ISSN: 1698-6180
www.ucm.es/info/estratig/journal.htm

Journal of Iberian Geology 31 (2) 2005: 253-275

Journal of Iberian Geology
AN INTERNATIONAL PUBLICATION OF EARTH SCIENCES

Stratigraphy and biofacies of the Lower Aptian of Cuchía (Cantabria, northern Spain)

Estratigrafía y biofacies del Aptiense inferior de Cuchía (Cantabria, N. de España)

M. Wilmsen

Institut für Paläontologie, Bayerische Julius-Maximilians-Universität, Pleicherwall 1, D – 97070 Würzburg, Germany
Fax: ++49/+931/31-2504; e-mail: m.wilmsen@mail.uni-wuerzburg.de

Received: 31/03/03 / Accepted: 12/03/04

Abstract

The lithostratigraphy and facies development of the Lower Aptian in the central part of the North Cantabrian Basin (NCB) are re-evaluated, and the Lower Aptian Caranceja Formation, consisting of a lower Calcarenite Member (shallow marine limestones), a middle Marl Member (basinal to prodeltaic marls), and an upper Sandstone Member (deltaic sediments), is formalized herein by designation of a lectostratotype. In response to transgressive development, a (?latest Barremian-) earliest Aptian carbonate ramp depositional system was established in the NCB. This system is documented by the Calcarenite Member of the Caranceja Formation, the biofacies of which is clearly dominated by heterotrophic organisms ('heterozoan carbonates'). A strong terrigenous nutrient input under wet-subtropical climate is held responsible for the more temperate carbonate facies in a warm water environment.

Shortly after its establishment, the 'juvenile' carbonate ramp system was drowned in the early Early Aptian. Stratigraphic, sedimentological, biofacies, and geochemical data suggest that the drowning occurred in response to synsedimentary tectonics associated with an eustatic sea-level rise and environmental perturbations associated with the Early Aptian oceanic anoxic event (OAE) Ia. The Calcarenite Member is overlain by deeper water marls of the Marl Member of the Caranceja Formation. Up-section, a coarsening and thickening-upward sequence suggests the progradation of a tide-dominated delta system ('Cuchía Delta') into the central NCB during the late Early Aptian.

A renewed flooding of the NCB during the late Early Aptian established a shallow marine, attached carbonate platform represented by the San Esteban Limestone Formation. The micro- and biofacies suggests a lagoonal setting with negligible terrigenous input for the deposition of the San Esteban Limestone Formation. This 'San Esteban Platform' was fragmented by tectonic movements associated with the "Gargasian event" during the Early/Late Aptian boundary interval.

Keywords: Cretaceous, Iberia, Urgonian system, biofacies, synsedimentary tectonics, drowning

Resumen

Se ha reevaluado la litoestratigrafía y el desarrollo de facies del Aptiense inferior de la parte central de la Cuenca Cantábrica Norte (CCN) y se ha dado un carácter formal a la Formación Caranceja del Aptiense inferior mediante la designación de un lectoestratotipo. Esta Formación esta compuesta por un Miembro inferior calcarenítico (calizas marinas someras), un Miembro medio margoso (margas de prodelta a zona más profunda de cuenca), y un Miembro superior de areniscas (sedimentos de delta). En respuesta al desarrollo de un episodio transgresivo, durante el (¿Barremiense terminal? -) Aptiense inferior, en la CCN se desarrolló un sistema de rampa carbonatada. Este sistema está representado por el Miembro inferior calcarenítico de la Formación Caranceja, cuya biofacies está netamente dominada por organismos heterótrofos ("carbonatos heterozoicos"). En el contexto de un clima subtropical húmedo, se considera que el que se produjese un fuerte impulso terrígeno rico en nutrientes fue el factor responsable de que se pudiesen dar carbonatos de condiciones más templadas en un ambiente de aguas cálidas.

