Tectonic and environmental controls on platform geometry and facies architecture: The late Aptian-early Albian carbonate episode of the Castro Urdiales platform margin (Cantabria, northern Spain)

Controles tectónicos y ambientales en la arquitectura de facies y geometría deposicional del episodio carbonatado Aptiense superior-Albiense inferior del margen de Castro Urdiales (Cantabria)

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RESUMEN

El episodio carbonatado Aptiense superior-Albiense inferior (Zonas jacobi-tardefurcata) del margen de plataforma de Castro Urdiales registra un aumento gradual del stress paleoambiental acompañado por cambios en el estilo y geometría de la plataforma carbonatada, que precedieron a un episodio de rifting que tuvo lugar durante el Albiense inferior. Este estudio sugiere que los cambios en la geometría de la plataforma carbonatada respondieron principalmente a cambios en factores paleoceanográficos y niveles tróficos que acompañaron a una etapa de hundimento general de la cuenca y aceleración de la subsidencia justo antes del episodio de rift.

Key words: *Late Aptian-Early Albian, Basque-Cantabrian Basin, carbonate platform-ramp evolution, palaeoenvironmental stress.*

Geogaceta, 30 (2001), 135-138
ISSN:0213683X

Introduction

The Aptian-Albian carbonate episode («Urgonian») of the Basque Cantabrian Basin (BCB, Fig. 1A) developed in an active extensional setting associated to the late stages of the Bay of Biscay Rifting. With strong differential subsidence related to active fault blocks, the resulting stratigraphic and palaeogeographic picture was a highly complicated mosaic of different coexisting facies and environments. In the central basin area (Fig. 1B) depositional facies broadly include alluvial plain and fluvial deposits to the south, that passed northward into mixed transitional environments (coastal plain) and finally into carbonate platforms and associated slope deposits, with a central deeper embayment around the Bilbao area (Fig. 1B). Carbonate platforms formed on zones of relatively low subsidence and on top of tilted blocks. They was separated by intervening tectonically-controlled troughs which trapped shallow siliciclastic sediments from the southern source areas and acted as conduits for fine

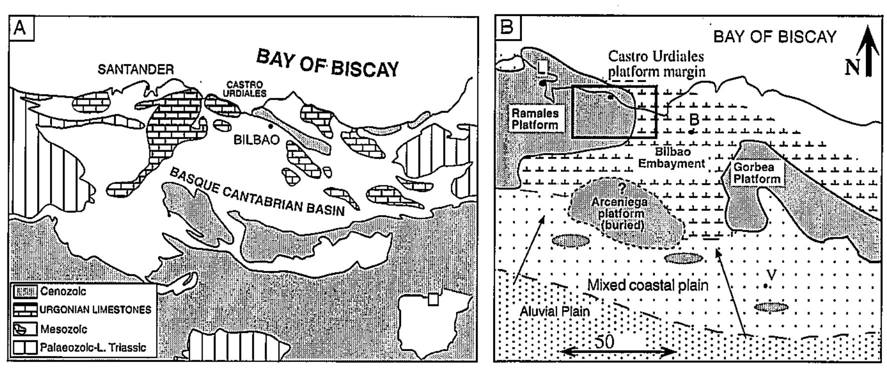

Fig.1.- (A) Simplified geological map of the Basque-Cantabrian Basin (BCB) showing the location of the main Urgonian carbonate platform outcrops. (B) Simplified palaeogeographic reconstruction of the central part of the BCB for earliest Albian times, with indication of the studied area. L, Laredo; B, Bilbao; V, Vitoria.

Fig. 1.- (A) Mapa geológico simplificado de la Cuenca Vasco Cantábrica mostrando la localización de los afloramientos principales de calizas urgonianas. (B) Reconstrucción paleogeográfica de la zona central de la Cuenca Vasco Cantábrica para la parte basal del Albiense inferior, indicando el área de estudio. L, Laredo; B, Bilbao; V, Vitoria.

siliciclastic sediments that actively fed the Bilbao basin, along with carbonate material shed from the carbonate factories (Fig. 1B).

