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Sedimentology of the Essaouira Basin (Meskala Field) in context of regional sediment distribution patterns during upper Triassic pluvial events

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ABSTRACT

Upper Triassic continental clastics (*TAGI: Trias Argilo-Greseux Inferieur*) in the Essaouira Basin are largely restricted to the subsurface, which has limited analysis of the depositional environments and led to speculation on potential provenance of the fluvial systems. Facies analysis of core from the Meskala Field onshore Essaouira Basin is compared with tentatively time-equivalent deposits exposed in extensive outcrops in the Argana Valley, to propose a process orientated model for local versus regional sediment distribution patterns in the continuously evolving Moroccan Atlantic rift during Carnian to Norian times. The study aims to unravel the climatic overprint and improve the understanding of paleo-climatic variations along the Moroccan Atlantic margin to previously recognised Upper Triassic pluvial events.

In the Essaouira Basin, four facies associations representing a progressive evolution from proximal to distal facies belts in a continental rift were established. Early ephemeral braided river systems are succeeded by a wet aeolian sandflat environment with a strong arid climatic overprint (FA1). This is followed by the onset of perennial fluvial deposits with extensive floodplain fines (FA2), accompanied by a distinct shift in fluvial style, suggesting increase in discharge and related humidity, either locally or in the catchment area. The fluvial facies transitions to a shallow lacustrine or playa lake delta environment (FA3), which exhibits cyclical abandonment. The delta is progressively overlain by a terminal playa with extensive, mottled mudstones (FA4), interpreted to present a return from cyclical humid-arid conditions to prevailing aridity in the basin.

In terms of regional distribution and sediment source provenance, paleocurrent data from Carnian to Norian deposits (T5 to T8 member) in the Argana Valley suggest paleoflow focused towards the S and SW, not directed towards the Meskala area in the NW as previously suggested. A major depo-centre for fluvial sediments is instead located in the southern Argana Valley, possibly the Souss Basin. To effectively source the reservoir sandstones found in the Meskala Field, a more local provenance area has hence to be envisaged. Despite this, the direct comparison of the genetic evolution of sedimentary sequences in the Argana Valley and Essaouira Basin shows a similar progression from dominantly arid ephemeral depositional environments to humid perennial sedimentation, returning to prominent arid conditions. This suggests climatic control in both regions, where an enhanced humid signal drives perennial fluvial flow in otherwise arid dominated sequences. On a regional scale, this is suggested to record the impact of strong Triassic pluvial events previously recognised in other basins along the Central Atlantic margin during the Carnian to Norian periods.

1. Introduction

Prior to the exploration efforts in SW Morocco, the development of new theories about global continent evolution during the initial stages of rifting along the Atlantic margin had already highlighted

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the importance of the investigated Moroccan basins for global pre-drift reconstructions (e.g. Van Houten, 1977; Manspeizer et al., 1978; Jansa and Wiedmann, 1980; Stets and Wurster, 1981; Hinz et al., 1981; Manspeizer, 1982, 1988; Laville and Petit, 1984; Beauchamp, 1988; Medina, 1991, 1995; Piqué and Laville, 1996; Piqué et al., 1998; Baudon et al., 2012; Leleu et al., 2016). With the discovery of hydrocarbons in the central part of the Agadir-Essaouira Basin (Fig. 1) in the early 1990's numerous studies evaluated the Triassic petroleum systems of Morocco (e.g. Broughton and Trépanier, 1993; Morabet et al., 1998; Hafid et al., 2000; Bouatmani et al., 2004). Apart from a facies classification based on electrical log character of wells in the Meskala Field (Bouatmani et al., 2004), most studies have a strong focus on the structural evolution, with little focus on integrated sedimentological analysis, leaving the regional facies distribution and provenance for the prolific Upper Triassic sandstone reservoirs within the greater Agadir-Essaouira Basin open to speculation. Broughton and Trépanier (1993) for example suggested the entire Triassic sequence of the Argana Valley as the eastward extension of the central Essaouira Basin, hence part of the sediment routing from the provenance area, while seismic interpretations and new dating of the overlying basalts led Hafid et al. (2000) to the conclusion, that only the upper part (Middle to Upper Triassic) of the Argana series was connected to the central Essaouira Basin, whereas the lower part was deposited in an isolated rift arm.

To-date, the relationship between Upper Triassic clastic sediments in the Argana Valley to Triassic reservoir sandstones of the central Essaouira Basin remains uncertain. In order to improve the regional understanding of the spatial distribution of these extensive fluvio-aeolian reservoir facies in SW Morocco, this study presents new sedimentological analyses of core data from the central Essaouira Basin (Meskala Field), integrated with results from sedimentological outcrop studies of the Argana Valley (Tadrart Ouadou Sandstone member, T6; Mader, 2005; Mader and Redfern, 2011), and additional published descriptions for Carnian-Norian deposits from the Argana Valley exposures (Brown, 1980; Hofmann et al., 2000). The study aims to integrate the sedimentological data within a regional climatic framework, improving the understanding of the control on sedimentation of extreme Triassic humid events as summarised by Preto et al. (2010) or proposed by Arche and Lopez-Gomez (2014) for example.

