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Evidence of a Cenomanian shallow-marine carbonate platform in the northwestern margin of the Bortziriak-Cinco Villas massif, eastern Basque-Cantabrian Basin

Evidencia de una plataforma carbonatada marina somera de edad Cenomaniense en el margen noroeste del Macizo de Bortziriak-Cinco Villas, este de la Cuenca Vasco-Cantábrica

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ABSTRACT

Basin margin evolution of rift basins is not always well constrained. In the northeastern margin of the Basque-Cantabrian Basin, a revision of a carbonate succession permits deciphering the transition from syn- to post-rift phases in the poorly studied northwestern margin of the Bortziriak-Cinco Villas massif. The sedimentological analysis shows three main lithofacies, attributed to a shallow-marine, non-rimmed carbonate platform. On the other hand, biostratigraphic analysis based on the presence of Caprina adversa *rudist indicates a Cenomanian age for the succession. Thus, this study illustrates the existence of a Cenomanian shallow-marine carbonate platform unconformably overlying the Palaeozoic massif. This platform development was the result of a generalized transgression during the early post-rift stage.*

Key-words: *Cenomanian, Basque-Cantabrian Basin, Caprina adversa, transgression, post-rift.*

RESUMEN

La evolución de las cuencas tipo rift en sus márgenes no siempre está bien acotada. En el margen noreste de la Cuenca Vasco-Cantábrica, la revisión de un afloramiento de una sucesión carbonatada ha permitido interpretar la transición entre las fases sin y postrift del escasamente estudiado margen noroeste del macizo paleozoico de Bortziriak-Cinco Villas. El análisis sedimentológico muestra la presencia de tres litofacies atribuidas a una plataforma marina somera sin resalte. La presencia de Caprina adversa *indica una edad Cenomaniense para la sucesión estudiada. Dicha plataforma se dispone de forma discordante sobre el macizo paleozoico. Se confirma que el desarrollo de la plataforma fue el resultado de una transgresión generalizada acontecida durante el inicio de la etapa post-rift.*

Palabras clave: *Cenomaniense, Cuenca Vasco-Cantábrica, Caprina adversa, transgresión, post-rift.*

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Introduction

Deep marine environments extended during the Late Cretaceous post-rift phase in the Basque-Cantabrian Basin (BCB). According to Martín-Chivelet and Floquet (2019), basin subsidence and transgression of marine facies was generalized due to thermal subsidence of the asthenosphere and eustatic sea level changes. In the northeastern BCB, syn-rift coastal and shallow marine environments of late Albian to early Cenomanian age evolved within a few million years into deep basin settings. Nevertheless, this relatively abrupt transition (Bodego *et al*., 2023) and coetaneous shallow marine facies distribution is not clearly recorded in the northeastern BCB margin.

The northwest margin of the Palaeozoic Bortziriak-Cinco Villas massif preserves Upper Cretaceous outcrops that are key to comprehend the geological evolution of the northeastern BCB margin. Based on lithofacies analysis and biostratigraphic revision, the aim of this work is to clarify the transition from syn-rift to post-rift in the northwest margin of the Palaeozoic Bortziriak-Cinco Villas massif.

Geological setting

The study area represents the northeastern margin of the Mesozoic Basque-Cantabrian hyperextended rift basin (e.g. Roca et al., 2011), to the northwest of the Palaeozoic Bortziriak-Cinco Villas massif (Fig. 1A). The basin underwent several rifting phases (Triassic, Jurassic and Lower Cretaceous) during which thick successions of marine to coastal sediments were deposited (*e.g.* EVE, 1992; Bodego *et al*., 2015). Controlled by those rifting pulses, subsiding blocks underwent episodic subaerial exposure periods until the early late Albian. Thereafter, coastal to marine environments covered the area (upper Albian-lower Cenomanian Oiartzun Fm; EVE, 1990). Subsequently, due to the widespread Late Cretaceous marine transgression, deep marine carbonates dominated, although local outcrops evidence the existence of shallow marine carbonates (*e.g.* Feuillée and Sigal, 1965)

The studied outcrop is located on top of the southern hanging-wall of the tectonically inverted E-W Ereñozu-Ari-

