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Evidences of “Lago-Mare” episode around the Messinian-Pliocene boundary in eastern Tunisia (central Mediterranean)

Mouna Frigui [a,*], Mohamed Ben Youssef [a], Mohamed Ouaja [b]

[a] Centre des Recherches et des Technologies des Eaux, BP 95, Hammam-lif 2050, Tunisia
[b] Faculté des Sciences de Gabès, Cité Erriadh, Zrig, Gabès, Tunisia

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A B S T R A C T

Eight stratigraphic sections, located in northeastern part of the Sahel area of Tunisia recorded evidences of “Lago-Mare” episode and events related to the Messinian-Late Pliocene interval. A comparison with previous studies carried on sections from neighboring areas and boreholes data drilled within the Gulf of Hammamet and the Gulf of Gabès, is conducted and gives useful information to characterize the Late Messinian to Late Pliocene events. The most notable feature distinguished in the studied area consists on the lack of gypsum, commonly recorded in relation with the crucial event of the Messinian Salinity Crisis. However, only lagoonal deposits, bearing messinian brackish fauna, are encountered. These sediments are usually attributed to the “Segui” formation or the so called “Mio-Pliocene continental”. Thin sections samples and field observations have recognized sands, marls, clays, lacustrine limestone, some gypsum lenses, mud-cracks, lignite and Messinian brackish fauna. Similar deposits were previously described in the Kechabta basin from the Northern Tunisia and in some wells from the Gulf of Gabès and the Gulf of Hammamet. We suggest that all these facies belong to the coeval of the “Lago-Mare” facies within Eastern and Western Mediterranean basins (e.g. Sicily, Mallorca, Libya and Cyprus). Finally, four major erosional surfaces have been recorded within the Late Messinian-Late Pliocene deposits, aged post-Tortonian, intra-Messinian, Late Messinian and intra-Pliocene times. They seem to be the result of local tectonic uplifts and eustatic fluctuations.

1. Introduction

During the Miocene–Pliocene transition, the Mediterranean was home of pronounced environmental changes. A combination of a dramatic sea level lowering and the disconnection of the Mediterranean from the global ocean, occurred during the Messinian 5.96–5.33 My (Bousquet, 1977, Carbonnel, 1980, Cita, 1982, Cita et al., 1978, Krijgsman et al., 2010; Van Gorsel, and Troelstra, 1980.), and limited the water exchange with the Atlantic Ocean. This gave way to massive salt deposition in the deepest part of the Mediterranean basin, proving its complete desiccation (Conesa et al., 1988; Gvirtzman and Buchbinder, 1977; Hsü et al., 1976; Hsü, and Giovanol, 1973; Mulder and Parry, 1977; Pedley, and Grasso, 1993). This uncommon event has been termed the Messinian Salinity Crisis (MSC). It was largely accepted that the MSC was established in two distinct episodes. According to Clauzon et al. (1996), the first episode (5.96–5.64 My) is characterized by a moderate sea-level drop (less than 100 m) and the second one has noted an important sea-level drop of 1500–2000 m (5.52–5.33 My). The latter was responsible massive evaporites deposition in the Mediterranean central basin and simultaneous intense erosion on its marginal basins.

This widespread huge thickness of evaporites was followed by the deposition of the so called “Lago-Mare” facies (Ruggieri, 1967), as a result of the setting of generalized low salinity conditions. These deposits are known under different facies; but, they are commonly characterized by the occurrence of *Ammonia beccarii*, *Ammonia tepida* and sometimes found associated to *Cyprideis* (Saint-Martin et al., 2000). As a result, some authors suggest that the Lago-mare biofacies ended the “MSC” and is isochronous in both of central and peripheral basins (Roveri et al., 2014). conversely, others studies consider that the “Lago-Mare” biofacies can be subdivided in three distinct periods (Clauzon et al., 2005; Do Couto et al., 2014; Popescu et al., 2009, 2015). The first one (LM1) ended the first step of the MSC in peripheral basins, the second (LM2) ended the second step of the MSC in the central basins and

* Corresponding author.
E-mail address: frigui_mouna@yahoo.fr (M. Frigui).

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the last one instantly succeeded the final deluge. These brackish conditions are ended abruptly by the restoration of open marine conditions thanks to the re-opening of Gibraltar gateway. However, the (LM_3) immediately follows the final catastrophic marine reflooding. Indeed, this transgression occurred at the beginning of the Pliocene 5.33 My and seems to be very rapid; less than 10,000 years (Hsü & Giovanol, 1973) and is considered as a catastrophic reflooding (Rouchy and Orsag-Sperberg, 1980).