Poco después de que se hubiese establecido, el sistema de rampa carbonatada "juvenil" fue inundado en el Aptiense inferior. Los datos estratigráficos, sedimentológicos, geoquímicos y de biofacies sugieren que la inundación se produjo en respuesta a una tectónica sinsedimentaria asociada a un ascenso eustático del nivel del mar y a las perturbaciones ambientales relacionadas con un evento anóxico oceánico Ia ("oceanic anoxic event" - OAE) del Aptiense inferior. Así, el Miembro inferior calcarenítico queda recubierto por las margas de aguas más profundas del Miembro medio margoso de la Formación Caranceja. Más arriba en la sección, la presencia de una secuencia granocreciente y estratocreciente hacia techo sugiere la progradación de un sistema deltaico dominado por las mareas („Delta de Cuchia") en el sector central de la CCN hacia el final del Aptiense inferior.

Todavía durante la parte terminal el Aptiense inferior tuvo lugar una nueva inundación de la CCN que permitió que se estableciese una plataforma carbonatada somera de carácter marginal, representada por la Formación calizas de San Esteban. Las micro- y biofacies de la Formación San Esteban sugieren un marco de lagoon con pequeños aportes terrígenos durante su sedimentación. Esta „Plataforma de San Esteban" fue fragmentada por los movimientos tectónicos asociados al „evento Gargasiense" durante al intervalo correspondiente al límite Aptiense inferior/superior.

Palabras clave: Cretácico Inferior, Iberia, sistema Urgoniano, biofacies, tectónica sinsedimentaria, inundación de la plataforma

1. Introduction

The Barremian-Aptian interval was a time of major change in the Mesozoic ocean/atmosphere system in response to strong magmatic and plate tectonic activity (see, e.g., Larson and Erba, 1999; Leckie *et al.*, 2002). Due to extension in the Biscay area and a concomitant eustatic sea-level rise, the north Iberian continental margin was flooded during the latest Barremian-Early Aptian, thus transferring vast areas formerly characterized by terrigenous deposition (Cantabrian Wealden facies) into shallow marine environments. This transgression gave rise to the development of widespread carbonate deposition of the Aptian-Albian 'Urgonian system' (e.g., Rat, 1959; Pascal, 1982, 1985, 1987; García-Mondéjar, 1990). Initially, carbonate deposition occurred on so-called 'immature' coastal carbonate platforms (Pascal, 1982) of Early Aptian ("Bedoulian") age. The superb coastal outcrops in northern Cantabria provide the unique opportunity to study the development and evolution of an Early Aptian shallow marine carbonate depositional system during an interval characterized by strong synsedimentary tectonics and major environmental changes.

Despite some magnificent outcrops, the Aptian-Albian of northern Cantabria is not well documented, most workers mainly concentrated on the Basque-Cantabrian Basin to the east (e.g., Pascal, 1985; Reitner, 1987; García-Mondéjar, 1990). The aim of the present paper is a detailed documentation of the Early Aptian transgression and the biofacies developing in the central part of northern Cantabria during this interval, representing the '1er système biosédimentaire' of Pascal (1982, 1985) or 'Urgonian sequence U1' of García-Mondéjar (1990). An additional objective is the formalization of the Caranceja Formation of García-Mondéjar (1982a) by designating and describing a lectostratotype. The formation is subdivided into three members and its distribution, lateral facies changes and sedimentologic significance are discussed.

In order to achieve these goals, the section at Cuchía was measured bed-by-bed. The rocks were described in the field, sampled for microfacies analysis and classified according to depositional texture (Folk, 1959; Dunham, 1962; Embry and Klovan, 1972). Macrofaunal occurrences and ichnological observations as well as sedimentary structures were integrated into the stratigraphic logs.

2. Geological setting

After two rifting phases between the European and Iberian plates in the Triassic and in the Late Jurassic/earliest Cretaceous, sea-floor spreading in the western Bay of Biscay started in the Early Aptian and proceeded zip-like eastward; sea-floor spreading ended in the latest Santonian (e.g., Wiedmann *et al.*, 1983; Olivet, 1996). Due to these distensional movements, numerous sedimentary (intra-shelf) basins developed on the tectonically very active passive North Iberian margin, often in halfgraben settings due to the tilting of 'domino blocks' (see Fig. 1D; cf. Leeder and Gawthorpe, 1987; Leeder, 1995). According to García-Mondéjar (1982b, 1989, 1990) and Agirrezabala and García-Mondéjar (1992), synsedimentary tectonics during Aptian-Albian times mainly controlled the stratigraphic architecture and facies distribution of the sediments of the Urgonian system.