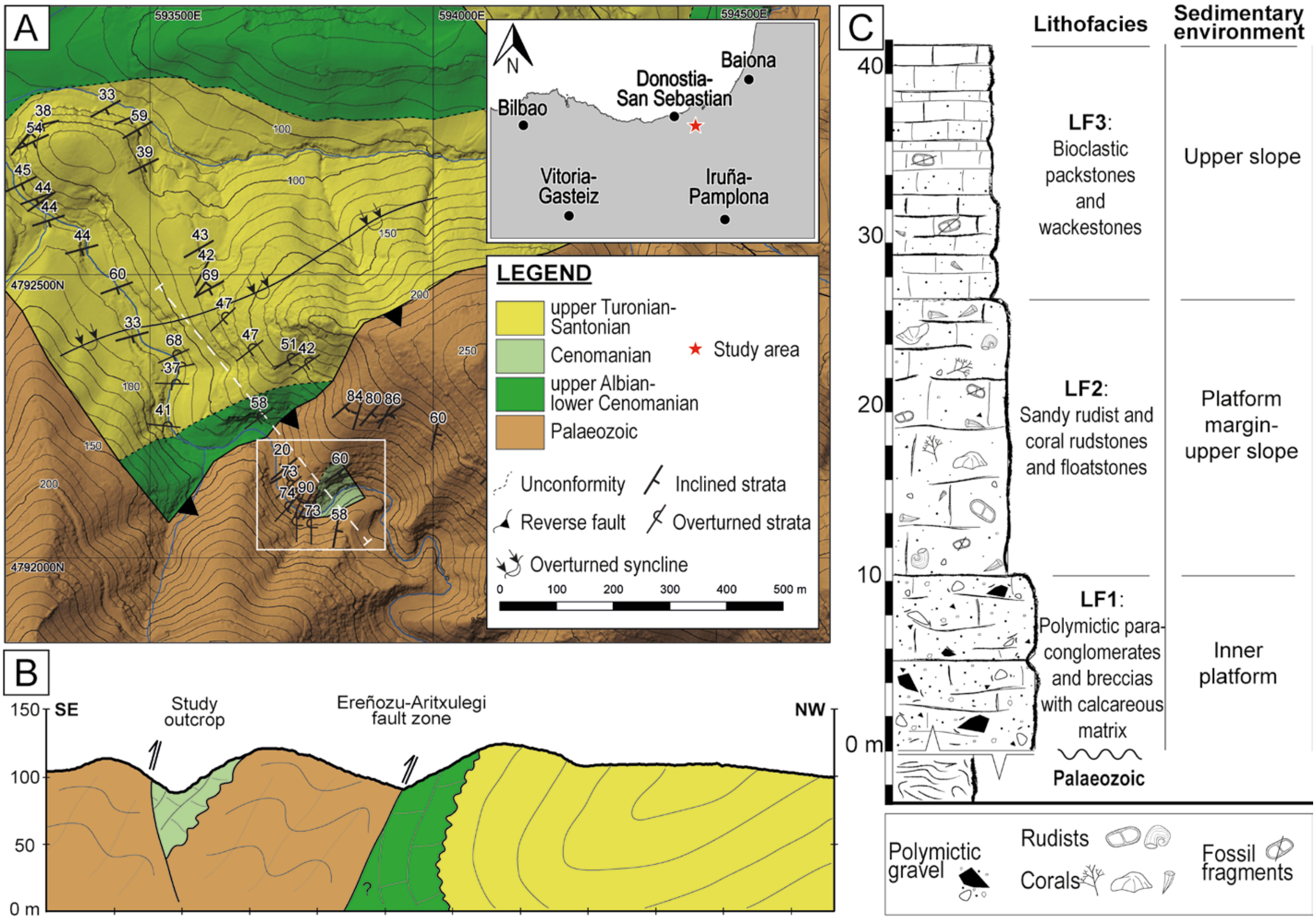

Fig. 1.- A) Location of the study area and the detailed geological map (study outcrop is delimited by a white box). B) Schematic cross section in a SE-NW direction (its location is indicated by the white dashed line in A). C) Stratigraphic log of the study outcrop. It highlights the different lithofacies together with the interpretation of the sedimentary environment and its assumed stratigraphic relationship with the Palaeozoic. See figure in colour in the web.

