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Estudio secuencial de las facies arrecifales de las Formaciones Candás y Portilla (Devónico Medio) de la Zona Cantábrica (NO de España)

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KEY WORDS: **Sequence Stratigraphy, Reefs, Portilla Fm., Candás Fm., Givetian, Cantabrian Zone.**

PALABRAS CLAVE: **Estratigrafía Secuencial, Arrecifes, Fm. Portilla, Fm. Candás, Givetiense, Zona Cantábrica.**

ABSTRACT

The laterally equivalent Portilla and Candás Formations (Givetian-earliest Frasnian), a dominantly carbonate succession with reef-bearing intervals, was deposited in a carbonate ramp setting, zoned into a backreef lagoon, a reef tract and a calcarenite forereef belt distally grading to outer shelf marls and terrigenous mudstones.

Sequential facies analysis of the reef-bearing intervals produced a model of ramp evolution. The succession is arranged in sequences up to several tens of metres thick. Each sequence has a sharp to rapidly transitional base and splits into a lower transgressive subsequence (commonly very thin or absent) and an upper regressive one. Reefs, when present, cap the regressive subsequence. From base to top the idealized reef-bearing sequence consisted of the following facies: i. Coral/stromatoporoid rudstones to floatstones. ii. Bioclastic grainstones to packstones. iii. Dark grey mudstones. iv. Alternations of dark grey mudstones, sandstones and bioclastic limestones. v. Branching/erect-palmate coral bafflestones/laminar coral bindstones. vi. Tabular coral/stromatoporoid bindstones. vii. Coral/stromatoporoid framestones. The top of the sequence is formed either by a sharp surface under the basal rudstone facies (i) of the next sequence or, else, by a thin interval of bafflestone facies (v) grading upwards into mudstone facies (iii).

Facies i is interpreted as trangressive lag and facies ii as bar deposits. The remaining facies reflect a regressive trend from outer ramp (facies iii) to shallow reef under wave action (facies vii). Reef demise is provoked by an abrupt deepening. The magnitude of the transgression and its position in a given sequence accounts for deviations from the idealized sequence described above.

RESUMEN

Las Formaciones Candás y Portilla (Givetiense-Frasniense inferior) son dos unidades lateralmente equivalentes, dominantemente calcáreas y con depósitos arrecifales. Su depósito tuvo lugar en una rampa carbonatada formada por un lagoon protegido por arrecifes que distalmente enlazan con un cinturón calcarenítico que finalmente grada a las margas y lutitas de la plataforma externa.

El análisis secuencial de los intervalos con arrecifes permite establecer un modelo evolutivo de la rampa carbonatada. Las secuencias, de espesor máximo decamétrico y base neta a rápidamente gradual, constan de una subsecuencia inferior transgresiva de escaso a nulo espesor y otra superior regresiva que culmina en los depósitos arrecifales (cuando aparecen). De muro a techo, la secuencia con arrecifes ideal consta de las siguientes facies:

i. Calizas (*rudstone* a *floatstone*) con matriz bioclástica.

ii. Calizas bioclásticas (*grainstone* a *packstone*) en secuencia granodecreciente.

iii. Lutitas a margas arcillosas grises oscuras con tentaculítidos y fragmentos de peces.

iv. Alternancias de lutitas/margas grises oscuras con capas de areniscas laminadas por *ripples* y calizas bioclásticas. La fauna presente (braquiópodos, briozoos, tabulados ramificados y laminares y rugosos ramificados) aparece transportada o *in situ*, formando ocasionalmente pequeños biohermos y biostromos sobre capas bioclásticas.

v. Calizas *bafflestone* (rugosos o tabulados ramificados y tabulados bifaciales) o *bindstone* (tabulados laminares) con matriz bioclástica arcilloso-arenosa.

vi. Calizas *bindstone* (tabulados o estromatopóridos tabulares) con matriz de caliza bioclástica arcillosa progresivamente más pura hacia el techo.

vii. Calizas *framestone* (tabulados masivos y/o estromatopóridos irregulares y rugosos masivos subordinados) con matriz *packstone* a *grainstone* bioclástica.

El límite de secuencia viene dado por una superficie neta bajo la facies i. En ocasiones, sin embargo, está formado por un delgado intervalo de la facies v que grada a la iii.