The study area, located in the northern part of the Spanish province Cantabria (Fig. 1A), is the North Cantabrian

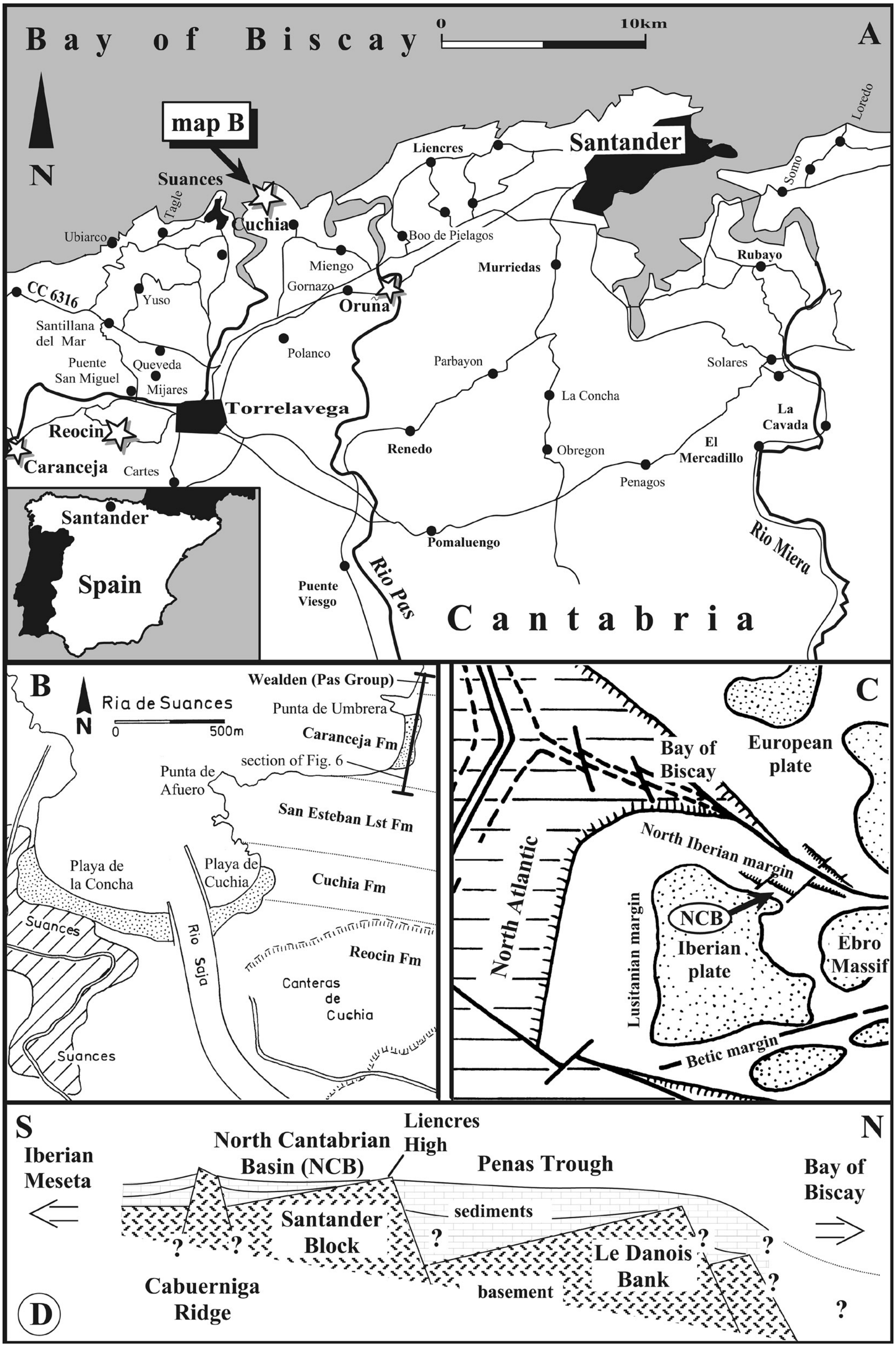


Fig. 1.– A. Map of the central part of northern Cantabria with indication of localities discussed in the text. B. Detailed locality map of the Cuchía section with indication of the measured section of Figure 6 and the lithological units discussed in the text. C. Generalized palaeogeography and plate tectonic setting of Iberia during the middle Cretaceous. D. Generalized cross-section of the north Iberian continental margin in a S-N transect between Santander and Torrelavega (not to scale).

