



Role of sea-level change and syn-sedimentary extensional Tectonics on Ladinian-Carnian Alpujarride carbonates (Alpujarride Complex, Betic Internal Zone, SE Spain)

Influencia de los cambios del nivel del mar y de la tectónica sinsedimentaria extensional en los materiales carbonatados alpujarrides ladiniense-carnienses (Complejo Alpujarride, Zona Interna Bética, SE de España)

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RESUMEN

En este trabajo se estudia el efecto de la acción combinada de los cambios del nivel del mar y la tectónica sinsedimentaria extensional en la formación Meta-carbonatada de la unidad de Gádor-Turón (Complejo Alpujarride, Cordillera Bética). Nuestro análisis apunta a que la parte inferior de la formación se depositó en una rampa carbonatada (miembros 1-4), con ausencia de actividad tectónica significativa. La parte superior de la formación (miembros 5-6) se originó en una plataforma carbonatada limitada por fallas y en un contexto en el que se alternaban momentos de actividad tectónica extensional con momentos de calma. El cambio de modelo de plataforma registrada en el miembro 5, tuvo lugar durante el Ladinense-Carniense, simultáneamente con un momento de gran actividad tectónica extensional. Los datos obtenidos parecen señalar que el depósito de los distintos miembros estaba controlada por los cambios del nivel del mar. Al descender a una escala de observación más detallada, la organización en intervalos y asociaciones de facies dentro del miembro 5 registran varias para-secuencias aparentemente relacionadas con la tectónica sinsedimentaria.

Palabras clave: Triásico, rampa, Complejo Alpujarride, evolución tectono-sedimentaria.

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Introduction

During the early stages of rifting of Pangea, the westernmost part of the Palaeo-Tethys was the site of deposition of Alpine- and Germanic-type Triassic series (shallow-marine sedimentary successions). Evidence of Triassic rifting has recently been recognized in the thick Ladinian-Carnian carbonate succession of the Gador-Turon unit (Alpujarride Complex, Internal Betic Zone, SE Spain; Martín-Rojas *et al.*, 2009). This succession represents a useful outcrop for the analysis of the interference between the syn-sedimentary extensional Tectonics and the sea-level changes during sedimentation. In this paper, we report the results of a multi-disciplinary study focussed both on the analysis of litho- and biostratigraphy, tectono-sedimentary relationships, and on the facies and environmental evolution of the

Alpujarride Triassic carbonates of the Gador-Turon unit.

Geological setting

The Betic Cordillera is formed by the External and Internal zones. The External Zone is composed of a Meso-Cenozoic sedimentary cover deriving from deformation of the southern palaeomargin of the Iberian Subplate. Particularly, the basal Triassic sediments are characterized by Germanic-type facies. By contrast, the Internal palaeo-Domain includes Meso-Cenozoic sedimentary covers deriving from areas located on the Mesomediterranean Block (Martín-Rojas *et al.*, 2009 and references therein). Their Triassic successions show facies with intermediate features between Alpine- and Germanic-type facies. Alpujarride Complex, focus of this research, belongs to the Betic Internal

Zone and is tectonically interposed between the overlying Malaguide Complex and the underlying Nevado-Filabride Complex.

The Alpujarride Triassic successions comprise continental clastic and shallow marine carbonate rocks. The Triassic carbonates studied in the Gador-Turon unit crop out in the Sierra de Gador (NW of Almería).

The Meta-carbonate fm

Litho-biostratigraphy

The Gador-Turon unit is composed of the Meta-detrital fm (Middle Triassic?) in the lower part and the Meta-carbonate fm (Ladinian-Carnian) in the upper part. The Meta-carbonate fm, topic of this research, is formed by six members of regional significance and shows a total thickness of 1300 m. These members, recently analysed by Somma *et al.* (2008) and

