT) (Reproduced after Medaouri 2014) and the structural scheme of the distribution of different units and Kabyle or AlKaPeCa

domain on land. Red frame: location of the inset that displays regularly organized NW–SE magnetic anomalies in the central part of the EAB. LK and GK: Lesser and Great Kabylia, respectively, and NBTZ: North Balearic Transform Zone

These anomalies provide fundamental constraints for determining the oceanic spreading modes and timing.

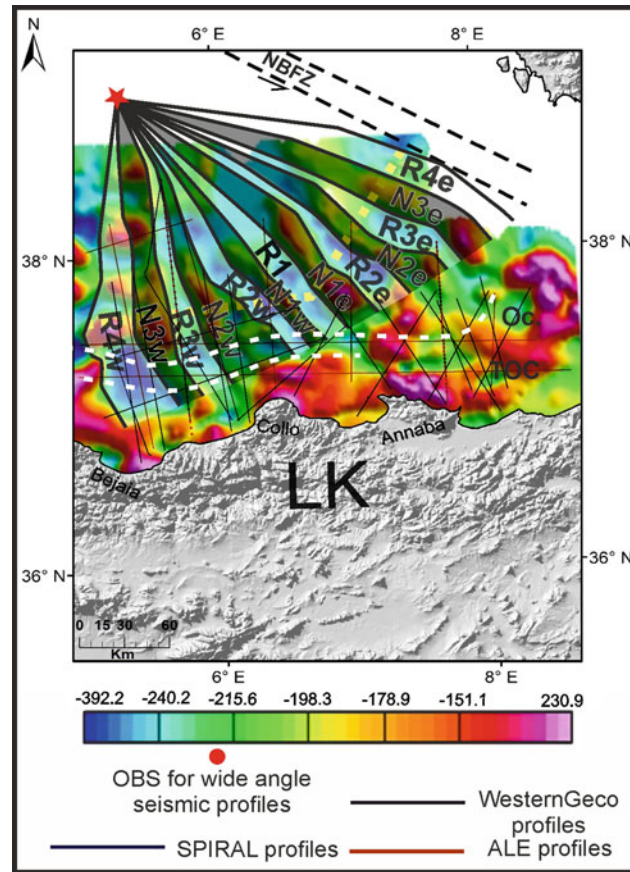
Firstly, we interpreted the RTP map to describe the MA shapes, directions and extensions. Then, a representative magnetic profile (Fig. 2) was drawn across the MA, which allowed us to compare amplitudes and wavelengths and made their comparison easy on both sides of a probable central axis. From this profile, we tried to build an interpretative model (Fig. 3) according to a magnetic reversal scale which helps to correlate MA inversions with the geomagnetic time scale (GMTS) (Gee and Kent 2007) in order to predict a mean time interval and a rate for seafloor spreading. We finally attempted to fit an opening model according to the normal and reverse identified anomalies.

Using available seismic profiles, mainly from WesternGeco (2000–2002) and the Spiral (2009) cruises, we mapped the changes of the top basement (depth, shape) and the

distribution of the first sedimentary deposits over the oceanic crust. A seismo-stratigraphic interpretation was used for deep seismic reflection lines on the basis of the land–sea correlation of Miocene sedimentary units (Arab 2016). Sub-Messinian units were identified by their seismic facies and reflector configurations on the seismic sections of which the limits were interpreted as chronostratigraphic time lines. This interpretation was made using the “IHS Kingdom” software.