Las facies i y ii son respectivamente depósitos residuales (*lags*) y de barras, ambos transgresivos. Las restantes facies reflejan una tendencia regresiva desde la rampa externa (facies iii) hasta depósitos de arrecife sobre el nivel de base de ola (facies vii). La finalización del desarrollo arrecifal se debería a una brusca profundización del medio. La magnitud de la transgresión y la posición en la que se observe una secuencia dada son los factores responsables de las desviaciones respecto de la secuencia ideal.

1. INTRODUCTION

The aim of this paper is to tie the sedimentological and paleontological studies of reefs under a sequence stratigraphic framework in the Portilla and Candás Formations. Because of outcrop qualities we have focused our observations on superb coastal exposures of the Candás Formation (Perán-Carranques and Aramar sections; Fig. 1), and have used inland outcrops of both formations as secondary sources (Beberino and Matallana sections; Fig. 1). This paper constitutes a first step in understanding both formations in their outcrop areas and the vertical extent of their reef-bearing and non-reef intervals.

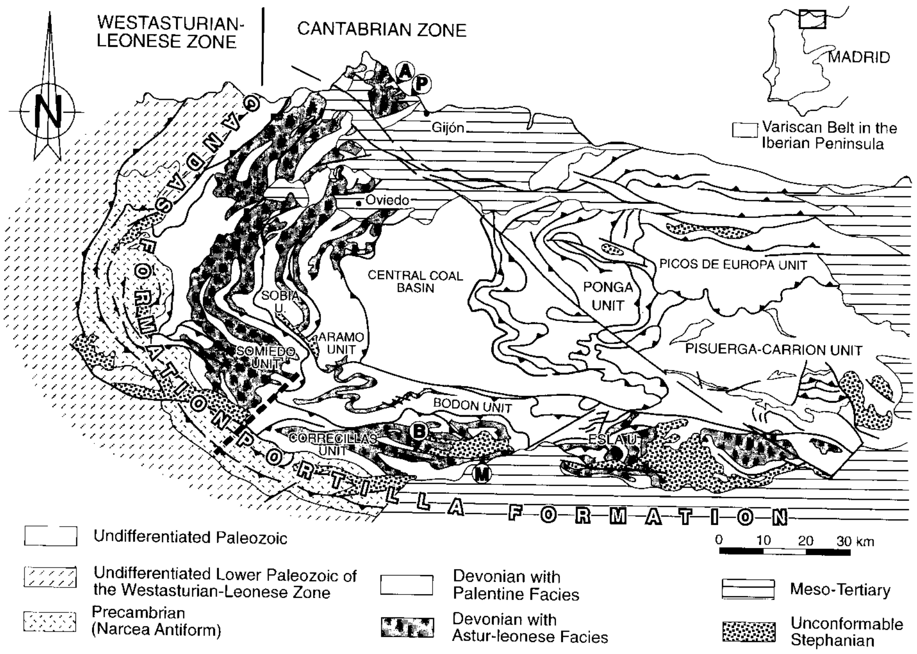

Fig. 1.–Schematic geological map of the Cantabrian Zone (after PÉREZ-ESTAÚN *et al.*, 1988) showing the distribution of Devonian rocks and the lateral extent of the Candás and Portilla Formations within the Somiedo-Correcillas Unit. P: Perán-Carranques section. A: Aramar section. B: Beberino section. M: Matallana section.

–Mapa geológico esquemático de la Zona Cantábrica (tomado de PÉREZ-ESTAÚN *et al.*, 1988) mostrando la distribución de los afloramientos devónicos y la extensión lateral de las Formaciones Candás y Portilla en la Unidad de Somiedo-Correcillas. P: Sección de Perán-Carranques. A: Sección de Aramar. B: Sección de Beberino. M: Sección de Matallana.

The Portilla and Candás Formations form a dominantly carbonate succession that crops out in the Somiedo-Correcillas Unit of

