Journal of African Earth Sciences 118 (2016) 205–230

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Sedimentology, diagenesis, clay mineralogy and sequential analysis model of Upper Paleocene evaporite-carbonate ramp succession from Tamerza area (Gafsa Basin: Southern Tunisia)

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ARTICLE INFO

Article history:
Received 30 November 2015
Received in revised form
19 February 2016
Accepted 23 February 2016
Available online 27 February 2016

Keywords:
Thelja
Evaporitic cycle
Evaporitic sequential stratigraphy
Facies analysis
Cyclicity
Sebkha

ABSTRACT

Integrated sedimentological studies, diagenesis, sequential analysis and clay mineralogy on the Upper Paleocene rocks in Tamerza area provide important information on the reconstruction of the depositional basin, cyclicity, and paleoclimatic contexts. Facies analysis and petrographic studies have led to the recognition of nine facies that were deposited in three facies belts: Sebkha, inner ramp and outer ramp summarized in a carbonate ramp model: Homoclinal ramp under an arid climate.

The upward and lateral changes in thickness and composition show a general regressive trend that records a transition from an outer ramp to Sebkha, creating different types of confinement. The facies stacking patterns constitute several kinds of meter-scale, shallowing-upward cycles. Nine different types of depositional cycles and several models of Sebkha sequences were defined. These different types of facies, characterized within the Thelja Formation, compose seven depositional sequences, mainly made of carbonates, marls and evaporates. Detailed multi approach analysis provides important information on evaporitic sequence stratigraphy.

In carbonates beds, the diagenetic analysis provides an overview and chronology of diagenetic processes. A particular attention was paid to early stage cementation which enables us to characterize better the depositional environments. In addition to cementation, other features define the diagenetic history.

X-ray diffraction reveals the presence of smectite suggesting an arid climate. Moreover, the clinoptilolite and the frequency of primary dolomite indicate different degrees of confinement.

The seven depositional sequences showing a hierarchical organization of many cycles, as described above, suggested that eustatic sea level oscillations caused by cyclic perturbations of the Earth's orbit play a fundamental role in determining the formation of hierarchical cyclic rhythmicity.

1. Introduction

The Upper Paleocene interval preceding the Paleocene-Eocene (P/E) boundary was characterized by a global warming climate change marked by a rise of 6 °C in the deep ocean waters (Late Paleocene Thermal Maximum: LPTM) (Kennett and Stott, 1991; Zachos et al., 1993). This event, which is considered as the warmest interval of the Cenozoic (Deconinck et al., 1985; Robert and Chamley, 1991; Zachos et al., 1994; Adatte and Lu, 1995; Bolle et al., 1999; Karoui-Yaakoub, 2006; Sluijs et al., 2006; Karoui-Yaakoub et al., 2011; Zilli, 2010), started from the Upper Paleocene and reached its maximum at the Lower Eocene leading to severe conditions as traduced by the reduction of the extension of fauna realms and the dwarfing of forams (Deconinck et al., 1985; Robert and Chamley, 1991; Bolle et al., 1999; Zachos et al., 1994, 2001, 2003; Speiger, 1994; Adatte and Lu, 1995; Wing et al., 2003; Billups et al., 2004; Guasti et al., 2005; Karoui-Yaakoub, 2006). These climatic changes caused an overall change in the mode of ocean circulation. Indeed, until the Lower Eocene, Tethys has a major role in the global ocean circulation. Global warming constitutes a potential source of deep water masses, hot and salty, during the brief episode of reversal of ocean circulation in the P/E limit. In addition, the Southern Tethyan margin was located in the Northern

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http://dx.doi.org/10.1016/j.jafrearsci.2016.02.020

tropical zone and was subject to upwelling episodes (Bolle et al., 1999). As constituting a part of the Southern Tethyan margin, Tunisia was under the control of synsedimentary tectonics. In fact, several authors (Salaj, 1980; Marie et al., 1982; Amri et al., 2005) have reported that during the Paleocene interval, synsedimentary tectonics were activated since the Campanian in both Central and North eastern areas, leading to complex pleotopography where horsts limit subsident areas (area of Ousselat-Bou Dabbous). These synsedimentary tectonics were attested by the frequency of gravity deposits, mainly slumps and turbidites, and a clear variation in terms of thickness. In fact, thin layers Paleocene deposits were measured on elevated areas (Serj-Bargou area) and hiatus were recognized within emergent areas by which we mean 'Kasserine Island' in the center and 'Jeffara Island' in the South East of Tunisia (Burollet, 1956).