M	F	Facies name	Microfacies texture	Sediment. structures or accessory features	Fossils and bioclasts / other main skeletal grains	Guide fossils content	Environments
Meta-detrital formation							
l. u.	A	Pelite and quartzarenite	/	Graded beds, lamination	/	/	Peri-continental and coastal
m.	B	Laminated limestone	Wackestone-mudstone	Lamination	/	/	Shoreface? zone
m.	C	Limestone with cherty nodules and ribbons	Wackestone-mudstone	Lamination	Dasycladaceae algae, sponge spicules, echinids	/	Offshore transition zone
m.	D	Dolostone with cherty nodules	Crystalline dolomite, relic mudstone-wackestone, siliciclastic grains	Cavities, red clayey-hematitic seams	Algal mats (?), gastropods, bivalves, echinids, thick-shell ostracods / Peloids	/	Shoreface? zone
Meta-carbonate formation							
1	E	Grey dolostone	Crystalline dolomite, relic grainstone-wackestone, mudstone	/	/	/	Shoreface? – upper offshore transition zone
1 3	F	Reddish to yellowish marly limestone and marl	/	Bioturbation	/	/	Offshore zone
1 3 4 5	G	Grey and dark limestone with molluscs	Wackestone-mudstone, packstone	Nodular fabric marked by red clayey-hematitic seams	Abundant pelagic gastropods - bivalves, echinids, sponge spicules, ostracods, foraminifers (abundant thin-shell nodosariids in m. 1; abundant thick-shell nodosariids and great size Involutinacea in m. 5) / Peloids	? <i>Nodosaria ordinata</i> (Trifonova; in m. 1.), <i>Lamellicomus</i> gr. <i>biconvexus-ventr.</i> (in m. 1), <i>Lamellicomus cord.</i> (Oberhauser; in m. 1, 4, 5) and ? <i>Triadodiscus eom.</i> (Oberhauser; in m. 4, 5)	Offshore zone
1 2	H	Brown dolostone	Grainstone-wackestone, mudstone	Laminations	Rare molluscs / Peloids	/	?Offshore transition z.-shoreface zone
1	I	Limestone with foraminifera	Packstone	Tractive parallel laminations	Abundant concentration of great size foraminifers (Involutinacea), nodosariids, pelagic gastropods - bivalves, echinids, sponge spicules / Peloids	<i>Lamellicomus</i> gr. <i>biconvexus-ventroplanus</i> and <i>Lamellicomus cordevolvicus</i> (Oberhauser)	Offshore transition zone-?offshore zone
3 4	J	Bioturbated limestone	Mudstone-wackestone	Planolites?, yellowish seams	Pelagic gastropods - bivalves, crinoids, foraminifers (nodosariids and possible re-crystallized small Involutinacea)	/	Offshore zone
3	K	<i>Lumachella</i> with crinoids	Floatstone-rudstone	Cross laminations	Crinoid ossicles (circular and star forms), bivalves, gastropods, algae, brachiopods (?), foraminifers (rare Involutinacea) / Coated grains, peloids	<i>Lyriomyophoria betica</i> (Hirsch), ? <i>Triadodiscus eom.</i> (Oberhauser)	Offshore transition zone-shoreface zone
3	L	Marly limestone	Mudstone	Cross laminations, bioturbation	Gastropods - bivalves, indeterminate bioclasts / Peloids	/	Shoreface zone
4	M	Limestone with algae and cherty nodules	Wackestone-mudstone, packstone, floatstone-rudstone	/	Dasycladaceae algae, pelagic bivalves – gastropods, spicule sponges, echinids, foraminifers (fine-shell nodosariids and rare Involutinacea) / Peloids	<i>Diplorora ?nodosa</i> , <i>Teutloporella ?herc.</i> , <i>Triadodiscus eom.</i> (Oberhauser), <i>Nodosaria ordinata</i> (Trifonova)	Offshore transition zone- offshore
4 5	N	Light and dark-grey nodular limestone	Mudstones-wackestone, packstones	Nodular fabric marked by red clayey-hematitic seams	Pelagic molluscs, sponge spicules, echinids, radiolarians, rare Dasycladaceae algae, foraminifers (nodosariids and rare Involutinacea) / Fecal pellets	<i>Triadodiscus eomesozoicus</i> (Oberhauser)	Offshore zone
5	O	Limestone with cement-filled cavities and evaporite minerals	Mudstone, wackestone-packstone	Cavities, evaporite minerals, red clayey-hematitic seams	Algal mats, echinids, indeterminate bioclasts	/	Interdigitation of slope and offshore zone
5	P	Oncoidal limestone	Floatstone-rudstone	Massive	Oncoids	/	Slope
5 6	Q	Black dolostone	Mudstone-wackestone, grainstone	Cross laminations (m. 5), evaporite minerals, red clayey-hematitic seams	Algal mats, indeterminate bioclasts, ostracods, rare foraminifers (autolortidae and microproblematica, m. 5) / Peloids, coated grains, rare oncoids, oolites	<i>Baccanella floriformis</i> (Pantic) (m. 5)	High-energy cond.: Slope (m. 5) Shoreface zone (m. 6)
5 6	R	Intraformational breccias	Clast-supported (m. 5) and matrix-supported (m. 6). Clasts of Facies Q and O	Slump, dykes	/	/	Slope
6	S	Limestone with lamination	Mudstone-wackestone, packstone	Tractive laminations, evaporite minerals	Algal mats, gastropods, bivalves, echinids, ostracods / Peloids	/	Shoreface zone
6	T	Yellowish marl and marly limestone	Mudstone-wackestone	Massive or laminated, bioturbation, abundant pyrite	Gastropods, bivalves, Ammonoids (?), echinids, ostracods / Peloids	<i>Bactryllium</i> sp. (Heer)	Shoreface-Offshore transition zone
6	U	<i>Lumachella</i>	Floatstone-rudstone	Cross laminations / pyrite	Bivalves, gastropods, rare crinoid ossicles, algae, brachiopods (?), ostracods / Coated grains, peloids	/	Offshore transition zone
6	V	Gypsum	Crystalline gypsum	Massive and laminated	/	/	Ponds in the inner ramp

Table I.- Classification, description of the facies and depositional environments.