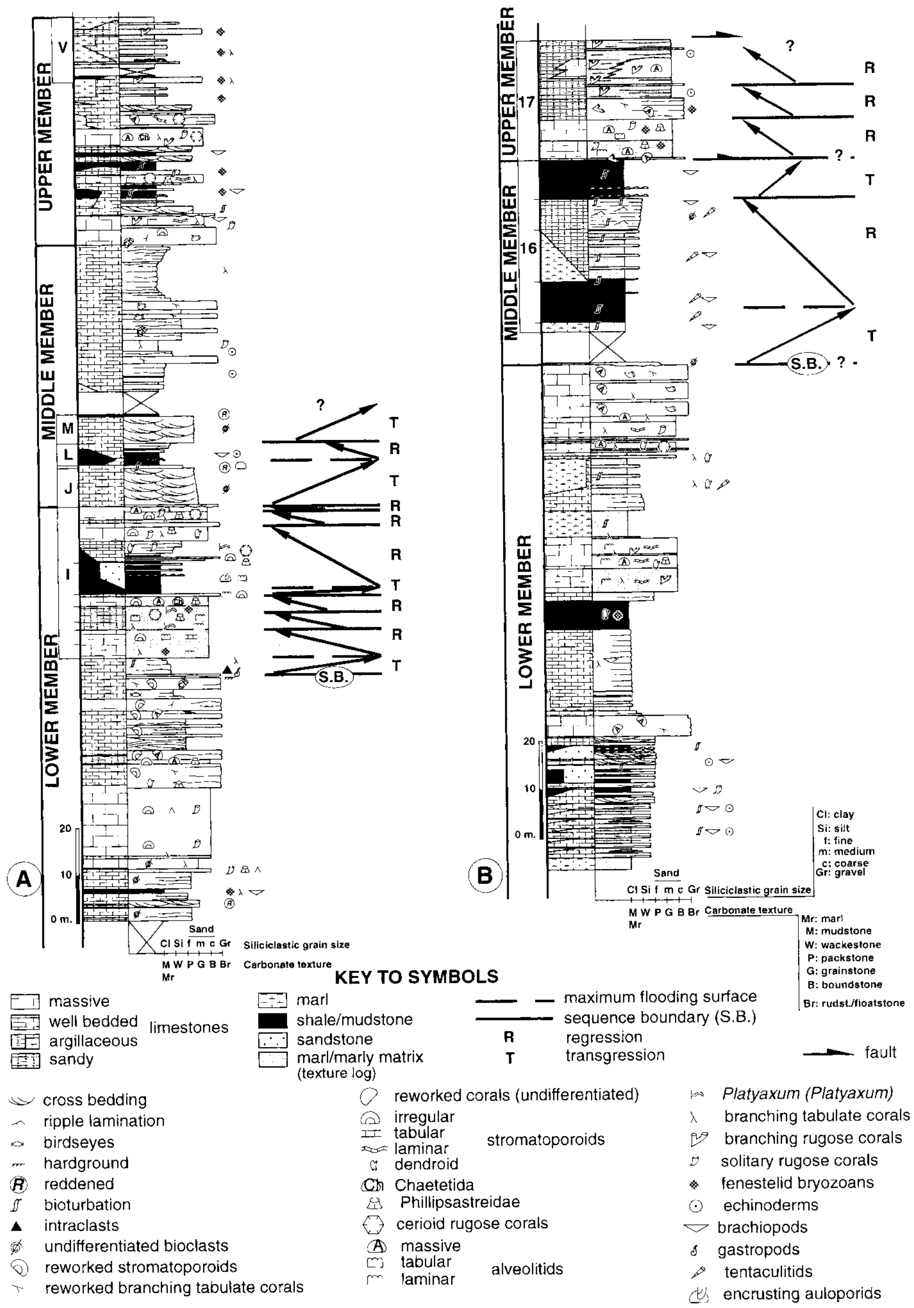

Fig. 3.–Measured sections of the Candás Formation showing the sequential arrangement in the selected intervals. A: Perán-Carranques section. B: Aramar section. Numbers and letters to the left of the selected intervals denote informal field descriptive stratigraphic units

–Secciones estratigráficas de la Formación Candás mostrando las secuencias distinguidas en los intervalos seleccionados. A: Sección de Perán-Carranques. B: Sección de Aramar. Los números y las letras presentes a la izquierda de los intervalos seleccionados delimitan tramos.

the Cantabrian Zone (Fig. 1). The succession has been named Candás in Asturias (northern slope of the Cantabrian Mountains) and Portilla in León (southern one) (Figs. 1, 2). The most complete sections of both formations are towards the Narcea Antiform, while in the opposite direction, towards the core of the Asturian Arc they disappear, more or less progressively, due to pre-Famennian erosion.

The Candás Formation (Barrois, 1882) is equivalent to the Portilla Formation *sensu lato* (Comte, 1936). The latter integrates the Portilla Formation *sensu stricto* plus the basal member of the overlying Nocedo Formation (Valdoré Limestones of Comte, 1938) (Fig. 2).

