Journal of African Earth Sciences 117 (2016) 358–388

Contents lists available at ScienceDirect

Journal of African Earth Sciences

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

Basin geodynamics and sequence stratigraphy of Upper Triassic to Lower Jurassic deposits of Southern Tunisia

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ARTICLE INFO

Article history:
Received 27 May 2015
Received in revised form
10 September 2015
Accepted 29 January 2016
Available online 5 February 2016

Keywords:
Late Triassic
Early Jurassic
Tunisia
Sequence stratigraphy
Basin geodynamics

ABSTRACT

Aims of this paper are to propose a geodynamic and sequential framework for the late Triassic and early Jurassic of and south Tunisia and to evidence the impact of local tectonics on the stratigraphic architecture. Facies of the Upper Triassic to Lower Jurassic of Southern Tunisia have been interpreted in terms of depositional environments. A sequential framework and correlation schemes are proposed for outcrops and subsurface transects. Nineteen middle frequency sequences inserted in three and a half low frequency transgression/regression cycles were evidenced. Despite some datation uncertainties and the unknown durations of Lower Jurassic cycles, middle frequency sequences appear to be controlled by eustasy. In contrast the tectonics acted as an important control on low frequency cycles. The Carnian flooding was certainly favored by the last stages of a rifting episode which started during the Permian. The regression accompanied by the formation of stacked angular unconformities and the deposition of lowstand deposits during the late Carnian and Norian occured during the uplift and tilting of the northern basin margins. The transpressional activity of the Jeffara fault system generated the uplift of the Tebaga of Medenine high from the late Carnian and led to the Rhaetian regional angular Sidi Stout Unconformity. Facies analysis and well-log correlations permitted to evidence that Rhaetian to Lower Jurassic Messaoudi dolomites correspond to brecciated dolomites present on the Sidi Stout unconformity in the North Dahar area. The Early-cimmerian compressional event is a possible origin for the global uplift of the northern African margin and Western Europe during the late Carnian and the Norian. During the Rhaetian and the early Jurassic a new episode of normal faulting occured during the third low frequency flooding. This tectonosedimentary evolution ranges within the general geodynamic framework of the north Gondwana margin controlled by the opening of both Neotethys and Atlantic oceans.

1. Introduction

After the late Paleozoic collision with Laurasia, North Africa recorded the early stages of the opening of the Neotethys during late Paleozoic and Triassic times (Gabtni et al., 2006; Memmi et al., 1986; Stampfli and Borel, 2002). In this geodynamic context, an intensive rifting affected the northern African margin during an anti-clockwise movement of Africa (Muttoni et al., 2001). As a consequence of the westward opening of the Neotethys, the age of the transition between the active rifting and the passive margin stages is supposed to be younger in this direction. On seismic profiles, tilted blocs and overlaying passive margin geometries were documented from Morocco to the Levant margin (Frizon de Lamothe et al., 2009; Galeazzi et al., 2010; Gardosh et al., 2010). However in some places the timing of this transition is different according to authors. In Tunisia, Stampfli et al. (1991) and Stampfli and Borel (2002) propose a late Permian onset of thermal subsidence with a short rifting in back-arc context during the Triassic on the northern Neotethyan margin. In contrast other authors considered that rifting was active until the middle-late Triassic (Galeazzi et al., 2010; Piqué et al., 1998), early Jurassic times (Golonka, 2007; Kamoun et al., 2001; Raulin et al., 2011; Schettino and Turco, 2011) or continuous until the early Cretaceous (Frizon de Lamote et al., 2009). Turner et al. (2001) also documented rifting

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http://dx.doi.org/10.1016/j.jafrearsci.2016.01.029
1464-343X/

episode during middle-late Triassic times in the Algerian Berkine Basin.

Detailed stratigraphic study is a powerful tool to better constrain the geodynamic history of a region. However, while studies on Triassic deposits have been done in many north African localities such as Southeast Algeria (Bourquin et al., 2010; Turner et al., 2001), Jordan (Makhlouf, 2006), United Arab Emirates (Maurer et al., 2008), Levant (Korngreen and Benjamini, 2011), no detailed tectonosedimentary and sequence stratigraphy study of the Upper Triassic and Lower Jurassic deposits was performed in Southern Tunisia. In addition, siliciclastic Triassic deposits contain large quantities of hydrocarbons in Algeria and southern Tunisia (Tigi Field). Middle-Upper Triassic dolomites may constitute targets for hydrocarbon exploration and the understanding of controls on their distribution in time and space is a challenge.

The aim of this paper is to investigate the sequence stratigraphy of mixed carbonates, siliclastic, and evaporites of the Upper Triassic and Lower Jurassic deposits in Southern Tunisia. In addition, major objectives are to constrain the timing of local deformations, to compare these results with depositional sequences, and to point out possible controls by local or more regional tectonics on sedimentation. To achieve this goal, sedimentological studies of outcrop and well logs using sequence stratigraphy methods were performed to propose local or basin scale correlations. Based on the locations of main faults, the geometries will be interpreted in terms of local variations in subsidence, eustasy, and sediment supply. Finally, results will be compared with structural frameworks of neighboring areas in order to propose a model of geodynamical evolution of the Southern Tunisia.

