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 sinsedimetaria extensional en los materiales carbonatados alpujárrides ladíniense-carnienses (Complejo Alpujárride, Zona Interna Bética, SE de España)

Iván Martin-Rojas [(1)], Roberta Somma [(2)], Francisco Delgado [(3)], Antonio Estévez [(1)], Alessandro Iannace [(4)], Vincenzo Perrone [(5)] and Valeria Zamparelli [(4)]

[(1)] Departamento de Ciencias de la Tierra y del Medio Ambiente, Universidad de Alicante, 03690, Alicante, Spain. Ivan.Martin@ua.es
[(2)] Dipartamento di Scienze degli Alimenti e dell'Ambiente, Università di Messina, Sant'Agata, 98166 Messina, Italy.
[(3)] Departamento de Estratigrafía y Paleontología, Universidad de Granada, Facultad de Ciencias, Av. Fuentenueva sn. Spain.
[(4)] Dipartamento di Scienze della Terra, Università di Napoli «Federico II», Largo San Marcellino 10, 80138 Napoli, Italy.
[(5)] Dipartamento di Scienze Geologiche e Tecnologie Chimiche e Ambientali, Università di Urbino Carlo Bo, Urbino, Italy.

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 Alpujárride, 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 Ladiniense-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 Alpujárride, evolución tectono-sedimentaria.

Geogaceta, 48 (2010), 63-66
ISSN: 0213-683X

Fecha de recepción: 15 de febrero de 2010
Fecha de revisión: 21 de abril de 2010
Fecha de aceptación: 28 de mayo de 2010

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; Martin-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 (Martin-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 Almeria).

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	*?Nodosaria ordinata* (Trifonova; in m. 1.), *Lamelliconus* gr. *biconvexus-ventr. (in m. 1)*, *Lamelliconus cord.* (Oberhauser; in m. 1, 4, 5) and *?Triadodiscus eom.* (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	*Lamelliconus* gr. *biconvexus-ventroplanus* and *Lamelliconus cordevolicus* (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	*Lumachella* with crinoids	Floatstone-rudstone	Cross laminations	Crinoid ossicles (circular and star forms), bivalves, gastropods, algae, brachiopods (?), foraminifers (rare Involutinacea) / Coated grains, peloids	*Lyriomyophoria betica* (Hirsch), *?Triadodiscus eom.* (Oberhauser)	Offshore transition zone-shoreface zone
3	L	Marly limestone	Mudstone	Cross laminations, bioturbation	Gastropods - bivalves, indeterminable 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	*Diplorora ?nodosa*, *Teutloporella ?herc.*, *Triadodiscus eom.* (Oberhauser), *Nodosaria ordinata* (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 spiculas, echinids, radiolarians, rare Dasycladaceae algae, foraminifers (nodosariids and rare Involutinacea) / Fecal pellets	*Triadodiscus eomesozoicus* (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, indeterminable 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, indeterminable bioclasts, ostracods, rare foraminifers (aulotortidae and microproblematica, m. 5) / Peloids, coated grains, rare oncoids, oolites	*Baccanella floriformis* (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	*Bactryllium* sp. (Heer)	Shoreface-Offshore transition zone
6	U	*Lumachella*	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 assemblage included in this member consists of molluscs, sponge spicules, and foraminifers. Particularly, the finding of carbonate beds showing a rich concentration of Tethyan Involutinids has important palaeogeographic implications in terms of relationships between the Internal and External domains (Somma *et al.*, 2010, in this volume). Mb. 1 is overlain by massive, strongly recrystallized dolostones (mb. 2). The fossiliferous calcareous-marly mb. (mb. 3) is Ladinian in age and consists of thin-bedded limestones, bioturbated and nodular limestones, marly limestones and marls. The fossil content is represented by an assemblage of molluscs, echinids and foraminifers. *Lumachella* beds are abundant in the upper part of the member. The overlying Ladinian limestones of mb. 4 are formed by cherty limestones with local concentrations of dasycladacean algae. Bioturbated and nodular limestones are also present. The fossil assemblage is formed by molluscs, echinids, sponge spicules, ostracods and foraminifers. The mineralized calcareous-dolomitic mb. (mb. 5), Ladinian-?Carnian in age, records a syn-sedimentary extensional Tectonics episode (Martin-Rojas *et al.,* 2009). This mb. consists of four intervals (I-IV), separated by sharp contacts and formed by a lower calcareous level evolving to an upper dolomitic level. Limestones usually show a fossil assemblage characterized by pelagic gastropods and bivalves, crinoids, algae, sponge spicules and foraminifers (Lagenidae and involutinids). Dolostones and limestones are locally characterized by centimetre-thick red layers, evaporitic minerals, convolute laminations, algal mats, oncoids and coated grains. The succession is topped by the marly-calcareous mb. (mb. 6). This is formed by marls with intercalations of limestones and dolostones. In the upper part, *lumachella* beds are present. In the middle part of mb.6 discontinuous gypsum bodies up to 20-m-thick occur. The presence of *Bactryllium* sp. suggests a Late Triassic (probably Carnian) age for these deposits.

