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Review article

Egyptian Tethyan margin in the Mesozoic: Evolution of a mixed carbonate-siliciclastic shelf edge (from Western Desert to Sinai)

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ABSTRACT

During the Mesozoic the Egyptian margin was an oblique margin with NW–SE oriented transform fault system. In the Eastern Mediterranean basin, Mesozoic margins were characterized by mixed carbonate-siliciclastics platforms where subsidence and eustasy were the main parameters controlling the facies distribution and geometries of the platform-to-basin transition. Geometries and facies on the platform–slope–basin profile, are today well constrained on the Levant side, but are still poorly known on the Egyptian side. Geometries and stratigraphic architecture of the Egyptian margin have been mapped, thanks to a regional seismic and well data-base provided by a joint industrial-academic group (UPMC-Total). This study brings new understandings on the seismo-stratigraphic architecture of the platform–slope–basin system in a key area from Western Desert to Nile Delta and the Levant margin. Mapping of the top Jurassic and top Cretaceous horizons shows the seismic geomorphology of the margin and the hinge line from Western Desert to Sinai. During the Jurassic, carbonate platforms were prograding with a distal thickening of the external platform with gentle slope profiles, paleo-valleys and embayments. Since the Cretaceous, the margin shows an aggrading and retrograding mixed carbonate-siliciclastic platform succession with abrupt NW–SE trending paleo-shelf-edges (affected by large gravity slide-scars) and distally steepened segments. This structure of the platform edges is strongly controlled by the inherited Tethyan transform fault directions. Along the hinge line, embayments are interpreted as megaslides. The basin filling is characterized by an alternation of chaotic seismic facies and high amplitude reflectors onlapping the paleoslopes. Mass Transport Complex (MTC) deposits are characterized by the mobilization of thick sedimentary sections (up to 3500 m in thickness) as a mixed amalgamation of debris flows, internally preserved blocks, and/or compressively-deformed distal allochthonous masses. Transported materials have been sourced from the dismantling of the Mesozoic mixed carbonate-siliciclastic platform and they can spread down slope over areas as large as 70,000 km^2. Based on stratigraphic correlations with global sea-level changes, platform instability could have been triggered by the gravitational collapse of the carbonate-siliciclastic platform under its own weight after successive subaerial exposures periods which were able to enable karstification processes.

Contents

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1. Introduction

In the Mediterranean region, the evolution of Peri-Tethyan Jurassic-Cretaceous margin-slope-basinfloor systems have been studied in recent decades for the stratigraphic architecture of base-of slope depositional system at outcrop sections (e.g., Provence margin: Floquet and Hennuy, 2001; Apulia margin: Borgomano, 2000; Eberli et al., 2004; Santantonio et al., 2013; Hairabian et al., 2014; Moroccan margin: Verwer et al., 2009; Della Porta et al., 2013) and on offshore 2D seismics (Moroccan margin: Heyman, 1989; Levant margin; Gardosh et al., 2006; Hawie et al., 2013). All of these studies highlighted a dominant tectonic control on the geometry and stratigraphic architecture and discontinuities within sedimentary systems at the platform–basin transition. In Egypt, Mesozoic platform–basin transition has been indicated on regional paleogeographic maps (e.g. Stampfli et al., 1991; Thierry, 2000), without information about stratigraphic architecture. Our main objective is to characterize the geometry and spatial-temporal evolution of the sedimentary systems at the platform–basin transition and its main controlling factors within a key area for hydrocarbon exploration from Western Desert to Nile Delta and Sinai margins, both onshore and offshore.

The Western Desert that covers two-thirds of Egypt, is bordered in its northern part by coastal basins (Matruh, Shushan, Alamein and Natrun) characterized by important oil and gas accumulations and oil production (e.g. Dolson et al., 2001). Recent offshore discoveries of light oil accumulations in the Lower Cretaceous carbonate platform (recent Zvor gas discovery), base-of-slope turbidites offshore Sinai (Ziv-1 and Mango-1) and Israel (Helez oil field) (Gardosh et al., 2006, 2011) and various oil shows (Marakia-1X; Ghaly et al., 2002) on the Cretaceous external platform play offshore Western Desert indicates that the Mesozoic platform-to-basin transition has significant hydrocarbon potential. In the Eastern Mediterranean, Mesozoic continental shelves are characterized by mixed carbonates-siliciclastic depositional systems (Levant margin: e.g. Gardosh et al., 2006; Hawie et al., 2013; Egyptian margin: e.g. Dolson et al., 2001) where facies and geometric architecture are mainly controlled by subsidence and eustasy. So far Mesozoic depositional facies and geometries along Egyptian margin platform–slope–basin profile have remained poorly described and interpreted. The characterization of the geometry and spatio-temporal evolution of the sedimentary systems presented in this paper is based on seismo-stratigraphic interpretation. For the first time, the Mesozoic 3D morphology of the shelf-edge and the stratigraphic architecture of the Egyptian margin can be illustrated thanks to a large onshore-offshore seismic and well data base provided by a joint industrial-academic group (UPMC and Total). The seismic stratigraphic interpretation is calibrated with industrial wells allowing a detailed paleogeography of the Egyptian margin to be established for the Cretaceous and Jurassic, integrating the stratigraphic evolution, tectonic setting and carbonate-siliciclastic mixed depositional systems.

2. Geological setting of the Egyptian continental margin

2.1. Regional geology

The Mesozoic Egyptian margin was the southern margin of the Eastern Mediterranean basin, at the northern African plate boundary. It inherited its position following a continental breakup phase from the Late Triassic to Middle-Jurassic times (Dercourt et al., 1993; Garfunkel, 1998; Guiraud et al., 2005; Bosworth et al., 2008). Many authors considered the Egyptian segment as a passive margin of the Eastern Mediterranean basin with a NE–SW rifting (Bein and Gvirtzman, 1977; Robertson and Dixon, 1984; Stampfli et al., 1991; Dercourt et al., 1993; Stampfli and Borel, 2002; Gerdes et al., 2010), but an alternative interpretation (Garfunkel, 1998, 2004; Frizon de la Motte et al., 2011; Tari et al., 2012a,b) implied that NW Egypt was an oblique margin, with a NW–SE opening direction (Fig. 1A–B). We follow this interpretation in our study. It is important to notice the Levant margin was affected by two major tectono-magmatic plume periods during Permo-Triassic stage and Late Triassic–Jurassic stage (Segev et al., 2011). By the Early Jurassic times the northwestward–thinning Levant margin was established (Garfunkel, 1998; Segev, 2002; Segev and Rybakov, 2010). Although not specifically related to the studied area, these events could have some impact on the thermal and mechanical evolution of the margin during the post-rift phase. From Middle-Jurassic to Middle-Cretaceous, post-rift subsidence was responsible for the formation of a shallow-marine shelf roughly parallel to the present-day coastline from Western Desert to Levant margin, and deep marine environment in the Eastern Mediterranean basin.

The present-day Egyptian margin (Fig. 2) can be divided into three onshore geological areas, from west to east: The Western Desert shaped by Mesozoic intra-shelf basins (e.g. Meshref, 1990), the Nile Delta with its large Tertiary sedimentary clastic accumulation (e.g. Gaullier et al., 2000; Loncke et al., 2002), and the North Sinai, characterized by inverted folds and faults formed during