Fig. 1.– A. Mapa de la parte central de Cantabria septentrional en el que se señalan las localidades citadas en el texto. B. Mapa detallado del área en la que se ha levantado la columna de Cuchía en el que se representan la traza de la sección de la Figura 6 y las unidades litológicas citadas en el texto. C. Marco paleogeográfico y paleotectónico general de Iberia durante el Cretácico Medio. D. Corte general S-N del margen continental noribérico entre Santander y Torrelavega (sin escala).

Basin (NCB, Wiese and Wilmsen, 1999), a relatively small E-W-elongated extensional basin (50 x 100 km), which developed as an independent structural unit on the North Iberian margin as a result of mid-Valanginian distensional movements. It was interpreted as a halfgraben by Wilmsen (1997; Fig. 1D). The NCB was separated from the strongly subsiding Basque Basin/Navarro-Cantabrian Ramp in the east by the “Rio Miera Flexure” (Feuillée and Rat, 1971); to the south, it was delimited by the Cabuerniga Ridge (an east-west trending horst-like structure formed of Palaeozoic and Triassic rocks) and the Asturian Massif, a part of the positive area of the Iberian Meseta (Fig. 1C). To the west, the North Cantabrian Basin graded into the Asturian Cretaceous Basin. Its northern extension was limited by a swell situated in the Bay of Biscay. This “Liencres High” (Wiese, 1995) can be traced to the west as far as the Asturian Cretaceous Basin and possibly represents the crest of a tilted block (Santander Block, Wilmsen, 1997; Fig. 1D). Deposition took place in subtropical palaeolatitudes of 25-30°N (Masse, 2000), and the Early Aptian was characterized by a warm palaeoclimate (e.g., Kemper, 1987).

The Cretaceous succession of the NCB was treated in the last century by mostly French, Spanish, and German workers. Mengaud (1920) and Ramirez del Pozo (1971) presented general stratigraphic surveys of the region. The Wealden was studied by Pujalte (1981) and individual Urgonian (Aptian-Albian) sections were the scope of the investigations of Rat (1959), Pascal (1985), and Reitner (1987). Feuillée (1967, 1971) and Wilmsen (1997, 2000) focussed on the Albian-Cenomanian, and Wilmsen *et al.* (1996) and Wiese and Wilmsen (1999) presented stratigraphic and sedimentologic studies on the Upper Cretaceous succession.

The sediments of the Early Aptian ‘first biosedimentary system’ of Pascal (1982) deposited in the central part of the NCB are the focus of the present study. They represent the early developmental stages of the Urgonian system in northern Spain, and only a few detailed sedimentological and biofacies descriptions of the Lower Aptian in the NCB were presented so far. Furthermore, most of the lithostratigraphic units are only poorly defined since only names but no type sections and adequate descriptions were published.

3. The Cuchía section

3.1. Location

The Cuchía section is located at the eastern side of the Ria (=river mouth) de Suances east of the Punta de Afuero (also known as the ‘Picco de la Barra’), ca. 3 km NW of the small village of Cuchía (Fig. 1B). The co-ordinates of the base of the section are 417480/4810950 (UTM co-ordinates, zone 31T). From the car parking at Playa de Cuchía a small road leads to an isolated beach (Playa de los Caballos) 700 m to the northeast where a steep trail descends to its southernmost part. The beds are dipping gently southwards and the section was measured along the cliff from north of the Punta de Umbrera (Fig. 1B). The cliff at the southern part of the beach forms the top of the measured section (see Fig. 2).