Fig. 1.-A) Localización de la zona de estudio y mapa geológico detallado (el cuadro blanco delimita la sección estudiada). B) Sección esquemática en dirección SE-NO. Nótese el trazado de la sección en el mapa detallado. C) Columna estratigráfica del afloramiento estudiado. En él se destacan las distintas litofacies junto a la interpretación del ambiente sedimentario y su relación estratigráfica supuesta con el Paleozoico. Ver figura en color en la web.

txulegi basement fault (Figs. 1A and B). The outcrop shows Cretaceous red carbonates overlying folded Carboniferous sandstones and shales (Culm facies) and it is limited by small-scale faults, disconnected from other Cretaceous outcrops. The carbonate succession is around 40 m thick and displays a high diagenetic imprint showing abundant post-depositional recrystallization textures, veins, diagenetic breccias and stylolites.

Facies analysis

Three lithofacies (LF1, LF2 and LF3) have been differentiated based on depositional textures (Fig. 1C):

LF1. Polymictic paraconglomerates and breccias

Lithofacies 1 crops out at the base of the succession and it is 10 m thick (Fig. 1C). It is made up of massive, poorly sorted, calcareous matrix-supported polymictic conglomerates and breccias (Fig. 2A). Grain size varies from very coarse sand to cobble, and locally, quartz sand is very abundant. Quartz grains are mono- and polycrystalline. Both types are rounded, but the seconds are more angular when they have siliceous overgrowths, which are presumably inherited. Planar-elongated gravels occasionally present horizontal alignment (bedding). Extraclasts are made up of: 1) Carboniferous black and green angular to sub-angular sandstone, shale, slate and schist (Culm facies); 2) Permo-Triassic red quartzarenite and siltstone (Buntsandstein facies); and 3) well rounded quartzite fragments (Buntsandstein facies). Carbonate matrix is strongly recrystallized, and it is largely composed by echinoderm plates, rudist fragments, peloids and cortoids besides carbonate mud (Fig. 1C).

The poor sorting and low roundness of the polygenic extraclasts, along with local horizontal bedding, suggests short and tractive sedimentary transport. The absence of clear sedimentary structures within the carbonate matrix (*e.g* cross lamination) is attributed to post-depositional diagenetic processes. Therefore, the existence of such primary structures cannot be ruled out. Thus, the input of the detrital coarse-sized material is attributed to energetic currents directly entering into a shallow marine platform environment.

LF2. Sandy rudstones and floatstones

Above the LF1 lies a 15 m thick limestone succession composed of massive, sandy, rudist and coral rudstone and floatstones (Figs. 1C and 2B). The transition from LF1 to LF2 is gradual. Bioclasts are composed of fragments and whole fossils of corals (branching, massive and solitary scleractinians) and bivalve rudist shells (caprinids) up to 20 cm in width (Fig. 2B). Locally, isolated polymictic gravel-size extraclasts, mostly rounded quartzite and sandstone, are present. Matrix consists of very-coarse, mixed, calcareous (70-90%) and siliciclastic (10-30%) sand. The carbonate sand is mainly made of echinoderm plates, calcareous skeletal rounded to sub-angular fragments, coralline red algae, bryozoans, gastropods, miliolids, orbitolinids, peloids and cortoids. The nature of the siliciclastic sand is similar to that of LF1.

The presence of caprinid and coral rubble points to relatively energetic shallow marine conditions. In addition, the presence of scarce extraclasts and sand-size quartz grains within the carbonate sand suggests the transport of siliciclastic sediment from more proximal environments (inner platform?). Therefore, this lithofacies indicates a relatively high energetic shallow marine carbonate dominated environment and implies the existence of adjacent rudist bioherms and reef-building corals.

LF3. Bioclastic wackestone-packstone

LF2 changes gradually to a 10 to 15 m thick bioclastic wackestone-packstone limestone (Figs. 1C and 2C). The grains, clasts and fossil fragments are relatively well sorted. They consist of medium to coarse grain-size, very well rounded, rudist and coral fragments (Fig. 2C), echinoderm plates, miliolids, orbitolinids, peloids and cortoids. Borings are common on shell fragments. Siliciclastic fraction is less than 20% and it is mostly made up by fine to medium size, mono- and polycrystalline quartz grains.

The bioclastic components suggest the deposition of this lithofacies under low to moderate energy conditions, below the wave abrasion zone (Fig. 2C) but above storm wave base level, allowing periodical energetic remobilization of the mixed carbonate and detrital sand. The absence of gravels and the relatively low proportion of siliciclastic grains corroborates its deposition further from the coastline, where currents supplied sand-sized quartz grains into this depositional environment.