2. Geological and structural setting

The studied area extends from central Tunisia to the extreme south and east near Algerian and Libyan borders (Fig. 1a). Northern Tunisia is affected by the recent alpine compressive tectonics, which generated thrusts and folding of evaporitic Triassic series. In Southern Tunisia, the normal and strike slip Jeffara fault system borders the Jeffara plain and the offshore Subratah Basin to the north (Fig. 1). A minor synthetic fault coincides with the present cuesta profile delimiting the Dahar plateau to the southwest and the Jebel Rehach (J. Rehach) to the south (Fig. 1b). The Dahar plateau covers the northern margin of the Paleozoic Talemzane High (Fig. 1). In Southern Tunisia the western continuity of the Libyan Ghadames Basin is characterized by a broadly monoclinal geometry with a gentle southwestward dipping. In Algeria, the Berkine Basin constitutes the western extension of the Ghadames Basin. The Middle-Upper Triassic-Lower Jurassic rocks are exposed in two geographic and geological provinces:

- (1) The northern outcrop on the northern margin of the Dahar Plateau extends from the south of the Jebel Tebaga massif to the Oarjaijin village to the southeast (Fig. 1b). In the North Dahar, the structure is a monocline. Upper Triassic to Lower Jurassic dolomites are gently dipping (1–2°) southwestward (Bouaziz et al., 2002) and overlay Lower and Middle Triassic deposits presenting a dipping of about 2–15° to the south.
- (2) In the J. Rehach, the Middle Triassic to Lower Jurassic series are outcropping along a 70 km long cuesta oriented northwest-southeast between the Tataouine city and the southeast of the Kirchaou village (Fig. 1b). Formations are gently dipping to the south-west. Sidi Toui outcrops in the southeast of Tunisia exhibits only Ladinian to Carnian strata (Kamoun et al., 2001) (Fig. 1b).

During the Late Triassic, emerged lands bordered the Ghadames Basin to the south and provided siliciclastic material to the North African margin (Fig. 2). Shallow carbonate and evaporite sedimentation occurred in a large part of the basin that was connected to the north to the western ending of the Neotethys (Sicanian Basin). Westward, during the first stages of the Atlantic rifting, NW–SE faulting formed a corridor between the emerged Iberian Massif and North Africa. Oceanic spreading was active in the Neotethys but did not extend as far as the Sicanian Basin. The Cimmerian orogeny started during the Carnian and subductions zones relieved by strike-slip faults developed on the northern margin of the Neotethys during the closure of the Paleotethys (Golonka, 2007; Sengör, 1984).

3. Method

Thirty five sedimentological sections have been logged and twenty eight are presented in this paper. Their GPS coordinates are given in Table 1. To build sedimentary logs, thicknesses were measured on outcrops using a Jacob staff. Cartography was performed locally to determine the geometry and the stratigraphic position of formations or facies (e.g. Kronab Fm.). Facies interpretations are based on petrography, faunal associations, sedimentary structures and microfacies (150 thin sections). A sequence stratigraphic interpretation was performed on each section. Since they were not ever easy to evidence in each section, sea level fall unconformities have not been used as sequence boundaries according to classical models of sequence stratigraphy (Schlager, 2004; Posamentier and Morris, 2000; Posamentier and James, 1993; Vail et al., 1991; Van Wagoner et al., 1988). In contrast, transgression surfaces sometimes merged with subaerial exposure surfaces and characterized by a sharp deepening of depositional environments, above a shallowing-up trend, are the most obvious in the studied sections and have then been used to delimit sequences (Embry, 2009). Early diagenetic features were also investigated in optical microscopy and cathodoluminescence on thin sections. Outcrops and subsurface correlations are based on available biostratigraphy and sequence stratigraphy. The subsurface analysis was done by the interpretation of electric facies (see below) on well logs and using available petrographic descriptions. A sequence stratigraphy interpretation consistent with the outcrop study was established for each well according to the vertical stacking of facies.

4. Stratigraphy

The Triassic system is separated from Paleozoic deposits by the Hercynian angular unconformity probably of local extension (Raulin, 2013) (Fig. 3). In the J. Rehach Lower and Middle Triassic deposits correspond to the alternation of fluviodeltaic siliciclastics (Bir El Jaja and Ras Hamia formations) and marginal dolomites and limestones (Kamoun et al., 2001; Mejri et al., 2006). The Ras Hamia Fm. comprises the siliciclastic and carbonate Ouled Chebbi Member and the fluvial siliciclastic Kirchaou Member separated by marine carbonates and shales of the *Myophoria* Limestones (Mennig et al. 1963; Burollet, 1963). Those formations were also described in subsurface in South Tunisia where the TAG-I Fm. corresponds to the lateral equivalent of the Kirchaou Fm. (Hamouche, 2006). In the North Dahar, Anisian siliciclastics of the Ouled Chebbi member occur below the Sidi Stout Unconformity. In eastern Algeria, Anisian to Lower Carnian deposits consist of continental sandstones of the TAG-I (Trias Argilo-Gréseux Inférieur) Fm. dated with vertebrates (Jalil, 1999) and palynomorphs (Bourquin et al., 2010).

In the J. Rehach, the Carnian deposits are characterized from base to top by the Mekraneb dolomites, the Tourag sandstones and the Rehach dolomites. Mekraneb dolomites are attributed with