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Research Paper

Temporal and spatial changes of the submarine Cretaceous paleoslope in Northern Tunisia, inferred from slump folds analysis

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ABSTRACT

This paper presents the first comprehensive, non-exhaustive, study of the genetic relationship between slump folds and the synsedimentary paleoslope during Cretaceous time in northern Tunisia. Slump folds occur mainly in the Cretaceous marl-dominated lithofacies, which exposes numerous slump folds structures. In addition, fault kinematic analysis is conducted to define the paleostress fields and the stress states characterizing the Cretaceous extension that triggers soft-sediment deformation and slumping. The MAM and the APM methods are used to deduce the paleoslope in several localities. The calculated values of paleoslope trend derived from MAM and APM methods precise the variation of the paleoslope trend during Cretaceous times in northern Tunisia. This paleoslope is ~NW-dipping during Berriasian, ~SSW-dipping during Valanginian, ~NW-dipping during the Barremian and ~N- to ~NNE or ~S- to ~SSW-dipping during Aptian–Albian period. The results of the back-tilted fault diagram show a ~North to ~Northeast-trending tectonics extension. The back-tilting of Cenomanian slump axis and poles of axial planes (MAM and APM methods) give close results with ~Southward or ~Northward-dipping paleoslope. The restored fault diagrams show ~North to ~Northeast-trending extension during Cenomanian times. Coniacian-Santonian marls deposits seal all the gravity-driven deformation structures. North Tunisian area exposes evidences for abundant soft-sediment deformation and slumping atop a northward facing submarine slope, which was probably dominant from the Early Cretaceous to Santonian with ~North-South tectonic extension related to the Southern Tethyan rifted continental margin evolution.

1. Introduction

Slumps folds, generated within unlithified sediments atop existent slope, form one of the most remarkable features indicative of slope and basin-floor settings. Submarine slumping characterizes the sediment-shape in both active and passive margins context (Woodcock, 1979; Strachan and Alsop, 2006; Alsop and Marco, 2014). In passive margin framework, the driving force of such structures is acknowledged to be the gravitational instability over a submarine slope. During and/or after sedimentation, and before complete lithification, sediments moving downward (naturally from continental shelf to basin) in successive depositional events. Subsequently, Slump horizons are classified as primary structures that reflect paleoslope direction. Geoscientists have developed several techniques, from slump folds, to deduce the direction of the paleoslope of both recent and ancient margins (Heifetza et al., 2005; Strachan, 2008; Peel, 2014). North Tunisian area (Fig. 1) exposes evidences for abundant soft-sediment deformation and slumping that characterized the evolution of the Southern Tethyan rifted continental margin. However, to our knowledge, studies of the gravity-driven deformational structures are still insufficiently characterized or even absents in this region.

By the evaluation and analysis of slump folds and associated soft-sediment structures, many paleoslope and paleogeographical reconstructions were tested worldwide (Woodcock, 1979; Debacker and De Meester, 2009). Several techniques have been developed for the deduction of the direction of the paleoslope from

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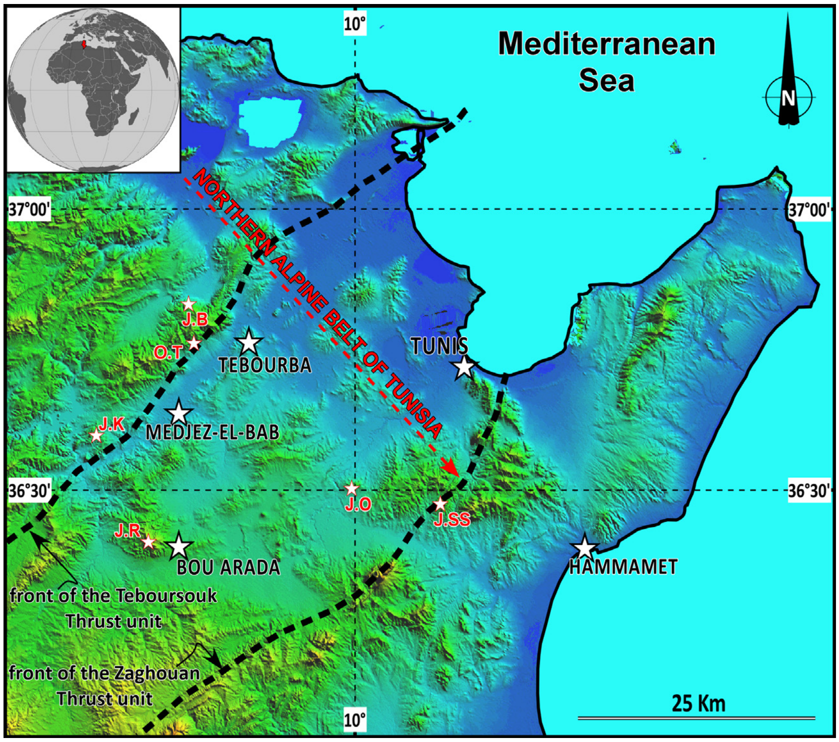