The Aptian-Albian succession of the Castro Urdiales area records the evolution of one of these carbonate platforms. The area crops out along the Cantabrian coast, between Laredo and Bilbao and formed the eastern margin of

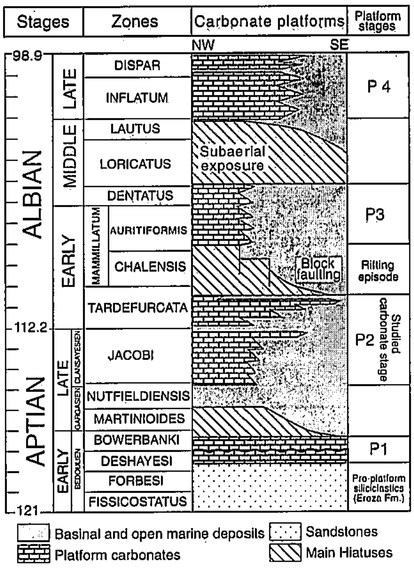

Fig. 2.- Stratigraphic distribution of carbonate platform episodes and main hiatuses/ unconformities in the Castro Urdiales platform margin. Modified after Rosales (1999).

Fig. 2.- Distribución estratigráfica de los principales episodios de sedimentación carbonatada y discontinuidades para el margen de plataforma de Castro Urdiales.

the larger Ramales platform (Fig. 1B). Within these platform carbonates four major stages of carbonate platform development has been differentiated (Rosales, 1999): 1) Early Aptian, 2) Late Aptian-Earliest Albian, 3) Early Albian, and 4) Late Albian. Their stratigraphic distribution has been illustrated on Fig. 2. These stacked major platform limestone sequences are vertically separated by three regional unconformities, and may be internally subdivided into smaller depositional sequences.

The second stage in the evolution of the Castro Urdiales platform margin (Late Aptian-Earliest Albian) developed during a period of relatively low tectonic activity before the ocurrence of a major tectonic rifting pulse. The age of the rifting event is assigned to the early Albian *regularis* Subzone of the *tardefurcata* Zone (Rosales, 1995, 1999). Internally, this carbonate stage recorded several contrasting platform geometries and internal facies assemblages. However general mechanism to explain these internal changes are still poorly understood. The purpose of this paper is to asses the role played by the interplay between regional tectonism and environmental factors in the control on depositional facies and geometry of these platform carbonates.

Platform substages: types and geometries

The age of this carbonate episode is well constrained as late Aptian-earliest Albian, *jacobi-tardefurcata* Zones, with benthic foraminifers and ammonites (Rosales, 1995, 1999). The basal datum is marked by an underlying argillaceous, glauconitic oyster-rich carbonate bed which approximates an isochronous horizon (middle Aptian incipient drowning event, Rosales, 1999). The top boundary is marked by a well-defined unconformity related to extensional synsedimentary tectonic movements with formation of tilted blocks. Based on internal facies patterns and platform geometries, this platform stage can be subdivided into four different platform sub-stages (A to D, Fig. 3). Boundaries between platform substages are represented by erosional surfaces or abrupt changes of facies. Platform evolved from a prograding rimmed platform (substage A) to a aggradational ramp (substage B), followed by a distally steepened, progradational offlapping ramp (substage C), and finally to a backstepped rimmed platform (substage D).

