

Sedimentology and sedimentary evolution of the Artoles Fm in Miravete de la Sierra (Teruel, Iberian Chain)

Sedimentología y evolución sedimentaria de la Fm. Artoles en Miravete de la Sierra (Teruel, Cordillera Ibérica)

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ABSTRACT

The sedimentology and sedimentary evolution of the Barremian Artoles Fm in the Camino de Miravete section (Galve sub-basin, Spain) is presented. The detailed log of the stratigraphic succession together with facies analysis and fossil content have allowed the distinction of four main facies associations: mixed terrigenous-carbonate lagoon, flood-tidal delta, proximal middle ramp and distal middle ramp. The sedimentary evolution of facies associations characterizes three successive stages: I- restricted carbonate lagoon system, II- middle ramp system and III- turning back to another carbonate lagoon with more open facies. Eustasy and tectonics may be responsible of the abrupt deepening that took place between stages I and II.

Key-words: Barremian, Galve sub-basin, carbonate ramp, extensional tectonics.

RESUMEN

Este trabajo analiza la sedimentología y evolución sedimentaria de la Fm. Artoles (Barremiense) en el perfil estratigráfico Camino de Miravete (sub-cuenca de Galve, España). El análisis sedimentológico ha permitido diferenciar cuatro asociaciones de facies: lagoon mixto detrítico-carbonatado, delta mareal de flujo, rampa media proximal y rampa media distal. La evolución sedimentaria interpretada a partir de las asociaciones de facies, indica la existencia de tres etapas sucesivas: I- lagoon carbonatado, II- rampa media distal que prograda hacia rampa media proximal y III- sistema de lagoon más abierto. La eustasia y la actividad tectónica pueden ser responsables de la abrupta profundización definida entre los dos primeras etapas.

Palabras clave: Barremiense, sub-cuenca de Galve, rampa carbonatada, tectónica extensional.

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Introduction

Stratigraphic and sedimentological studies about the Artoles Fm (Late Barremian) in western Maestrazgo region of the Iberian Range are scarce (García-Ramos, 1985; Salas, 1987; Soria, 1997). Such studies interpreted the Artoles Fm in the Galve sub-basin as deposited in muddy tidal flats, internal platforms or lagoons. Based on a new stratigraphic section logged near Miravete de la Sierra, a detailed stratigraphic and sedimentologic analysis of the Artoles Fm is carried out. The results allow the refinement of the sedimentologic model, and to propose the general sedimentary evolution and controlling factors for this formation.

Geological setting and methods

The studied Camino de Miravete section of the Artoles Fm is situated between the localities of Aliaga and Miravete de la Sierra

(Teruel province, western Maestrazgo), at the western limb of the Aliaga-Miravete Anticline (Fig. 1). It was located at the depocentral area of the Early Cretaceous Galve sub-basin, which represented a western, marginal sedimentation area of the Maestrazgo Basin. The extensional structure of the Cretaceous Galve sub-basin was characterized by the activity of two fault sets trending NNW-SSE (Miravete and Alpeñes-Ababuj faults) and ENE-WSW (Campos, Santa Bárbara, Aliaga, Remenderuelas, Camarillas and Jorcas faults), respectively (Liesa *et al.*, 2004).

The Artoles Fm is an Upper Barremian unit deposited during the second Mesozoic rifting period that affected the eastern Iberian plate (Salas, 1987; Soria, 1997). This unit, mainly consisting in gray marlstones and limestones and occasional brown sandstones, gradually overlies the Camarillas Fm (red sandstones and clays of a back-barrier island system; Navarrete *et al.*, 2013) and is

sharply overlapped by the red clays of the Morella Fm.

The stratigraphic section was logged in detail recording lithology, texture, bedding geometry, fossil content, sedimentary structures, and palaeocurrent directions (Fig. 2). Sedimentological interpretations are also based on the analysis of 63 polished sections and 18 thin sections. Outcrop conditions also allowed the observation of lateral and vertical relationships between facies.