These tectonic features were also expressed by changes in terms of facies. In fact, the Paleocene deposits were characterized by two main lithology. In the Northern part of Tunisia, gray to dark marl characterizes deep environment, Lower circalittoral to Upper bathyal, based on the studies of benthic and planktonic foraminifera associations (Berggren, 1974; Berggren and Aubert, 1975; Karoui-Yaakoub, 1999, 2006; Karoui-Yaakoub et al., 2011; El Daway, 2001; Zili, 2010). As for the second lithology, it is evaporate and carbonate deposits in the Gafsa Basin and carbonate in the Mezzouna Meknassy area. These climatic upheavals have generated large variations within the composition and the organization of shallow marine carbonates and evaporites. The purpose of this work is to carry a careful facies analysis and to examine the spatial relationships between studied deposits. We tried to present the main depositional processes governing the sedimentation of Late Paleocene rocks exposed West of the Gafsa Basin. By the present work we attempt to apply a sequential analysis to evaporitic deposits and to focus on the main contribution of climatic changes on sedimentation. A depositional model was also proposed to reconstruct the Late Paleocene paleoenvironments in the West Gafsa Basin.

2. Geological setting

The study area is located in the Western part of the Gafsa Basin in South-Central Tunisia (Fig. 1). The outcropping lithostratigraphic series range from Upper Cretaceous to Quaternary. As for the sedimentary study, rocks belong to the Metlaoui group (Burollet, 1956) and precisely to the Thelja Formation (Fournié, 1978). The Thelja Formation is overlain by the Chouabine Formation and overcome the El Haria Formation (Burollet, 1956).

The Upper Cretaceous–Lower Paleogene sedimentary sequence in the Gafsa Basin begins with the El Haria Formation, which overlies a hardground at the top of the chalky Abiod Formation (Upper Cretaceous). Dark phosphate layers with glauconite and pyrite grains were initially deposited on the hardground, and surmounted by gray to black marl succession. This lithology is also common in the North of Tunisia, where it continued to accumulate during the Paleocene and Early Eocene (Chaabani, 1995; Zaier et al., 1998; Bolle et al., 1999). However, in the Gafsa Basin, new lithofacies were developed due to the modification in depositional environments related to palaeogeographic organization and sea-level fluctuation. Paleocene deposits are various. They are made by bioclastic carbonates beds interbedded with metric shell beds mainly rich in oyster. Besides, marls and gypsum-rich levels are forming the Thelja Formation (Fournie, 1978; Chaabani, 1995). Above this Formation, the Ypresian Chouabine Formation contains massive phosphorite layers which alternate with marly limestones, marls and silica-rich layers (e.g., Sassi, 1974; Chaabani, 1995: Henchiri and Slim-S'himi, 2006; Henchiri, 2007; Chaabani and Ounis, 2008; Galfati et al., 2010; Kocsis et al., 2014; Haj Ahmed et al., 2014). The Formation exhibits a general transgressive trend, although smaller-scale sea-level fluctuations are apparent within the phosphorite succession. Relative sea-level continued to rise during the deposition of the Kef Eddour Formation (Chaabani, 1995) and reached its maximum in the overlaying carbonates series. Later, the sea gradually retreated and the sedimentary sequences were topped by the massive gypsum and dolomitic beds of the Seugdal Formation (Figs. 1 and 2).

3. Distribution of the lithostratigraphic units

In the studied area, the carbonatic and evaporitic series of the Thelja Formation were evolved under active synsediementary tectonics (Fig. 3) The Thelja Formation was cut either at the base or at the top. With a synthetic section, we attempted to present the vertical evolution of sedimentary characters. The succession of events is well recognized due to clear correlative banks outcropping in both localities. The vertical evolution within the Lower part was studied in Wday Ouadi (section W) 60 m in thickness. However, the Upper part was studied in Little Cluse (PC section). Many levels allowed us to correlate the two sections and mainly to establish a synthetic log (95 m in thickness) where all the significant events were recorded. An analysis of the arrangement of the deposits on the field and a detailed study of facies were used to characterize the succession of six lithostrtatigrahpic Units (Fig. 4).

Units T1, T2 and T3 were described in Oued Wday section (Fig. 5). However, Units T4, T5 and T6 were characterized in Little Cluse locality (Fig. 6). According to this synthetic section, the stacking of the whole Units from the base to top were identified:

3.1. Unit 1 or T_1

Unit1 which is 12 m in thickness is represented by massively bedded carbonates essentially rich in oysters (80% of all allochems) and intensively burrowed at the top. The Middle part exhibits several current structures. Indeed, we can distinguish two metric banks fossilizing hummocky cross-stratifications (HCS) structures separated by a centimetric coarse-grained bed with small cross bedding structures.

3.2. Unit 2 or T2

This Unit measuring 20 m is formed by the stacking of regressive sequences composed of marls, limestones and gypsum. The limestones, which are rich in bioclasts at the base, show gypsum nodules at the summit. The presence of stromatolite levels can be noticed locally.

3.3. Unit 3 or T3

Total thickness is 17 m: It is composed mainly of well-bedded carbonates and gypsum. The limestones, mainly rich in bioclastes (50% of all allochems), are interbedded with carbonate levels, including decimetric gypsum nodules and passing up to stromatolitic beds. The summital part is represented by massive gypsum (7 m in thickness).

3.4. Unit 4 or T4

Total thickness is 20.5 m. It started by well-bedded coarse-grained carbonates containing rare gasteropds and fossilizing current structures. These carbonates are overlaid by an intensively burrowed level. The rest is formed by the succession of regressive sequences composed of marls, bioclastic limestones and carbonates