Tabla I.- Clasificación, descripción de facies y medios sedimentarios de las mismas.

Martin-Rojas *et al.* (2009), have been denoted, from base to top (Fig. 1): (1) marly-calcareous-dolomitic mb., (2) dolomitic mb., (3) fossiliferous

calcareous-marly mb., (4) cherty calcareous mb., (5) mineralized calcareous-dolomitic mb. and (6) marly-calcareous mb. In each mb., several

lithostratigraphic intervals have been recognized (Fig. 1). Mb. 1 is Ladinian in age and consists of dolostones, limestones, and marly limestones. Fossil

facies from O to V probably formed in shallow waters on a shelf with intra-shelf basins (Fig. 1, Table I; Somma *et al.*, 2009). An environmental interpretation for each of the studied mbs. is proposed below (Fig. 1, Table I). Facies of mb. 1 (Fig. 1, Table I) record an evolution from the inner (?) ramp to the distal zone of the inner (-middle?) ramp. Consequently, this mb. presents a general deepening-upward trend. Mb. 2 (Fig. 1, Table I) consists of recrystallized dolostones (lacking any evidence of peritidal structures). An offshore-shoreface transition zone could be proposed as the probable environment. Facies of mb. 3 (Fig. 1, Table I) developed from the distal part of the outer ramp to the inner ramp, recording a general shallowing-upward trend. We interpret mbs. 1, 2 and the lower and middle intervals of mb. 3 as a transgressive system tract (TST, Fig. 1), while the upper interval of mb. 3 could represent an high-stand system tract (HST, Fig. 1). The lower part of mb. 4 is characterized by the most distal facies of the ramp (Fig. 1, Table I). In this lower interval, the presence of a maximum flooding surface can be postulated (Fig. 1). Above this surface, an evolution from the distal area of the outer ramp to the proximal zone of the outer ramp is hypothesized. Accordingly, mb. 4 represents the next TST (lower part) and HST (middle-upper part). A para-conformity, interpreted as sequence boundary, can be identified between mbs. 3 and 4. Facies of mbs. 5 and 6, differently from those of the underlying succession, formed in very contrasting depositional environments (Fig. 1, Table I) suggesting a sedimentation onto a

platform limited by fault scarps. In mb. 5, at the interval scale a general shallowing (from the calcareous level to the dolomitic one) can be identified. Differently, the sharp contact between two successive intervals testifies an abrupt deepening. We interpret this deepening trends as parasequences as probably depending on the extensional Tectonics widely developed in this member. At the scale of the mb. 5 deposited during a long-term shallowing-upward trend corresponding to a HST (Fig. 1). The evolution of parasequences is in contrast with that observed in Germanic and Alpine Triassic, and so suggests a local tectonic control on sedimentation. The syn-sedimentary normal faults recognized by Martin-Rojas *et al.* (2009) provide a significant support to this scenario. Mb. 6 (Fig. 1, Table I) formed after the end of the main syn-sedimentary Tectonics. It should have been deposited on coastal areas of a carbonate platform characterized by arid climatic conditions (Facies Z, Sabkha).

Conclusions

The interference between the syn-sedimentary extensional tectonics and the sea-level changes has been analyzed in the Meta-carbonate fm of the Gador-Turon unit. Tectono-sedimentary analysis suggests that the lower part of the succession (mbs. 1-4) was deposited on a carbonate homoclinal ramp and in the absence of tectonic activity, while the upper part formed on a carbonate platform limited by fault scarps (mbs. 5-6). Particularly, mb. 5 formed during alternating phases of activity and

quiescence of syn-sedimentary extensional tectonics. The change of platform morphology was recorded by mb. 5 during the Ladinian time. The deposition of mbs. 1-5 occurred during two sequences (Fig. 1): a lower sequence showing mb. 1, 2 and 3 (lower and middle intervals) as TST, while the upper interval of member 3 represents de HST. An upper sequence presenting the lower interval of mb. 4 as TST, and the middle-upper intervals of mb. 4 and mb. 5 as HST. The sequences identified correlate with those recognized in the Germanic and Alpine-type Triassic. The sequence stratigraphy evolution of mb. 5 does not correlate with eustatic cycles probably because it was mainly controlled by local active tectonics. Consequently, the control of the sea-level fluctuations has been recorded only at the scale of the entire member.

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