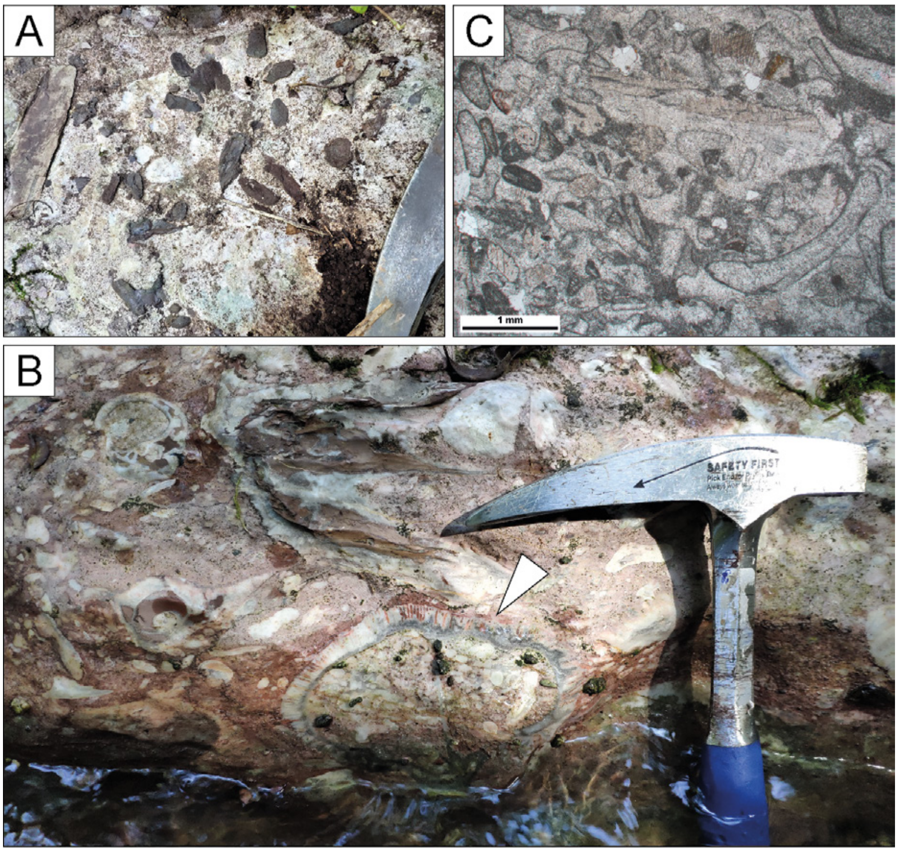

Fig. 2.- A) Field picture of LF1. Note the angular dark coloured rock fragments "floating" in a whitish calcareous matrix. B) Field example of a red coloured limestone with several fossils and calcareous fragments (LF2). Note the transverse section of Caprina adversa (white arrow) and the multiple sections of other rudists (Ichthyosarcolites?) and corals. C) Bioclastic packstone (LF3) PPL microphotograph. See figure in colour in the web.

Fig. 3.- A) Imagen de LF1 en campo. Nótese los fragmentos oscuros y angulosos "flotando" en la matriz blanquecina calcárea. B) Ejemplo de una caliza de color roja con gran variedad de fósiles y fragmentos calcáreos. Nótese una sección transversal de Caprina adversa y las múltiples secciones de otros rudistas (Ichthyosarcolites?) y corales. C) Microfotografía PPL de LF3. Ver figura en color en la web.

Biostratigraphy

The fossil content of the succession is very diverse. In particular, there are well-preserved sections of *Caprina adversa* d'Orbigny, 1822 (Fig. 2B). Transverse, oblique and longitudinal sections of complete left valves are widely present (Fig. 2B). Sections are elliptical in shape and elongated anteroposteriorly, with the two characteristic cavities corresponding to the body cavity and the posterior myophoric cavity, separated by a thin wall. Around the inner shell layer, there are numerous thin and pyriform paleal canals, which locally bifurcate. In a similar way, transverse sections of incomplete right valves are common too. In them, a distinction is made between the body cavity and the posterior accessory cavity, which forms a row of rectangular canals in sections far from the commissure.

Similarly, partial sections of *Ichthyosarcolites* genus have been found, as well as other unidentified Polyconitidae rudists (Fig. 2B).

This rudist assemblage is representative of the Cenomanian, being *Caprina adversa* the species of *Caprina* genus, which is characteristic of that age (Troya, 2016).