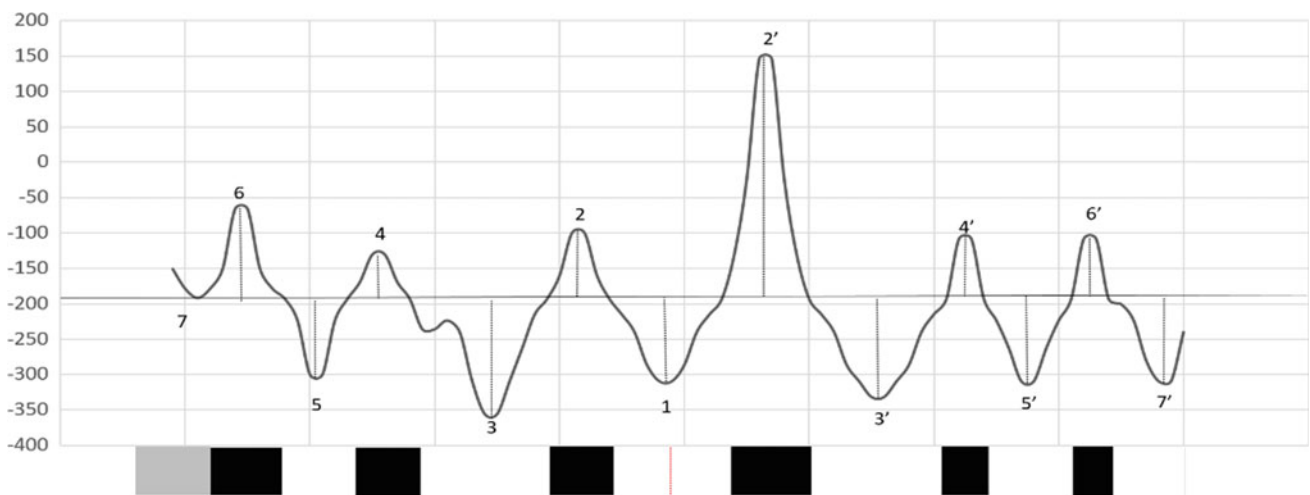
### 3 Results

Based on the RTP-MA map and the magnetic profile plotted across the triangular zone (Figs. 2 and 3), we assumed an opening centered on a pole of rotation A (Fig. 2) and we identified 13 subparallel positive–negative magnetic strips including a central axis characterized by a negative anomaly



**Fig. 2** RTP magnetic anomalies map (values in nT) for the EAB. Colored lines: location of data set of the seismic lines available in this zone. LK: Lesser Kabylia. Black and white strips represent intervals of normal and reverse polarity anomaly, respectively. The R4O strip to the west is interpreted as a reverse polarity anomaly assumed to be

overprinted by late magmatic intrusions. A is the pole of rotation assumed to best fit the pattern of MA identified. Dashed yellow line is the position of the magnetic cross-section of Fig. 3. Dashed white lines locate the limits of the ocean-continent transition from wide-angle seismic profiles



**Fig. 3** Top: magnetic anomalies profile (values in nT) plotted along the triangular zone (dashed yellow line on Fig. 2). Bottom: interpretative model where the black and white blocks represent normal and reverse polarities of the magnetic field. The gray block is interpreted as

the symmetrical anomaly of 7/R4E anomaly and thus as a reverse polarity anomaly assumed to be overprinted by late magmatic intrusions which gave the positive signature



of  $-356$  nT of amplitude (Fig. 3). In contrast with the hypothesis of Bayer (1973), this magnetic model, therefore, implies six magnetic polarity reversals besides the final central accretion of negative polarity.

It is worth noting that the negative anomaly (R4E) is continuous with the North Balearic Transfer Zone (NBTZ), and its westernmost symmetrical negative anomaly (R4O) is affected by the magnetic signature of a post accretion magmatism which gave its positive signature. All of this was assessed by seafloor topography on seismic lines (Arab 2016).

We used the geomagnetic polarity timescale (GPTS) (Gee and Kent 2007) in order to build a time interval for seafloor spreading in the EAB. To this end, we computed an average accretion period from the GMTS, counting six inversions and starting from a central inverse anomaly. An arithmetic average time interval of ca. 2 Myr was obtained using a time window between 16 Ma and  $\sim 11$  Ma (Gee and Kent 2007). We finally used the basement depth and the first pre-Messinian deposits identified in our set of seismic sections crossing the MA to ascribe an approximate age of the seafloor and discuss the ability of published opening models (S–N, E–W or combined) to explain this match.

Using the age model (Arab 2016), we have shown that the oldest seismic units laying over the top of the oceanic basement are likely of Langhian (15.97–13.65 Ma) age, i.e., younger than the syn-rift deposits identified on the stretched continental crust further south (Arab 2016).

## 4 Conclusions

Based on magnetic and seismic data, we revisited the opening of the EAB during Miocene time and showed that this basin opened during a period lasting about 2 Myr in Langhian time (15.97–13.65 Ma) or even Serravallian (13.65–11.608 Ma) time, i.e., later than generally assumed, i.e., when the anticlockwise rotation of Sardinia to the east and the collision of Lesser Kabylia with Africa to the south

were ending. The pattern of magnetic anomalies represents the first evidence of oceanic-type crust and suggests an opening around a close rotation pole that is likely related to the onset of the westward motion of the Alboran domain driven by the Tethyan slab segment retreat toward Gibraltar (Hinsbergen et al. 2014).

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