Stratigraphy

The Artoles Fm in the Camino de Miravete section includes three lithologic units (units I to III, Fig. 2 and 3A). Unit I is composed of 86.5 m of alternating layers of gray marlstones and ochreous limestones containing ostracods, charophytes, remains of bivalves (including ostreids) and occasional gastropods. Brown sandstones, lumachelle limestones and ostreid bioconstructions ap-

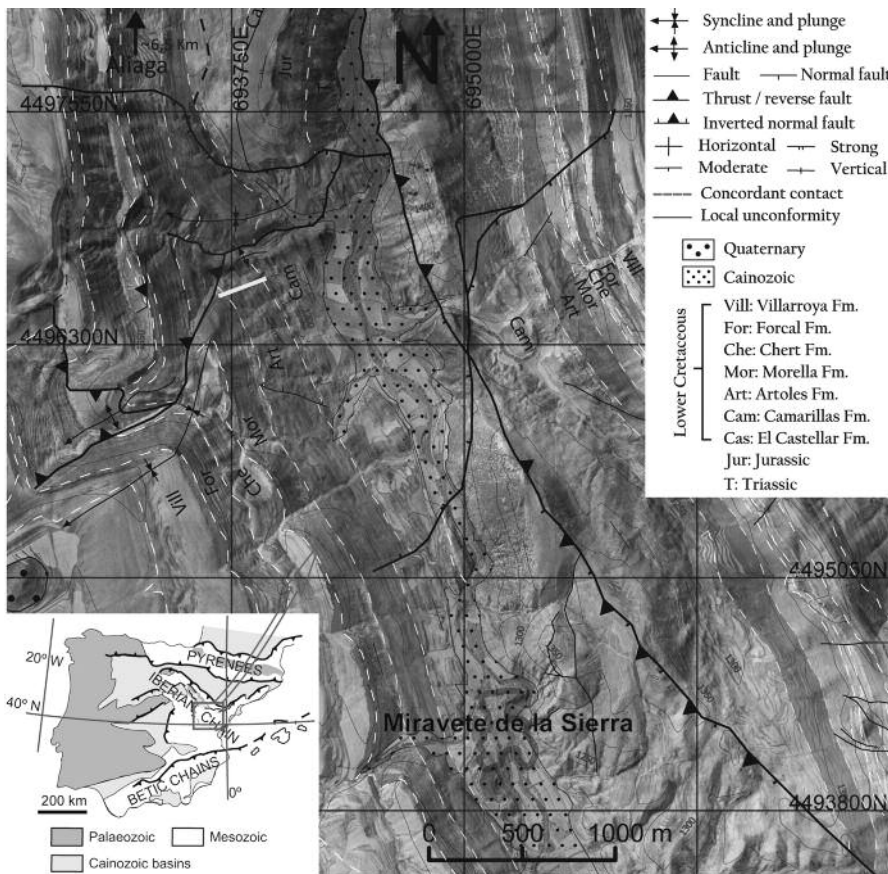


Fig. 1.- Geological sketch on aerial photograph of the studied area and location of Camino de Miravete section. Inset shows its location in Iberia. (See colour figure on the Web).

Fig. 1.- Mapa geológica de la zona de estudio sobre imagen aérea y localización del perfil. El mapa incluido muestra su localización en Iberia. (Ver figura en color en la Web).

pear interbedded. Decimetre-scale bioturbation (*Thalassinoides*-like traces) and indeterminate vertical bioturbation traces are also present. Unit II consists of 50 m of gray marlstones with intercalations of gray limestones and ochreous and brown sandstones with hummocky cross-stratification (HCS). They contain bivalves, ostracods and occasional benthic foraminifera. Unit III is 28 m thick and consists of alternating layers of gray marlstones and ochreous limestones made up by ostracods, remains of bivalves, ostracods, gastropods, benthic foraminifera and echinoderms. Lumachelle limestones and brown sandstones are also present.

Sedimentology

The analysis of the different facies and of their vertical stacking have allowed the identification of four main facies associations (FA) in the Camino de Miravete section:

Mixed terrigenous-carbonate lagoon FA

This facies association consists of alternating layers of gray massive marlstones and

gray limestones with occasional brown sandstone levels. It mainly constitutes units I and III. The marlstone layers, 20 cm to 7 m in thickness, have tabular geometries, and contain ostracods, charophytes and occasionally bivalves, plant fragments and vertebrate remains. The limestone layers are 10-30 cm in thickness with tabular and nodular geometries and they are stacked in up to 1 m-thick packages. Mud-supported textures (mudstone to wackestone) dominate, but packstone and rudstone textures are also present. They mainly contain ostracods, charophytes, bivalves, ostracods, and sand-size quartz grains; occasionally gastropods, corals, plant fragments, intraclasts, ooids, and extraclasts are identified. In unit III the charophytes disappear whereas benthic foraminifera (miliolids and *Choffatella*) and echinoderms are very common (Fig. 3B). A 50 cm-thick, 2 m-long ostracod bioconstruction patch (bafflestone texture) is also present. The limestone layers are locally bioturbated by roots and *Arenicolites*-like, *Skolithos*-like, and *Thalassinoides*-like traces, and occasional dinosaur footprints.