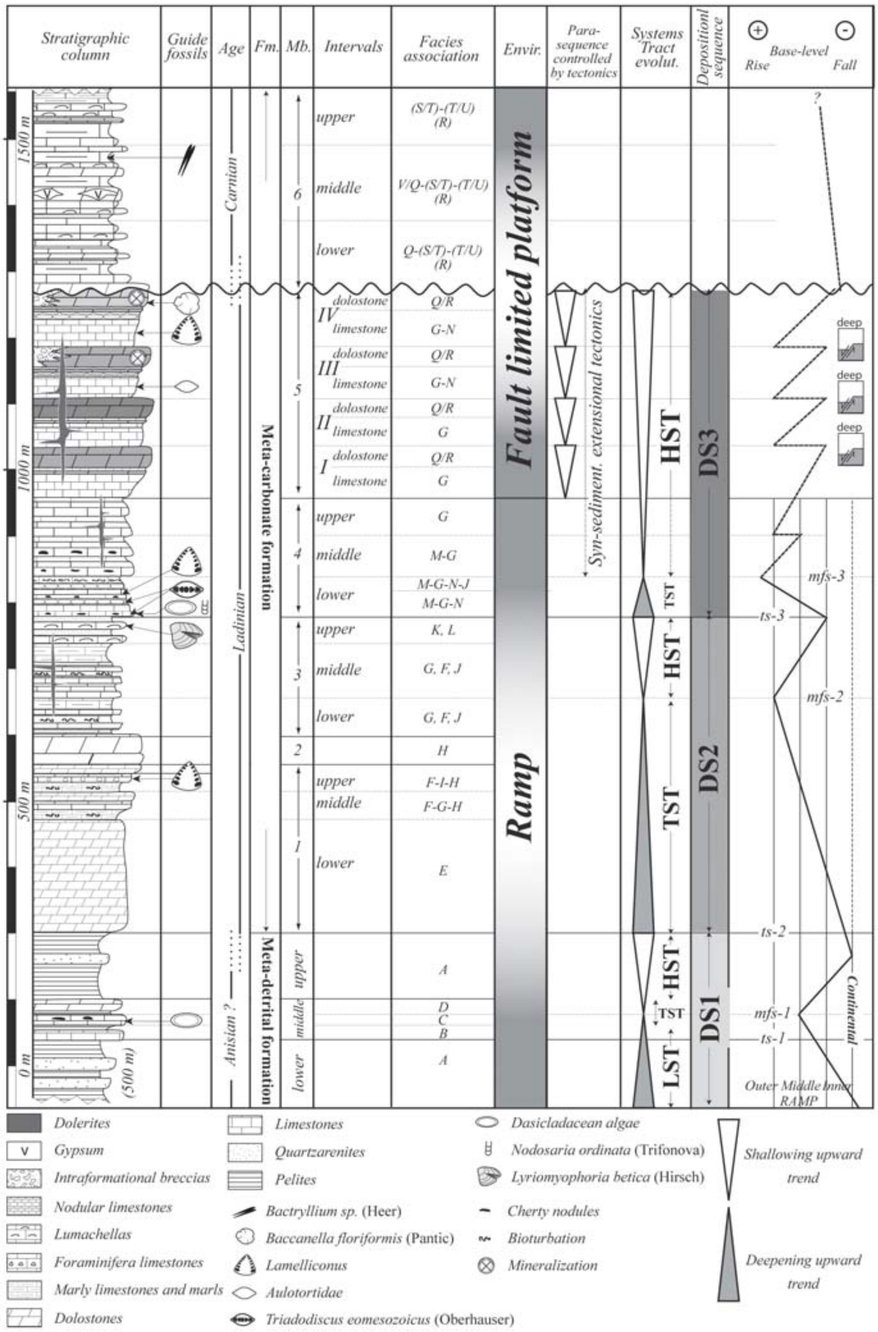

Fig. 1.- Synthetic stratigraphic column of the Gador-Turon unit.

Fig. 1.- Columna estratigráfica sintética de la unidad de Gádor-Turón.

Ladinian - Carnian syn-sedimentary extensional tectonics

Direct evidence of syn-sedimentary extensional Tectonics related to the Pangea continental rifting is provided by the recognition of macro- to meso-scale normal faults overstepped by younger strata. The fault activity is capped by beds of mb. 6, locally defining a post-fault unconformity between mb. 5 and 6 (Fig. 1). Mb. 5 presents a wedge-like shape at regional scale. This shape is probably related to the above mentioned faults. In mb. 5, as a matter of fact, soft-sediment deformation, gravity-flow deposits and unconformities are widely developed. Syn-tectonic mafic igneous intrusions cutting the studied formation have also been identified. The age of this syn-sedimentary extensional tectonics is constrained as Ladinian-Carnian.

Facies analysis and palaeo-environmental interpretation

18 facies (Table I), several facies associations and intervals have been distinguished in the six mbs. of the studied Meta-carbonate fm (Fig. 1). Table I synthesises the main features of the analyzed facies and the related depositional environments, identified mainly on the base of the cyclicity and trend of facies as observed on the field. According to that, facies from E to N presumably developed in different areas of an homoclinal carbonate ramp, while

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 trasngressive system tract (TST, Fig. 1), while the upper interval of mb. 3 could represents 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 para-sequences 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.

Acknowledgments

This study was supported by the projects CGL2006-08848, GV06/169, GV/2007/143, ACOMP09/138, GRJ06-08,VIGROB053.

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