Fig. 1. Location of the studied sections in northeastern Tunisia. The inset on the top left shows the location of Tunisia in North Africa.

slump folds. Jones (1940) was the first who quantified the application of this idea using the Mean Axis Method (MAM) based on the correlation of mean slump fold axis with paleoslope strike in estimates of paleoslope direction (Fig. 2). Alternative method thereafter designated used the Separation Arc Method (SAM) is based on determining the paleoslope direction from the bisector of a separation Arc named Separation Arc Method reviewed these methods and suggested a procedure for determining paleoslope directions which reflects the respective strengths of the two methods. More recently, other studies have focused on the study of slump folds and described other methods to estimate the paleoslope direction from these structures (Bradley and Hanson, 1998; Strachan and Alsop, 2006; Strachan, 2008; Debacker and De Meester, 2009; Alsop and Marco, 2011, 2012a,b, 2013, 2014; Debacker, 2012). These methods use well-determined parameters of slumps such as slump fold axis, axial plane, interlimb angle . . . etc. reviewed the methods (i.e. fold facing directions, mean axis method -MAM-, mean axial plane strike method -MAPS-, mean axial-planar dip method -MAD-, separation arc method -SAM-, axial planar intersection method -AIM-), estimating the paleoslope direction from slumps folds structures (Fig. 2) with the contemporary understanding. Authors gave a detailed description highlighting similarities and differences between methods to deduce the direction of paleoslope from slumps folds (for more detail see Alsop and Marco, 2012a).

The analysis of slump folds and faults data together with sequences correlation are used in this study to evaluate Cretaceous soft-sediment deformation in north Tunisia. This work is the first comprehensive, non-exhaustive, study in north Tunisia applying known techniques to deduce paleoslope of the Cretaceous basin based on the slump folds analysis. The work intention is to present a structural contribution, via syndepositional deformation, to the debate about the basin paleogeography which is usually studied in this basin by stratigraphy and/or sedimentology. The northeast Tunisia exposes evidences for abundant soft sediment deformation features atop a synsedimentary Cretaceous submarine slope. This study presents the compilation of 100 slump folds collected along 54 km section from the Sidi Salem in the Southeast to the Jebel Boulahouadjeb in the Northwest.

2. Geological setting

Northern Tunisia is a part of the northern edge of the African plate and represents the eastern part of the Atlas System. The Atlas fold-and-thrust belt, extending from Morocco to Tunisia, is itself a part of the alpine chain of Africa named "the Maghrebides belt" which is related to the Alpine orogeny. Tunisia makes the eastern frontier of the Maghrebides belt. Except its northerly edge which corresponds to the Numidian range, the Northern Tunisian Atlas (Fig. 1) is divided into two distinguished structural units: (1) First, a major southeastward major thrusted unit called Teboursouk thrust unit, which corresponds to the front of the Alpine Range and shows a thick Aptian–Albian sequences. This area exhibits also numerous outcropping salt structures belonging to the northeastern Maghreb salt province (Masrouhi et al., 2013; Jaillard et al., 2013, 2017), (2) second, the Zaghouan-Ressas unit, acknowledged by last reviews to be the front of the Northern Tunisian Alpine Range. The present Zaghouan Thrust Fault corresponds to an inverted inherited fault, which during Mesozoic time, makes a paleogeographic line dividing a relatively shallow platform to the south, with a condensed Aptian section from a deep basin in the north (Morgan et al., 1998; Soua, 2016) with a thick Aptian–Albian section (Chihaoui et al., 2010).

The present-day fold-and-thrust belt in northern Tunisia is the result of the Meso–Cenozoic geological evolution of the northern African margin, which can be summarized in two main periods. The first is the Mesozoic rifting, highlighted from Late Permian(?) to the Early Cretaceous (Guiraud, 1998). This rifting is related to the Tethyan and Atlantic Oceans opening. Early Triassic salt basins were shaped, overall Tunisia, during the earlier stage of this evolution (Soussi et al., 2017). The extensional setting prevailed during Jurassic and Early Cretaceous (Boughdiri et al., 2007;

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