Alternating marls and mud-supported limestones with low faunal diversity (charophytes, ostracods, bivalves and ostracods) are interpreted as deposited during low-energy episodes within a mixed terrigenous-carbonate lagoon (e.g., Sanders and Höfling, 2000; Lee *et al.*, 2001). The presence of benthic foraminifera and echinoderms and absence of charophytes in unit III would indicate more open conditions of the lagoon. Under low-energy conditions the generation of small ostracod bioconstructions was possible. Levels with trace fossils could be related with possible arrival of siliciclastic materials and nutrients to the lagoon, which favoured the proliferation of endobenthic organisms (Navarrete *et al.*, 2013). Bioturbation by roots, dinosaur footprints and vertebrate remain in the base of Unit I is interpreted as shallow lagoonal facies related to the back-barrier environments described by Navarrete *et al.* (2013). The presence of packstone and rudstone facies indicates high-energy events within the lagoon, possibly related to storm episodes (Aigner, 1985).

Flood-tidal delta FA

This facies association consists of a metre-thick sandstone package of lenticular geometry located at the base of unit I and encased in carbonate lagoon deposits (Fig. 3C). Internally, it shows a coarsening-upward trend, trough cross-stratification and asymmetric ripples (see a detailed description in Navarrete *et al.*, 2013).

Based on its geometry and internal structure, these authors interpret this sandstone body as a flood-tidal delta deposit in relation with a barrier-island system identified in the Miravete de la Sierra area, located ca. 2 km southwards of our studied section.

Proximal middle ramp FA

It is composed of gray massive marlstones layers and intercalated medium- to coarse-grained brown sandstones. It is located in the upper part of unit II. The marlstones are arranged in metre-thick tabular layers and contain benthic foraminifera and fish teeth, and occasional bivalves and trace fossils (*Thalassinoides*-like traces). The sandstones appear as tabular bodies of decimetric to metric thickness with flat bases and undulating tops. They present hummocky cross-stratification (HCS) and bivalves, ostracods and vertical trace fossils (*Arenicolites*-like traces) (Fig. 3D).