Moreover, the typical facies related to this event has been described in most of the Mediterranean sub-basin both in land and in deep sea under blue pelagic marls e.g. the "Trubi" formation in sicily (Di Stefano et al., 2010). Some basins did not experience the classical marls deposition; however, they were home of deposition of coastal facies (e.g. Bajo Segura Basin in Spain; Caracuel et al., 2004) and in Melilla basin in Morocco (Rouchy et al., 2003). Also, the early Pliocene deposits were missing, in some others such as eastern Sardinia; where only the late Pliocene deposits are recognized (Giresse et al., 2011). The same features are present either in Northeastern part of the Sahel of Tunisia. Furthermore, the Early Messinian limestones deposits and Late Messinian gypsum are missing while the Late Zanclean and Plaisancian deposits are locally recorded. In the studied area, the Mio-Pliocene transition is generally marked by deposits assigned to the "Segui" formation or the so called "Mio-Pliocene continental" (Burollet, 1951) due to the lack of fauna and the predominance of a vast continental Quaternary deposits that make hard to characterize the boundary between Pliocene deposits and older sequences.

In this paper, we advance a description of the Mio-Pliocene transitional deposits and a chronology of the different events occurring around the Messinian-Pliocene boundary.

2. Geological setting and general stratigraphic architecture

The Sahel area (Fig. 1) is a flat foreland domain, which extends eastward from the so called "North-South Axis" to the Mediterranean Sea. The cropping series are mainly ranged in time from the Late Miocene to the Quaternary (Bedir, 1995; Ben Youssef et al., 2002; Besème and Kamoun, 1988; Burollet, 1956; Demarcq et al., 1967; Frigui, 2003; Kamoun, 1981).

Subsurface previous studies have identified a complex sedimentary architecture, in response to successive Meso-Cenozoic tectonism. Cenozoic tectonic phases identified in the studied area are dated Middle-Late Eocene (Pyrenean event), followed by the Langhian–Serravalian Alpine event and the Late Tortonian which corresponds to the Atlasic event (Belghith, 2010; Blanpied, 1978; Bouaziz et al., 2002; Boussiga et al., 2009, Ellouze, 1984; Haller, 1983; Khomsi et al., 2006; Patriat et al., 2003; Winnock and Bea, 1979).

The Mio-Pliocene boundary is represented in Northern Tunisia (Kechabta Basin) by the succession of five formations, from the base to the top: "Kechabta", "Oued Belkhedim", "Chabet Tabala", "Raf Raf" and "Porto Farina". The three lowest formations are characterizing the Messinian interval, the fourth one is of Zanclean age and the uppermost one is of Plaisancian age (Burollet, 1951). In Northeastern Tunisia, particularly, Cap Bon and Gulf of Hammamet basins, almost of the totality of the sediments, ranging in age from the Messinian to the Pliocene, are recorded (Bensalem, 1992; Colleuil, 1976; Derbel-Damak and Zaghbib-Turki, 2002; Wiman, 1980). The Messinian interval is represented by the "Beni Khiar" and the "Oued El Bir" formation, which are assigned respectively, to the Early Messinian and Late Messinian. (Bensalem, 1992; Colleuil, 1976; Derbel-Damak and Zaghbib-Turki, 2002).

The Early Pliocene deposits are represented by the so called the "Argile des Poitiers", the "Sables Jaunes de Nabeul" and the "Argiles de Sidi Barka". The Late Pliocene is represented only by the "Sables de Hammamet" (Bensalem, 1992; Colleuil, 1976); except in the North of the Cap Bon and in some localities in the Gulf of Hammamet, where, the Late Pliocene overlie directly the Serravalian deposits (Bensalem, 1992; Colleuil, 1976; Derbel-Damak and Zaghbib-Turki, 2002; Temani and Gaaloul, 2007).

In Southeastern Tunisia, the Gulf of Gabès basin records the deposition of the limestones of the "Melqart" formation (Early Messinian) and the "Oued Belkhdim" formation (Late Messinian). This latter is represented by two facies, the lower is mostly composed by evaporites and sandstones while the upper one is represented by an intercalation of silty to sandy green clays, sands, calcareous sandstones and locally evaporites (Bismuth et al., 2009; Bonaduce et al., 1988; Fournie, 1978).

Central Eastern Tunisia constitutes the western part of the Pelagian bloc, which is relatively considered as an uplifted domain, located between the Gulf of Hammamet and the Gulf of Gabès basins. In this area, the Mio-Pliocene transition is different from the more frequent ones recorded in the Mediterranean basins and is dominated by terrigenous siliciclastic deposits with local intercalations of carbonates (Frigui, 2003; Gaaloul-Announ, 1995; Kamoun, 1981; Moisette et al., 2010). However, it is marked, in some places, by the lack of the Latest Messinian deposits and/or the Lower Pliocene marine marls. If they exist, they are represented by scarce Early Messinian oolithic limestones of the "Ksour Essaf" formation (Beseme and Kamoun, 1988; Frigui, 2003; Kamoun et al.,

Fig. 1. Location map of the studied region with indication of the geographical location of the sections.