3.2. Stratigraphy

The Cuchía section superbly exposes a continuous succession of the Valanginian-Barremian Pas Group of the Cantabrian Wealden facies and the Lower Aptian

Fig. 2.– (opposite page) Field aspects of the Cuchía section, location see Figure 1B. A. Angular unconformity (outlined) between Lower Jurassic marl/limestone alternations and pebbly, coarse-grained sandstones of the Wealden; person (lower right) for scale. B. Soft, partly overgrown siltstones and proud-weathering channel sandstones of the Wealden. The arrow marks the base of the Caranceja Formation (Calcarenite Member). C. Transgressive contact (arrow) of the marine Calcarenite Member of the Caranceja Formation (above) and rooted floodplain deposits (Wealden, below) north of the Punta de Umbrera; persons (lower part) for scale. D. The Calcarenite Member and the lower part of the Marl Member of the Caranceja Formation at the Punta de Umbrera; note the (northward) onlapping marl (arrowed) overlain by the terminal bed of the Calcarenite Member and the abrupt contact to the Marl Member (see also Fig. 10). E. Upper part of the Caranceja Formation (Sandstone Member) in the southern part of the Playa de los Caballos; note the normal fault (arrow marks the base of the San Esteban Limestone Formation). F. Contact of the Caranceja Formation (heterolitic rocks of the Sandstone Member, below) and the San Esteban Limestone Formation (arrow, above) at the southern cliff of the Playa de los Caballos. The recessing lower beds of the limestones are still strongly siliciclastic and rich in orbitolinids.

Fig. 2.– (página opuesta) Aspectos de campo de la sección de Cuchía; para su localización ver Fig. 1B. A. Discordancia angular (resaltada) entre la alternancia margo-caliza del Jurásico Inferior y las areniscas del Weald de carácter grosero y con cantos; una persona de escala (parte inferior derecha). B. Limolitas blandas parcialmente recubiertas y areniscas canalizadas alteradas del Weald. La flecha señala la base de la Formación Caranceja (Miembro calcarenítico). C. Contacto transgresivo (flecha) del Miembro calcarenítico marino de la Formación Caranceja (encima) y los depósitos wealdienses de llanura de inundación con huellas de raíces (debajo) al norte de Punta de Umbrera; unas personas de escala (parte inferior). D. El Miembro calcarenítico y la parte inferior del Miembro margoso de la Formación Caranceja en Punta Umbrera; obsérvese la marga en onlap hacia el norte (señalada con flecha) recubierta por la capa terminal del Miembro calcarenítico y el contacto abrupto con el Miembro margoso (ver también Fig. 10). E. La parte superior de la Formación Carnceja (Miembro de areniscas) en la parte meridional de la Playa de los Caballos; obsérvese la falla normal (la flecha señala la base de la Formación calizas de San Esteban). F. Contacto de la Formación Carnceja (rocas heterolíticas del Miembro de areniscas, debajo) y la Formación calizas de San Esteban (flecha, encima) en el acantilado sur de la Playa de los Caballos. Las capas inferiores de las calizas, que morfológicamente constituyen un entrante, son todavía marcadamente siliciclásticas y ricas en orbitolínidos.


A
B
C
Marl Mb
Calcarenite Mb
D
Sandstone Mb
E
F

Caranceja and San Esteban Limestone formations. The stratigraphy and sedimentology of the section was treated by Mengaud (1920), Rat (1959), Collignon *et al.* (1979), Pascal (1985) and Birkenhake (1996). However, no valid lithostratigraphic subdivision was applied yet. Thus, the Caranceja Formation is formalized in this paper and the section at Playa de los Caballos is suggested as the lectostratotype (see Salvador, 1994), comprising three members.

3.2.1. Lithostratigraphy

Overlying a karstified palaeo-relief of tilted Triassic-Lower Jurassic carbonates (Carñiolas and Lower Liassic marl/limestone alternations, Fig. 2A), the succession can be subdivided into the following lithostratigraphic units (from base to top):

(1) Cantabrian Wealden facies (ca. 50 m, Figs. 2B, 4): red siltstones with intercalated fine- to coarse-grained sandstone bodies up to five metres in thickness showing fining-upward, trough cross-bedding and lateral accretion surfaces. Basal part pebbly with cobble-sized quartzites; some intercalated white limestone beds and palaeosols. According to Birkenhake (1996), these sediments belong to the Valanginian to Barremian 'Pas Group' of Pujalte (1981).