Depositional model and discussion

LF1 is interpreted as inner shelf deposits (Fig. 1C) where occasional wave, storm and currents reworked and winnowed the sedimentary substrate. The presence of gravel- and sand-size extraclasts in the sediment indicates episodic continental inputs, probably derived from subaerial domains during flood events. These may be attributed to fan deltas or wadi channels penetrating into the inner carbonate platform. Nevertheless, the absence of channel geometries does not rule out the possibility of the existence of coastal cliffs, which could derive the clastic material directly into the platform.

LF2 is attributed to a margin to upper slope environment (Fig. 1C), with organic build-ups (rudist and coral bioherms). The occurrence of *Caprina adversa* and coarse skeletal debris (matrix), suggests an energetic environment with constant wave and/or current action. The presence of rudist and coral rudstones and floatstones indicates periodic storm activity.

Finally, LF3 is attributed to an upper slope environment (Fig. 1C), where finer skeletal grains were transported from energetic zones and deposited under less energetic conditions, where they were bioturbated. However, episodic storms would rework the sediments, mixing them with skeletal debris from the margin.

The gradual decrease in siliciclastic content resulting in an upward-deepening trend also supports the development of more distal environments towards the upper part of the succession.

Although the outcrop is limited and it has no lateral continuity, based on the presented data and the proximity of coetaneous flysch deposits towards the west in basinal areas (Bodego *et al*., 2015), it must be suggested a quite steep and narrow facies belt distribution from proximal to distal depositional settings. Thus, the studied lithofacies association can represent the development of a relatively narrow non-rimmed carbonate platform in the northwest margin of the Bortziriak-Cinco Villas massif during the generalized Cenomanian transgression registered in the area (Bodego *et al*., 2023) and in other parts of the BCB (*e.g.* López-Horgue *et al*., 2014). Drzewiecki and Simo (2000) suggested the development of carbonate platforms of similar characteristics in other parts of the Pyrenees for the Cenomanian and Turonian.

The described succession was previously ascribed to the upper Albian-lower Cenomanian Oiartzun Fm (EVE, 1992; Bodego *et al*., 2015, 2019). However, Cenomanian *Caprina adversa* is not present in the limestones included in the Oiartzun Fm (*e.g.* EVE, 1992; Bodego *et a*l., 2015, 2019). Besides that, limestones of the Oiartzun braidplain depositional system were interfingered with alternating conglomerates, sandstones and mudstones related to coastal environments, which are not observed in this study and were restricted to specific areas (palaeohighs), away from the input of siliciclastic material. Moreover, although the stratigraphic contact with respect to older Palaeozoic materials is not visible, stratigraphic and sedimentological evidences suggest that the studied carbonates lie unconformably on top of Palaeozoic rocks. This outcrop represents the easternmost Urgonian facies of the area, which are spatially disconnected to the other mapped Oiartzun Fm outcrops (EVE, 1992; Bodego *et al*., 2015, 2019). Based on the biostratigraphy and its location, we interpret that these carbonates are part of a younger lithostratigraphic unit (middle to late Cenomanian? in age) rather than being part of the Oiartzun Fm. Hence, it is now correlated with the Sara Limestone unit, which is described in the eastern adjacent Sara-Vera basin (Floquet *et al*., 1988; Razin, 1989)

Conclusions

It has been carried out the sedimentological and biostratigraphic study of a carbonate succession on top of the Palaeozoic Bortziriak-Cinco Villas massif, in the norheastern margin of the BCB. The presence of *Caprina adversa* indicates a Cenomanian age. The three lithofacies identified (LF1, LF2 and LF3) reflect a fining- and deepening-upward trend resulted from the development of a shallow-marine non-rimmed carbonate platform. This platform represents a younger lithostratigraphic unit (Sara Limestone unit) than the previously ascribed Oiartzun Fm, indicating its formation during the Cenomanian transgression overlaying unconformably the northwest margin of the Bortziriak-Cinco Villas Palaeozoic massif.

Author contributions

Ladron de Guevara: conceptualization, coordination, fieldwork, investigation, writing and visualization. Bodego: conceptualization, supervision, fieldwork, writing, editing and funding acquisition. Troya: palaeontologic analysis, writing and editing. Damas-Mollá: fieldwork, palaeontologic analysis and editing. Aranburu: conceptualization, supervision and editing. Iriarte: fieldwork, supervision and editing.

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