Substage A: Prograding rimmed platform

The age of this platform stage, determined with ammonites, correspond to the late Aptian *jacobi* Zone (Rosales, 1999). Thicknesses range from 75-100 m on the platform to 180-300 m on the slope and basinal areas. Sedimentary facies can be grouped from west to east into inner-platform, platform margin, platform-slope and basinal facies (Fig. 3). **Inner-platform** facies are characterized by rudist, chondrodontid and miliolid wackestones, with only minor skeletal and coral packstones and grainstones. **Platform margin** facies are composed of coral/rudist boundstone with marly to micritic inter-coral matrix. This facies formed the core of lenticular mounds and buildups, few metres to 20 m high, that rimmed the platform. The **platform slope** facies consist of massive to laminate skeletal grainstones forming a terminal limestone tongue that may reaches more than 2 km into the basin. Finally, **basinal** facies consists of dark laminated marls and lutites. The end of this carbonate substage is marked in the platform areas by an interval 15-20 m thick of argillaceous limestones with oyster beds, that sharply overlie the shallow water limestones, suggesting incipient drowning. Basinward, this boundary is represented by a sharp lithological change from dark marls and shales to hemipelagic, spiculite marly limestones.

Substage B: Aggradational ramp

Thickness during this interval (earliest Albian, *tardefurcata* Zone) range from 65 m in the western shallow ramp areas to more than 220 m toward the eastern and southeastern deeper ramp areas. This ramp substage shows three major depositional environments: inner (shallow) ramp, mid (outer) ramp and distal (deep) ramp (Fig. 3). The **inner ramp** is characterized by relative low to moderate energy facies with rudist assemblages. They involve rudist and chondrodontid wackestone, skeletal-coral packstone and coral patch reefs. The **mid-ramp** environments are represented by disperse coral mounds and fine-grained skeletal and orbitolinid packstone. Bioclasts are mainly benthic foraminifera and fragments of rudists, bivalves, echinoids, oysters, brachiopods and sponges. Isolated tabular corals may be found colonizing the substrate. Coral mounds are meter-scaled and lenticular-shaped, with mud-supported frameworks. Basinward, **distal ramp** deposits are characterized by hemipelagic limestones rich in sponge spicules (25 to 50%). They consist of alternating decimetric layers (up to 60 cm) of fine-grained spiculitic wackestones and marls. Limestones are dark, organic-rich and well-bedded, locally with nodular fabric. Macrofossils include echinoids, sponges and ammonites. Bioturbation is very important mainly as *Chondrites* and few horizontal burrows. Biogenic silica, preserved as chert, is also common. Occasionally, limestone beds may show skeletal layers with erosive bottoms and parallel to wavy lamination, indicating deposition from sporadic, probably storm-generated distal density currents. Facies and sedimentary structures in the distal ramp are indicative of deposition in an open marine environment, below the zone of storm wave reworking.

Substage C: Progradational offlapping, distally steepened ramp

Thickness during this interval range from 350 m in the shallow ramp, to less than 150 m in the distal ramp and proximal basin. **Inner ramp** facies are exposed to the NW of the study area (Oriñón sector). Facies consist of well-bedded, 1-10 m thick, coarse to fine-grained packs-