2. Geological setting

Triassic sediments in Morocco outcrop within the Middle and High Atlas mountain chain, along the western margin of the African platform, and have also been encountered by wells in the Essaouira and Souss Basins, and along the present offshore Moroccan continental margin (Fig. 1). The Triassic sequences of Northwest Africa typically overlay a major unconformity and are deposited on Palaeozoic rocks deformed by the Hercynian and older orogenies. Deposition of the Triassic sequences took place in a series of (half-) grabens or strike-slip basins related to rifting along the Atlantic margin during the break-up of the Pangaean continent (Mattis, 1977; Van Houten, 1977; Manspeizer et al., 1978; Laville and Petit, 1984; Medina, 1988, 1991, 1995) (Figs. 1 and 2). Recent research suggests a change in how rift-basin geometry along the Central Atlantic Margin is viewed, and rather than the typical narrow rift-basin geometries more uncharacteristic broad sag-type basin styles have been reported, particularly for the Eastern provinces (Baudon et al., 2012; Leleu et al., 2016). The Triassic deposits infilling these basins commonly consist of coarse alluvial conglomerates, continental fluvial or aeolian sandstones, and alternations of fine siltstones, with evaporitic or non-evaporitic (playa) mudstones. In most parts of Morocco, the Triassic red beds are capped by the CAMP basalts (Central Atlantic Margin Province), which in turn are conformably transgressed, or interfinger, with limestones, dolomites, algal stromatolites, anhydrites, mudstones and halite deposits of an Early Jurassic sabkha environment (e.g. Courel et al., 2003).

3. Structural evolution

Mesozoic sequences in SW Morocco record the break-up of the super-continent Pangaea where crustal thinning and deep seated thermal activity led to the development of the Atlantic Ocean (Veevers, 1994). The Moroccan passive margin on the eastern side of the central Atlantic Ocean (e. g. Van Houten, 1977; Manspeizer et al., 1978; Piqué et al., 1998) demonstrates at least four major tectonic phases influencing deposition of Latest Palaeozoic to Early Mesozoic strata (Manspeizer et al., 1978; Laville and Petit, 1984; Piqué et al., 1998). In a time period covering the Permian to the Middle Triassic, extensive uplift with related crustal thinning along the axis of the future Atlantic defines the initial phase of break-up (Van Houten, 1977). The second, late Middle Triassic tectonic phase, resulted in strike-slip faulting along E-trending fracture zones and initiated W trending Tethys transgressions (Piqué et al., 1998). During the Late Triassic, continued rifting along the proto-Atlantic axis led to the deposition of clastic-evaporite sequences up to 5000 m thick in a relatively broad rift-setting with sag-geometries (Leleu et al., 2016) (Figs. 1 and 2B). Shearing occurred dominantly along E- to W-trending fracture zones inducing the decoupling of African and North American segments (Manspeizer et al., 1978), creating a pathway for Tethyan transgressions from E to W. In a last major tectonic phase (Late Triassic to Early Jurassic) global plate reorganisation led to crustal extension and seafloor spreading, resulting in massive extrusions of olivine and quartz tholeiitic basalts and igneous rock emplacement across a large area of North America and West Africa described as the Central Atlantic Margin Province (CAMP) (Marzoli et al., 1999; McHone, 2000; Olsen et al., 2000; Youbi et al., 2003; Knight et al., 2004; Marzoli et al., 2004; Verati et al., 2007; Whiteside et al., 2010; Deenen et al., 2010). During this last phase, a strong transcurrent component with transtension is proposed by Laville and Petit (1984), while Piqué et al. (1998) suggest normal faulting during this final syn-rift stage in Morocco.

4. Basin fill

The Agadir-Essaouira Basin forms part of the El Jadida-Agadir rift segment (Fig. 1). It developed as a set of half-grabens and underlies an extensive area of the modern day eastern passive Atlantic margin (Piqué et al., 1998). The nomenclature utilised to describe the Agadir-Essaouira Basin varies widely due to the complex basin segmentation and the lack of sufficient sub-surface or outcrop control (e.g. Société Chérifienne des Pétroles, 1966; Brown, 1980; Broughton and Trépanier, 1993; Piqué et al., 1998; Hafid, 2000). For consistency, the sediments of the Meskala Field are described in this paper as clastics deposited within the “central Essaouira Basin”, and the term “Argana Valley” is adopted synonymously to describe clastic deposits exposed in the present day Argana physiographic depression due to the lack of a so far clearly defined outline or structural framework for a potential “Argana Basin”.

4.1. Central Essaouira Basin (Meskala Field)

The Essaouira Basin is situated in central western Morocco and extends towards the N and S of the city of Essaouira, offshore and onshore, along the present day coastline (Figs. 1 and 2). The central basin is limited in the N by the Tensift-fault zone, and to the S by the