Both formations are made up of limestones, argillaceous limestones, marls, shales and sandstones. In general, these formations can be described as a lower interval of detrital limestones transitionally overlain by a first episode of reef development. This reef-bearing unit is unconformably overlain by an interval of detrital limestones, shales and sandstones, the latter being more abundant in the Portilla Formation. Finally, the formations end with a second episode of reef development (equivalent to the Valdoré Limestone of Comte, 1938).

Subdivision of the formations have been guided by the above mentioned patterns of lithological distribution; some authors (Bosch, 1969; Mohanti, 1972; Reijers, 1972; Bereskin, 1978 amongst others) separate four members, though others (Raven, 1983) considering the transitional relationships between the two first units, include them in the lower member and thus only distinguish three members. We divide both formations into three members (lower, middle and upper; Fig. 3), of which only the lower forms the Portilla Formation *sensu stricto*.

The stratigraphy and sedimentology of the Portilla Formation have been extensively studied by numerous authors (Mohanti, 1972; Reijers, 1972, 1985; Reijers *et al.*, 1984; Frankenfeld, 1981 and Raven, 1983), whereas the Candás Formation investigations have only been carried out in two sections by Fry & Bereskin (1977), Bereskin (1978) and Raven (1983). These authors consider that most of both formations have been deposited in a shallow-water, lagoonal to shelfal environment.

Biostratigraphical and paleoecological studies have been carried out by some of the above mentioned authors and by García-Alcalde *et al.* (1979), Fernández-Martínez *et al.* (1994) and Méndez-Bedia *et al.* (1994).

There is no agreement concerning the age of both formations. The Candás Formation was considered by Barrois (1882) as Frasnian. Delepine (1932) dated the majority of the Formation as Givetian, regarding only the upper 20-25 m as Frasnian. Most subsequent authors (Comte, 1959; Radig, 1962; Altevogt, 1967; Brouwer, 1964; Julivert *et al.*, 1971; García-López, 1972, 1987; Bereskin, 1978; Raven, 1983, amongst others) drew the Givetian/Frasnian boundary

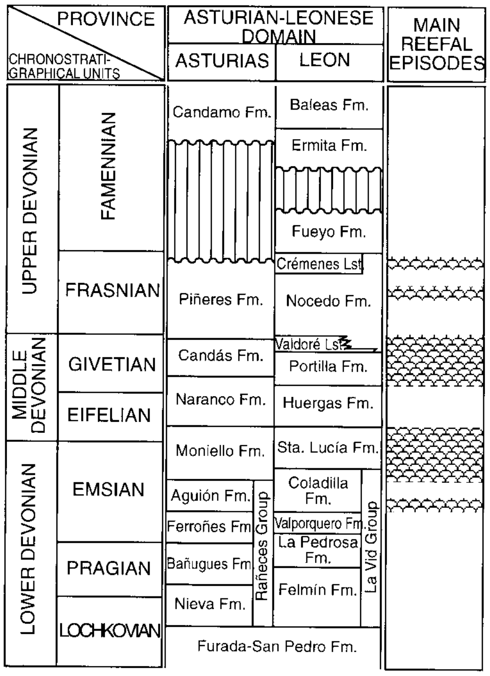

Fig. 2.–Chronostratigraphic chart of the Devonian of the Cantabrian Zone (Suárez de Centi *et al.*, 1989; Vera de la Puente, 1989; Truyols *et al.*, 1990; and references herein for further information) showing the distribution of main reefal episodes.

–Esquema cronoestratigráfico mostrando las unidades del Devónico de la Zona Cantábrica (para más información ver Suárez de Centi *et al.*, 1989; Vera de la Puente, 1989; Truyols *et al.*, 1990 y las referencias en ellos contenidas) y la distribución de los episodios arrecifales principales.

within the formations. Recently GARCÍA-ALCALDE (1995) considered the formations to be Givetian, though they could reach locally into the Frasnian (GARCÍA-LÓPEZ, *pers. comm.*, 1995).

2. FACIES

At first glance the succession of both formations is clearly organised in well-defined sequences (Fig. 3). These sequences of basic genetic stratigraphic units, have been used to study both reefs and the surrounding deposits.