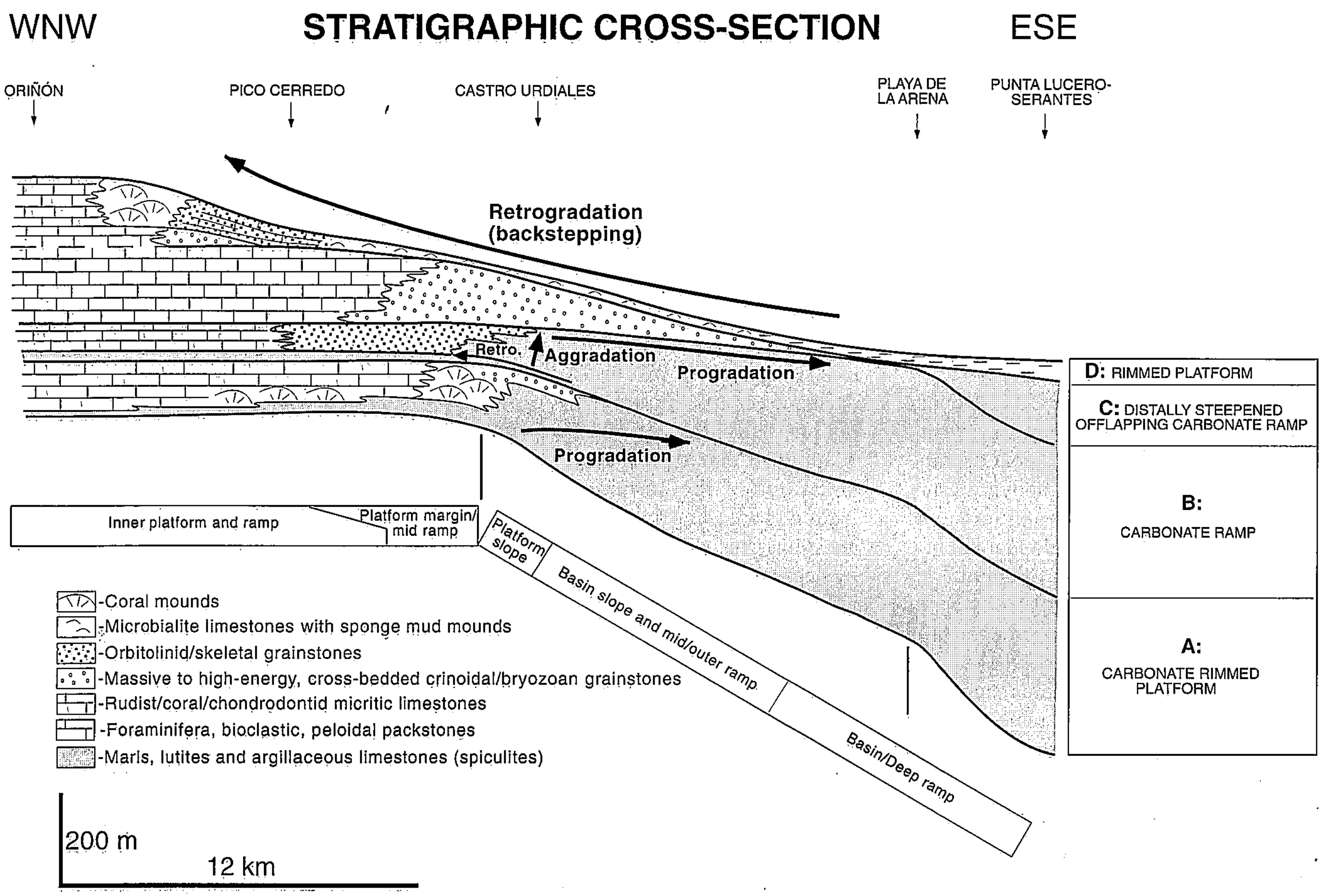

Fig. 3.- Restored shallow to deeper-water stratigraphic cross-section of the late Aptian-earliest Albian carbonate episode of the Castro Urdiales platform margin showing depositional facies and geometrical relationships between the four platform substages (A to D).

Fig. 3.- Corte estratigráfico plataforma-cuenca del sistema carbonatado del Aptiense superior-Albiense inferior. El corte muestra las distintas relaciones geométricas y facies deposicionales entre los 4 subsistemas de plataforma (A-D) desarrollados.