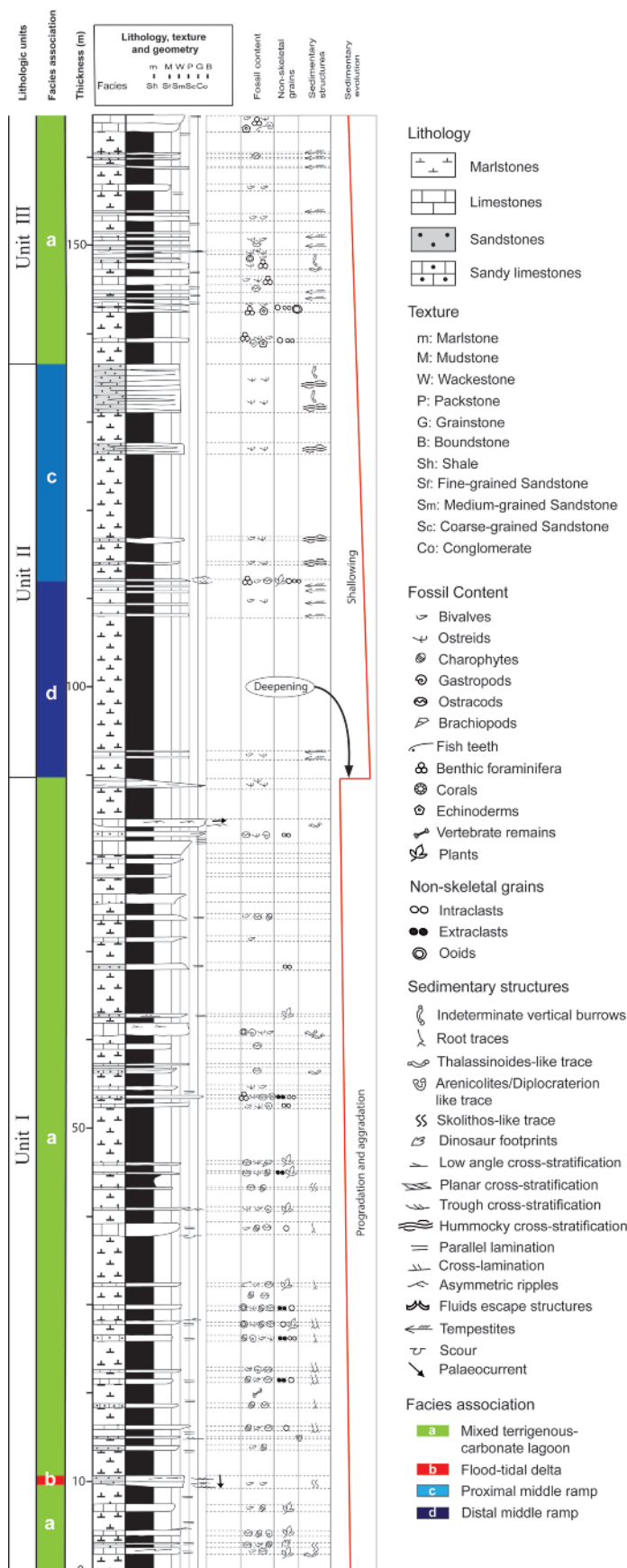


Fig. 2.- Simplified stratigraphic profile of the Artoles Fm at Camino de Miravete section. Facies associations and the sedimentary evolution are shown.

Fig. 2.- Perfil estratigráfico simplificado de la Fm Artoles en la sección Camino de Miravete. Se muestran las asociaciones de facies y la evolución sedimentaria.

The presence of marlstone layers alternating with sandstones with HCS is interpreted as typical deposition in a proximal middle ramp (e.g., Tucker and Wright, 1990; Seilacher and Aigner, 1991). In this context, the sandstones with HCS were originated during storm episodes and the marlstones are interpreted as deposited during fair weather periods. The carbonate mud in marlstone facies could be originated from microbial activity (Leinfelder *et al.*, 1993), pelagic deposition by calcareous nannoplankton (Tucker and Wright, 1990), and/or mud transported from shallow ramp positions (e.g., Bádenas *et al.*, 1993; Aurell *et al.*, 1998).

Distal middle ramp FA

This facies association is made up by gray marlstones interbedded with ochreous bioclastic limestones and medium- to coarse-grained brown sandstones. It is located at the lower part of unit II. Marlstones appear in decimetre to metre-thick tabular beds and contain benthic foraminifera and fish teeth. Sandstones are arranged in centimetre-thick tabular beds with flat bases and undulating tops, and display parallel- and cross-lamination, and asymmetric ripples (Fig. 3E). The sandstone levels contain abundant bivalve and ostreid fragments and benthic foraminifera. Bioclastic limestones (ostreid and bivalve packstone) are also arranged in centimetre-thick tabular beds and display parallel lamination due to preferential orientation of bioclasts.

The presence of centimetre-thick layers of bioclastic limestones and sandstones intercalated within massive marlstones is interpreted as distal middle ramp deposits (Bádenas, 1997). Marlstones represent deposition during fair-weather episodes whereas bioclastic limestone and sandstone levels are interpreted as distal tempestites associated to storm episodes (Aigner, 1985). During storm episodes powerful return currents produce the offshore resedimentation of muddy and sandy sediment from littoral to the distal parts of the carbonate ramp.

Discussion: sedimentary evolution and controlling factors

The described facies associations allow the interpretation of a carbonate ramp system affected by storms for the Artoles Fm. Within this model, mixed terrigenous-carbonate lagoon facies association characterizes the restricted inner ramp areas, and the proximal and distal parts of the middle ramp are characterized by marlstones with interbedded sandstones with HCS and distal tempestites, respectively. The inner ramp high-energy facies belt protecting the lagoon was not recorded in the studied succession.