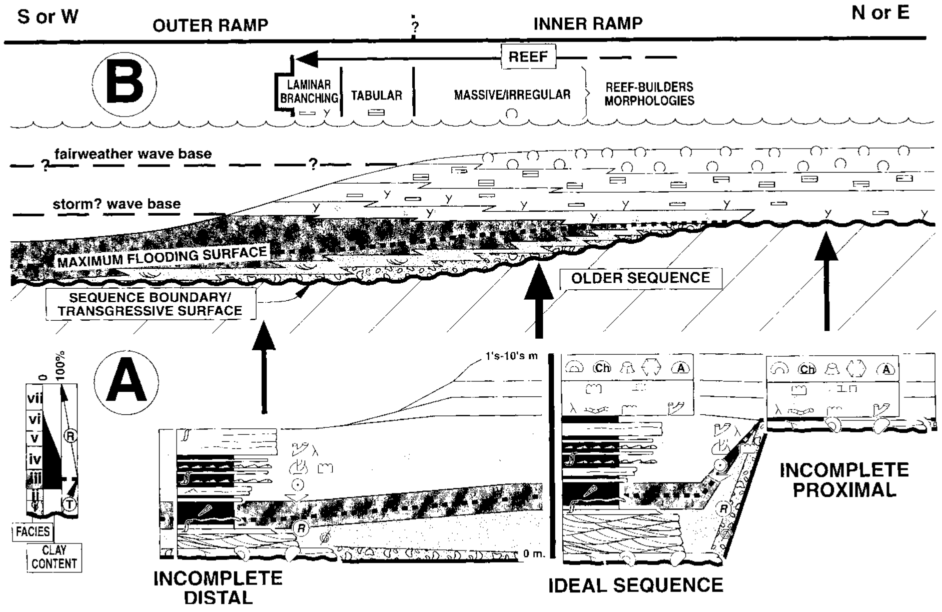

Fig. 4. A.–Types of reef-bearing sequences of the Candás and Portilla Formations (symbols as in Fig. 3). B. Idealized model of Candás-Portilla carbonate ramp showing the facies distribution in the reef-bearing intervals.
–Tipos de secuencias con arrecifes en las Formaciones Candás y Portilla (los símbolos como en la Fig. 3). B. Modelo idealizado de la rampa carbonatada de las Formaciones Candás y Portilla mostrando la distribución de las facies en los intervalos con arrecifes.

Reef-bearing sequences, and those other sequences that are closely spatially-related to them, allow the recognition of seven facies (Fig. 4A) that essentially fit the facies models of previous authors (REIJERS, 1972, 1985; RAVEN, 1983). Lagoonal facies, described by these authors, have been detected but they are not dealt with here due to their poor representation in the studied intervals of the selected sections. Facies are discussed below separating the description from the interpretation for each facies.

i. Coral/stromatoporoid rudstones to floatstones. This facies constitutes massive or thickly-bedded intervals up to 2-3 m thick. It is formed by fragments of organisms that built the underlying reef, set in a matrix of bioclastic lime packstones to grainstones. It erosively overlies other facies, typically reefal, and is gradationally, overlain either by grainstone-packstone facies (ii) or by mudstone facies (iii). When overlain by mudstone, the matrix of rudstone facies becomes argillaceous upwards.

The position of facies i within sequences (see below), its erosional relationships with respect to reefal facies (v-vii), and its gradational to facies ii or iii, suggest that this facies constitutes a transgressive lag deposit and precludes its interpretation as reef talus. No rudstone to floatstone deposits exist in the successions that can be interpreted as reef talus. This means that the reefs displayed low-angle smooth slopes and that there was not a true downdip break in slope gradient from the shallow-water reef-crest and lagoon to the deeper outer ramp.

ii. Bioclastic grainstones to packstones. This facies occurs as fining-upward packages up to 8 m thick. It consists of cross-bedded bioclastic lime grainstones to packstones forming centimetre to decimetre-thick sets. Both trough and low angle cross-bedding are present. Each set typically fines upwards and has a variously burrowed top. Packages of this facies are sharply overlain by mudstone facies (iii). Bioclasts are diverse, but dominated by fragments of corals and stromatoporoids.

The position of facies ii and its gradational relationships to the coarser-grained facies i suggest that both facies are process-related. So, facies ii is considered as transgressive bar deposits formed once water depth was sufficient to allow sand-grade sediments to be deposited. In this context, the overall fining-upward trend displayed by the packages of facies ii conceivably reflects the progressive deepening of the environment as the transgression advanced. The sedimentary structures of this facies suggest that sediments formed a blanket of bars and dunes, sometimes possibly related to storm activity. The sharp and burrowed top of packages of this facies represents an omission surface formed during the advancing transgression when the sea bottom was below current and storm wave activity.

iii. Dark grey mudstones. This facies forms intervals up to 10 m thick that are gradually overlain by facies (iv). It consists of dark grey shales and/or terrigenous mudstones to argillaceous marls with tentaculitids and fish fragments. Rarer faunal elements are brachiopods and occasional branching tabulate corals or stromatoporoids. Burrowing is quite variable, ranging from none to common.