tone and grainstone with miliolids, small benthic foraminifera, orbitolinids and fragments of crinoids, bryozoans and rudists, along with other molluscs and coral debris. Coral patch reefs are also common in this environment. They consist of massive-bedded coral boundstone that grade laterally and vertically into the bioclastic facies. These facies deposited in a high to moderate energy, shallow subtidal environment. **Mid-ramp** facies consist of actively progradational subtidal grainstone shoals that form an extensive fringing ramp complex. The shoals are made up of megarippled and rippled, cross-bedded skeletal grainstone and rudstone, arranged into heterometric cross-sets up to 2 m thick. Palaeocurrent data obtained from trough cross-bedding and ripple cross-lamination show a predominate palaeoflow to the ESE, although the presence of some SW-directed paleocurrents and herringbone structures indicate reversal of flow directions at times. Grain types are dominated by debris of crinoids, bryozoans and bivalves. Minor components are brachiopods and algae fragments, intraclasts and peloids. This facies was deposited in an active, high-energy, open marine environment. Carbonate grains were shed from the platform by storms and currents and accumulated basinward, caused the rapid progradation of the mid ramp. The thickness of this facies belt gradually decrease basinward from 150 to 1 m (Fig. 3), and then it rapidly grade downdip into the deeper-water distal ramp deposits. Normal faults at depth in the area of Playa de la Arena (Fig. 3) probably steepened the distal ramp, separating a shallow-water, inner to mid ramp to the northwest from deeper water carbonates and resedimented deposits to the east (Punta Lucero-Serantes, Fig. 3). The slope area between these two domains is characterized by argillaceous hemipelagic limestones and marls with small meter-scale gullies. Gullies are filled by coarse-grained skeletal grainstones and were the result of bypassing currents that carried sediments from the mid ramp into the distal ramp. Distal ramp deposits mainly consists of fine-grained calcarenites and graded calcareous turbidites with some intercalated resedimented deposits, including slumps and intraformational calcarenite breccias. These materials are interpreted as the result of slope instabilities related to the distal steepening of the ramp.

Substage D: Backstepped, aggradational rimmed platform

During the last substage the previous carbonate ramp evolved into a rimmed platform, with rapid platform backstepping (Fig. 3). Accommodation space rapidly increased and relatively deeper water conditions covered the majority of the platform area causing an incipient drowning. Low energy, micritic and muddy facies characterized this episode. Shallow-water carbonates retrograded to the more proximal areas located to the northwest (Oriñón sector), where platform sedimentation was able to keep pace with the relative sea-level rise. **In-**

ner platform facies during this substage consists of metric-bedded rudist, orbitolinid, chondrodontid and coral wackestone with intercalated rudist biostromes and coral patch reefs. A rimmed platform margin developed between the inner platform and the slope deposits (Fig. 3). The **platform margin** facies are composed of low-energy coral-algae mud mounds, up to 20 m high, stacked in an ascending progradational pattern. Foreslope clinoform angles up to 20° gradually decrease downdip, grading to the subparalleled-bedded upper slope deposits. The **upper slope** facies are composed of well-bedded, bioturbated, fine to coarse-grained calcarenites with chert nodules. Carbonate grains are mainly peloids and fragments of molluscs, equinoderms, bryozoans and small benthic foraminifera. In the space between the upper slope and the basin a broad lower slope depositional system took the position of the former mid-ramp during the previous substage (Fig. 3). The **lower slope** facies (deep-shelf) consists of lithistid sponge mud-mounds and well-bedded inter-mound microbialite limestones containing abundant sponge debris and other skeletal fragments as crinoids, bryozoans, sponge spicules and planktonic foraminifera, in a peloidal micrite matrix. Lower slope facies gradually change downdip into marly **basinal** deposits.