The vertical evolution of facies associations in the Camino de Miravete section allows us to define three sedimentary stages for the Artoles Fm (Fig. 2). Stage I is represented by a restricted mixed terrigenous-carbonate lagoon with a local intercalated flood-tidal delta deposit. This stage is in sedimentary continuity with the barrier-island system defined by Navarrete *et al.* (2013) for the uppermost part of the Camarillas Fm (the transition interval between the Camarillas and Artoles formations), thus defining a general progradational trend. This evolution is also shown by the progradation of inner lagoon facies on back-barrier lagoon fa-

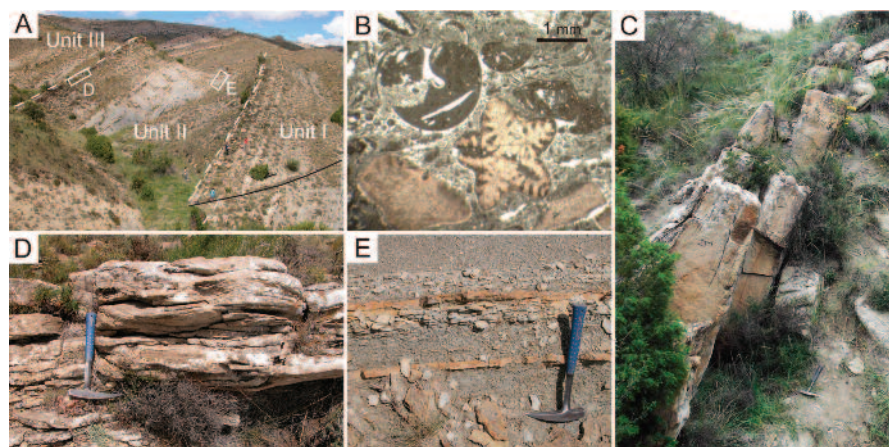


Fig. 3.- A) Field view of the Artoles Fm at the Camino de Miravete Section. **B)** Thin section showing a packstone of echinoderms, benthic foraminifera (*Choffatella* and miliolids), gastropods and ostreids of the mixed terrigenous-carbonate lagoon facies association in Unit III. **C)** Field view of the flood-tidal delta facies association. **D)** Sandstone bed with hummocky cross-stratification. **E)** Field view of distal tempestites.

Fig. 3.- A) Imagen de campo de la Fm. Artoles en el perfil Camino Miravete. *B)* Lámina delgada de un packstone con equinodermos, foraminíferos bentónicos (*Choffatella* y miliólidos), gasterópodos y ostreidos de la asociación de facies de lagoon mixto terrígeno-carbonatado en la Unidad III. *C)* Aspecto de campo de la asociación de facies de delta de flujo. *D)* Arenisca con estratificación cruzada hummocky. *E)* Aspecto de campo de tempestitas distales.

cies. Stage II begins with a net deepening of the carbonate ramp system, which produces a superimposition of distal middle ramp deposits over inner ramp lagoon facies, and evolves from distal to proximal middle ramp sub-environments. Stage III represents the sharp progradation of inner ramp facies (high-energy facies related to the barrier-island system have been not recorded) with the establishment of a new carbonate lagoon, which was better connected to the open sea than the developed during the stage I. This third stage ended with a sharp increase of detrital input (mainly red clays), which characterizes the base of the Morella Fm.

In relation with the origin of the abrupt deepening from lagoon to distal middle ramp facies between stages I and II, and the sharp progradation of lagoon facies over middle ramp deposits between stages II and III, allocyclic factors such as eustasy and/or extensional tectonics can be envisaged. Regarding to eustasy, eustatic cycles have been described during the Late Barremian (Haq, 2014). They might be tentatively correlated to both the first and second stages, but there are not enough biostratigraphical or chronological data to constrain such interpretation. As regard to tectonics, the activity on major faults controlling the Galve sub-basin structure during Barremian rifting (e.g., Soria, 1997; Liesa *et al.*, 2004) could cause the general subsidence of the basin

floor and its consequent deepening. Further studies at basin scale should be carried out to interpret the origin of this sharp deepening.

Conclusions

The study of the Barremian Artoles Fm. at the Camino de Miravete section (Galve sub-basin) has allowed to distinguish four facies associations characterizing different sub-environments within a carbonate ramp affected by storms: mixed terrigenous-carbonate lagoon, flood-tidal delta and proximal and distal middle ramp.

The sedimentary evolution of the Artoles Fm is characterized by three successive stages: restricted mixed terrigenous-carbonate lagoon (stage I), abrupt deepening to distal middle ramp sub-environment and progressive progradation of the proximal middle ramp (stage II), and the installation of another carbonate lagoon system with good connection with the open sea (stage III). Late Barremian global eustatic variations and/or extensional tectonics related to rifting in Galve sub-basin could be responsible for the abrupt deepening described between stages I and II.

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