The fine grained lithology of this facies clearly points to a depositional setting below storm wave base. This agrees well with the (comparatively) open sea character of the fauna occurring in this facies.This environment would correspond to a basin setting in the ramp facies model (TUCKER, 1985). Nevertheless, we prefer to use the term «outer ramp» because the preserved sedimentary basin is only a small portion of the original, and we do not know what lay seawards. Those deeper reaches that were seawards of the most distal outcrops and that should crop out in the Asturian-Leonese Zone, were completely eroded during the Variscan Orogeny.

This facies represents the deeper and most distal deposits and marks an inflection point between the transgressive trend represented by the facies i and ii (see above) and the regressive, progradational trend reflected by the arrangement of the next four facies (see below).

iv. Alternations of dark grey mudstones, sandstones and bioclastic limestones. This facies occurs in intervals up to 10 m thick. It is formed by dark grey terrigenous mudstones to argillaceous marls, commonly silty, that contain intercalations of centimetre-thick beds of fine-grained, ripple-laminated bioclastic quartzarenitic sandstones and of bioclastic lime wackestones to packstones. Faunal content is richer than in the underlying mudstone facies (iii) and consists (Table I) of bryozoans, brachiopods, branching tabulate or rugose corals and laminar tabulate corals. Fossils occur either as transported or *in situ* individuals and colonies growing preferentially on bioclastic beds, sometimes forming small bioherms and biostromes. Deposits of this facies are gradually overlain by bafflestone-bindstone facies (v).

The lithology of this facies clearly points to a shallower environment than that of facies iii. The presence of ripple laminated sandstones and of bioclastic limestones as isolated beds encased within the mudstones points to the discrete and occassional reworking of the sea bottom by currents with long periods of inactivity. Storms are the most probable agent that can account for this discontinuous sea bottom reworking. The richer and more varied character of the fauna present in this facies also points to a setting more favourable to epifauna. In this context, the preferential growth of organisms on bioclastic beds shows different sea bottom stability.

v. Branching/erect-palmate coral bafflestones/laminar coral bindstones. This facies forms massive to crudely bedded

clearer and better organized exposition of data and interpretations. English version of an early draft of this MS was improved by A. Soto O'Reilly.

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vii. Coral/stromatoporoid framestones. This facies is the last stage of reef development. It overlies gradational to apparent sharp the bindstone facies (vi) and consists of framestones (irregular to massive tabulate corals and/or stromatoporoids with subordinate massive rugose corals; Table I). The matrix is a bioclastic lime packstone to grainstone. Intervals of this facies are typically massive and very variable in thickness ranging from about 1 m to 15 m. In the case of the thicker intervals this variability could be explained by the presence of several stacked sequences comprising only this facies. A careful examination of good outcrops can lead to the distinction of individual sequences given the massive appearance of this facies.

The features of this facies imply a shallower, higher-energy environment than the preceding one. Its bioclastic, well-washed matrix and the morphologies of the organisms point to a high energy environment, above wave base.

3. SEQUENCES

The sequential study leads to a determination of whether the facies superposition is due to a genetic relationship between the facies or to an external mechanism, i.e. an abrupt shift in the depositional environment.

As a first approximation, the succession is formed by a number of basic sequences ranging in thickness from several decimetres to several tens of metres (Fig. 3). Each sequence has a sharp to rapidly transitional base and is divisible into two subsequences, a lower transgressive (deepening upward) and upper regressive (shallowing upward). Commonly the transgressive subsequence is very thin, or absent, and the whole sequence reflects a shallowing upward trend. Reefs, where they occur, form the upper part of the shallowing upward subsequence. The dominantly asymmetric shallowing upward aspect is inherent to carbonate systems and has been explained by many authors (JAMES & KENDALL, 1992; and references herein)

The ideal complete reef-bearing sequence is composed, from base to top, by the whole suite of facies arranged in ascending numerical order (from i to vii; Fig. 4A), though as commented above, in some sequences facies ii is not present and facies i is gradationally overlain by facies iii. In most cases, the sharp non-erosional limit between facies ii and iii is thought to merely represent the passage of the storm wave base (see the discussion of facies ii) and not the maximum flooding surface (i.e. the maximum extent of the transgression) that must lie within the overlying facies iii interval.