Discussion

The studied late Aptian-early Albian carbonate episode was internally formed by 4 stacked carbonate sub-stages separated by abrupt changes in platform-margin geometries. Accompanying these changes, platform fringing depositional facies also showed a shift from rudist/coral dominance during the first two substages to a crinoidal/bryozoan dominance in the third substage and finally to mud-dominated sponge-rich lithologies with microbialites in the later substage, prior the tectonic breakup and collapse of the platform during the early Albian rifting episode. These benthic faunas were probably adapted to mesotrophic to eutrophic environmental conditions, reflecting an «unhealthy» mode of carbonate production. Environmental stress affected mainly to the reefal platform communities, causing a decrease in carbonate productivity, now dominated by carbonate sands (substage C). Physical sedimentary processes (tidal-, storm-, wind-induced traction currents) actively transported these carbonate sands from shoreface to offshore, forming non-regressive offlapping progradational sand bodies. This progradation of the platform margin was not accompanied by regression or subaerial exposure in the inner ramp. Finally, the platform evolved to a rimmed platform (substage D) as a consequence of a tectonically enhanced subsidence pulse, causing incipient drowning and backstepping of the platform margin, now dominated by sponge-microbialite micritic limestones (filter feed benthos adapted to eutrophic conditions). The character of the carbonate platform margin changed again significantly. Low angle marginal slopes (<1°) were replaced by steeper talus (up to 20°), as a result of an increase in differential subsidence between platform and basin realms.

Therefore, changes in the platform style (aggradation-progradation-backstepping) during deposition of the pre-rift late Aptian-early Albian carbonate episode were probably related to a gradual increase in subsidence rates accompanied by changes in trophic levels. The cause of such events may include either: 1) upwelling of eutrophic waters into shallow waters due to palaeoceanographic changes, 2) uplift of nutrient-rich waters by endo-upwelling currents through synsedimentary faults, related to synsedimentary volcanic/hydrothermal vent activity. Volcanic activity of latest Aptian-earliest Albian age has been recently reported in the Basque Cantabrian basin (Fernández-Mendiola and García-Mondéjar, 1995) and was probably associated with times of increased nutrient levels in the basin, causing changes in the sea environment that may have reduced the growth potential of the platforms or caused their demise (Aranburu *et al.*, 1998; Rosales, 1999). High nutrient levels in the bottom waters might may have stressed the marginal coral-algal communities that were replaced by mesotrophic first (crinoidal and bryozoan facies) and later eutrophic communities (large masses of siliceous sponges). But in the shallower parts of the shelf rudist, corals and other tropical benthic communities were able to thrive.

Conclusions

The Late Aptian-Earliest Albian carbonate stage of the Castro Urdiales platform margin recorded an increasing environmental stress along with changes in platform geometry that preceded an early Albian tectonic rifting episode. The platform geometries changed from a prograding rimmed platform (Substage A) to an aggradational ramp (Substage B), later to highly progradational offlapping, distally steepened ramp (Substage C), and finally to a backstepped, aggradational rimmed platform (Substage D). Accompanying changes in platform geometry, depositional facies also showed a shift from «healthy» rudist/coral dominance during the first two substages to a progressively «unhealthy» carbonate production style, recorded by crinoinal/bryozoan dominance during the third substage followed by mud-dominated sponge-rich lithologies with microbialites during the later substage. Environmental stress affected mainly the platform margin reefal communities that were replaced by carbonate sands. Physical sedimentary processes (storm and currents) actively transported the carbonate sands to offshore areas, causing non-regressive phases of carbonate platform progradation. This alternative model proposes that carbonate platform aggradation-progradation-backstepping occurred as a response of a gradual platform drowning caused by a combination of increase in downwarping and fauna response to regional palaeoceanographic and trophic changes (eutrophication).

Acknowledgements

This work was supported by the Research Project UE-1999/8, jointly financed by the Basque Government and Sociedad de Hidrocarburos de Euskadi S.A (SHESA). Research was possible thanks to a postdoctoral (Incorporation) contract supported by the Spanish Ministry of Education (MEC).

References

Aranburu, A. Fernández-Mendiola, P.A., Owen, H.G. and García-Mondéjar, J. (1998): 15th International Sedimentological Congress, I.A.S., Alicante, Spain, Abstract book, 143-144.

Fernández-Mendiola, P.A. and García-Mondéjar, J. (1995): Cretaceous Research, 16, 451-463.

Rosales, I. (1995): Tesis doctoral, Universidad del País Vasco, 496 pp.

Rosales, I. (1999): Journal of Sedimentary Research, 69, 447-465.