The top of the sequence is commonly formed by an erosional surface overlain by the coral/stromatoporoid rubble of facies (i) that forms the base of the next sequence. Sometimes the top is formed by a thin interval of *in situ* or transported branching tabulate or rugose corals set in a matrix that becomes progressively muddier upwards (-facies v and i? respectively). This interval forms the transition to the dark mudstones of facies (iii) that in this case occurs in the base of the next sequence.

Besides this idealized complete reef-bearing sequence, two other types of sequences are common in the investigated sections, the incomplete proximal and distal sequences (Fig. 4A).

The incomplete-proximal type has a sharp to erosive base. It commonly begins with the rudstone facies (i), though they can be absent, overlain by reefal facies (from facies v to vii).

The incomplete distal type has a sharp to erosive base and is characterized by a thin or absent rudstone and grainstone-packstone facies (i and ii, respectively) in such a way that some sequences of this type begin with mudstone facies (iii). Finally, the mudstone facies is overlain by facies iv that constitutes the upper part of the sequence. The top of the facies iv interval (i.e. the top of the sequence) is heavily burrowed.

These two types of incomplete sequences cannot be envisaged as the extreme types. These extreme types should consist of either framestone facies (vii) (see comments about facies vii above) or lagoonal facies in the case of the proximal-end type and of mudstones facies (iii) in the case of the distal-end type.

Because of the nature of the abrupt facies change across sequence boundaries, these surfaces are interpreted as due to a transgression. Both their variable character (erosive, sharp or rapidly transitional) and intervals up to 3 m thick and consists of bafflestones or bindstones. The bafflestones are composed by branching tabulate corals or laminar colonies bearing corallites on the two sides (erect-palmate tabulate corals of the subgenus *Platyaxum (Platyaxum)*). Some rugose corals are also present in this facies. The bindstones are made of laminar tabulate corals (Table I). Matrix is a bioclastic marly terrigenous mudstone with variable amounts of quartz sand and closely resembles the bulk lithology of the underlying facies (iv) though the sand. Also reefal faunas are sometimes quite similar to those of facies iv, content is less though much more abundant and diverse (Table I). Nevertheless, in some instances it is difficult to assign a given rock interval to specific facies, especially with compactional effects in terrigenous mudstones resulting in an organism-supported texture in which was originally a muddy deposit with 'floating' organisms that did not exert any baffling or binding role. For that reason we use a fully organism-supported texture with enough spatial continuity to assign a given deposit to the bafflestone-bindstone facies.

This facies marks the onset of reef development and is characterized by the extensive colonization of the sea bed by reef-forming organisms. The delicate morphologies of the reefal organisms and the texture of the interstitial matrix both reflect a low energy environment similar or identical to that of facies iv.

Table I.–Facial distribution of the most frequent reef building organisms.
–Distribución por facies de los organismos arrecifales más frecuentes.

FAUNAL CONTENT / FACIES	Facies iv	Facies v	Facies vi	Facies vii
STROMATOPOROIDS				
Amphipora sp.				■
Atelodictyon cf. *strictum*	■	■	■	■
Hermatostroma sp.			■	
Stachyodes sp.				■
Taleastroma sp.	■	■	■	■
RUGOSE CORALS:				
Acantophyllum cf. *concavum*		■	■	■
A. confusum				■
Aristophyllum occidentale	■	■		
Breviphrentis kullmanni		■	■	
Charactophyllum cf. *lotzei*			■	
Charactophyllum lotzei	■	■		
Charisphyllum altevogti		■	■	
Disphyllum caespitosum lazutkini	■	■		
D. caespitosum furcatum	■	■		
Dohmophyllum aff. *wedekindi*			■	
Endophyllum sp.		■		
Grypophyllum denckmanni	■			
Heliophyllum chengi	■		■	■
Hexagonaria cf. *mirabilis*			■	■
Medusaephyllum pradoanum	■		■	
Mesophyllum (Cystiphylloides) secundum secundum		■		
M. (C.) secundum conistructum		■		
Phillipsastrea sp.		■	■	■
Sinaxis bulbosa	■			■
Siphonophrentis cantabrica	■		■	
Stringophyllum aff. *primordiale*		■		
Tabulophyllum sp.				■
Xistrigona sp.		■	■	■
TABULATE CORALS:				
Alveolites parvus	■	■	■	■
Platyaxum (Platyaxum) escharoides	■	■	■	■
Platyaxum (Roseoporella) n. sp.		■	■	■
Spongioalveolites sp.	■	■	■	■
Thamnopora alta	■	■	■	■
Thamnopora beliakovi		■	■	■
Thamnopora patula	■	■	■	■

vi. Tabular coral/stromatoporoid bindstones. This facies gradationally overlies the bafflestone-bindstone facies and forms massive to crudely stratified intervals up to 3 m thick. It consists of bindstones (thick platy tabulate corals and/or stromatoporoids; Table I). The matrix is a marly bioclastic limestone whit the terrigenous content lower than in the underlying facies (v) and also decreasing upwards within the intervals of this facies.

This facies implies a higher energy level, with a coarser-grained matrix and reefal faunas displaying more robust morphologies.

the different facies that may overlie them are related to the magnitude rate of the transgression and to the level of energy (shoreface erosion) involved. It is clear that the more distal a given setting in the ramp is, the less erosion it will undergo during transgression. The same causes are thought to be responsible for the several sequence types here depicted, i.e. the magnitude of the transgression and the position at which we observe it in a given sequence (Fig. 4A).

Another point to discuss is the character of the sequences here described. Sequence stratigraphy postulates a fall-and-rise cycle of relative sea level as the driving mechanism for sequence formation. This leads to a tripartite architecture of sequences consisting ot a lowstand or shelf margin wedge system tract, a transgressive system tract and a highstand system tract related to a complete wavelenght of sea-level oscillation rate (VAN WAGONER *et al.*, 1990 and references herein). The sequences described here consist only of the transgressive and highstand system tracts (the transgressive and regressive subsequences respectively). Though similar sequences have been described elsewhere (e.g. in the Devonian of the Western Canada Sedimentary Basin; WENDTE, 1992), it is necessary to find an explanation for the lack of a lowstand record. We can tenptatively compare the described sequences with parasequences or high frequency sequences (GOLDHAMMER *et al.*, 1987; VAN WAGONER *et al.*, 1990) because parasequences are related to a negligible, or absent, sea level fall.

Nevertheless, some sequences in the more distal sections (Aramar section, Fig. 3) possess an apparent shelf margin wedge system tract. On the one hand, this suggests that the sequences described here are arranged as lower order sequences. On the other hand this can mean that we have failed to detect the lowstand deposits and hence the true sequence boundaries. No karst features have been detected below any sequence boundary and, though more information is needed, specially in the most proximal outcrops, we can suggest sequence boundaries are type 2. These are more subtle than type 1 and need a detailed correlation between the Perán-Carranques and Aramar sections to detect them. Such a correlation has not been stablished yet due to differences in succession between both sections (Fig. 3) and are thought to be a result of synsedimentary tectonic activity. Because of the presumed tectonic activity we do not attribute the sequential arrangement to any externally driven mechanisms, either eustatic or tectonic.

4. SEDIMENTARY MODEL: CONCLUSIONS

Facies analysis together with sequential analysis allows development of a detailed model of platform evolution as well as of reef onset and evolution. Previous sedimentary models for the Portilla Formation (REIJERS, 1972, 1985; RAVEN, 1983) have involved a reef-rimmed carbonate platform that, in a downdip direction, consisting of (a) a lagoonal backreef facies belt (peloidal, ostracodal, gastropodal and brachiopodal limestones), (b) a reef tract with biostromal and biohermal limestones and (c) a forereef facies belt (bioclastic and oolitic calcarenites) distally grading to deeper-water marls and shales. Though our results (Fig. 4B) are consistent with the overall pattern of REIJERS' (1972) facies distribution, our model implies a preferential development of the calcarenites during transgressions, and not at any moment of ramp evolution. Also we do not agree with the reef-rimmed platform geometry proposed by REIJERS (1985); evidence points rather to a ramp model for the Portilla-Candás carbonate platform.

The mechanism of reef development and demise is another aspect to highlight. RAVEN (1983, Fig. 7) suggested that these reefs formed part of deepening upward sequences and that reef demise took place when depth and deposition of clay increased. In our opinion (Figs. 3 and 4) reefs formed part of shallowing upward sequences, and were killed during transgressions. It cannot be excluded that emersion could have played a role, at least in some cases

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