(2) Caranceja Formation (García-Mondéjar, 1982a, ca. 110 m, Lower Aptian, Figs. 2C-F, 6), which is subdivided into three members herein:

(2a) A lower Calcarenite Member (new, 25 m in thickness, 'Schillkalke' of Birkenhake, 1996) consisting of thickly bedded coarse-bioclastic limestones of yellow-brownish colour with large-scale trough cross-bedding and diverse shallow water biota (Fig. 7) separated by thin marl beds.

(2b) A middle 'Marl Member' (new, ca. 55 m) of dark clayey to silty marls with red ironstone nodules and abundant ammonites in the lower part; some intercalated nodular sandy bioclastic limestones with bivalves, brachiopods, echinoids and orbitolinids as well as wood debris and intense bioturbation.

(2c) An upper member of sandy bioturbated marl, heterolitic sandstone/clay intercalations with strong bioturbation, and fine- to medium-grained, mica-rich sandstones, up to several metres in thickness, with trough cross-bedding, convolutions and frequent wood fragments.

In the original definition of the Caranceja Formation, García-Mondéjar (1982a, p. 66) did not figure a stratotype but only referred to the type area of the formation, the "*characteristics of which can be observed in the valley of the River Saja, at the high of Caranceja (west of Torrelavega)*" [translated from Spanish]. Thus, the section at Cuchía, shown in Figure 6, is designated as the lectostratotype of the Caranceja Formation. The name is derived from the village of Caranceja to the west of Torrelavega (Fig. 1A). The formation is synonymous with the informal 'formation calcaréo-gréseuse inférieure' (Calcarenite Member) and the 'formation terrigène à ammonites' (Marl and Sandstone members) of Collignon *et al.* (1979). Pascal (1985, p. 290ff.) referred to the formation as 'Niveau 1' (Calcarenite Member) and 'Niveau 2' ('marnes bleues', Marl and Sandstone members) whereas Birkenhake (1996) mapped the units as 'Schillkalke' and '*Deshayesites* marls'. The formation also occurs to the south southwest at Reocín (see Fig. 1A) where the 'formation terrigène inférieure' of Collignon *et al.* (1979) forms a lateral equivalent of the Sandstone Member of the Caranceja Formation (see below, Fig. 11). It also occurs to the southeast at Oruña (Fig. 1A) where the Calcarenite and the Sandstone members can be recognized (see Pascal, 1985, p. 286, fig. 65).

(3) San Esteban Limestone Formation (García-Mondéjar, 1982a, ca. 50-100 m, upper Lower Aptian, Figs. 2F, 6): thickly bedded to massive light grey limestones with rudists (*Toucasia, Requienia*), corals, benthic foraminifera and calcareous algae. Only the lower part of this unit, referred to as '1er barre Urgoniens' or 'barre inférieur' by Pascal (1985) and 'Lower Urgonian Limestones' by Birkenhake (1996), was studied here.

(4) Cuchía Formation (García-Mondéjar, 1982a, ca. 20-100 m, lower Upper Aptian, "Gargasian"): The Cuchía Formation represents a lithologically very variable succession of immature sandstones, (sandy to silty) marl, nodular limestones, and conglomerates, unconformably overlying the San Esteban Limestone Formation. The succession ('Gargasian beds' of Birkenhake, 1996) is characterized by rapid lateral facies and thickness changes.

(5) Reocín Formation (García-Mondéjar, 1982a, ca. 100-300 m, upper Lower Aptian to lower Lower Albian): This formation refers to a thickly bedded to massive unit of micritic rudistid limestones, conformably overlying the Cuchía Formation. It is referred to as '2er barre Urgoniens' or 'barre supérieur' by Pascal (1985) or the 'Upper Urgonian Limestones' by Birkenhake (1996). Often, the rocks are characterized by intensive secondary dolomitization or lead-zinc mineralization.

3.2.2. Biostratigraphy

No biostratigraphic data can be given for the Wealden facies of the Cuchía section. According to Pujalte (1981), the deposition of Wealden sediments in northern Cantabria started in the middle Valanginian (Pas Group) and lasted to the Barremian.

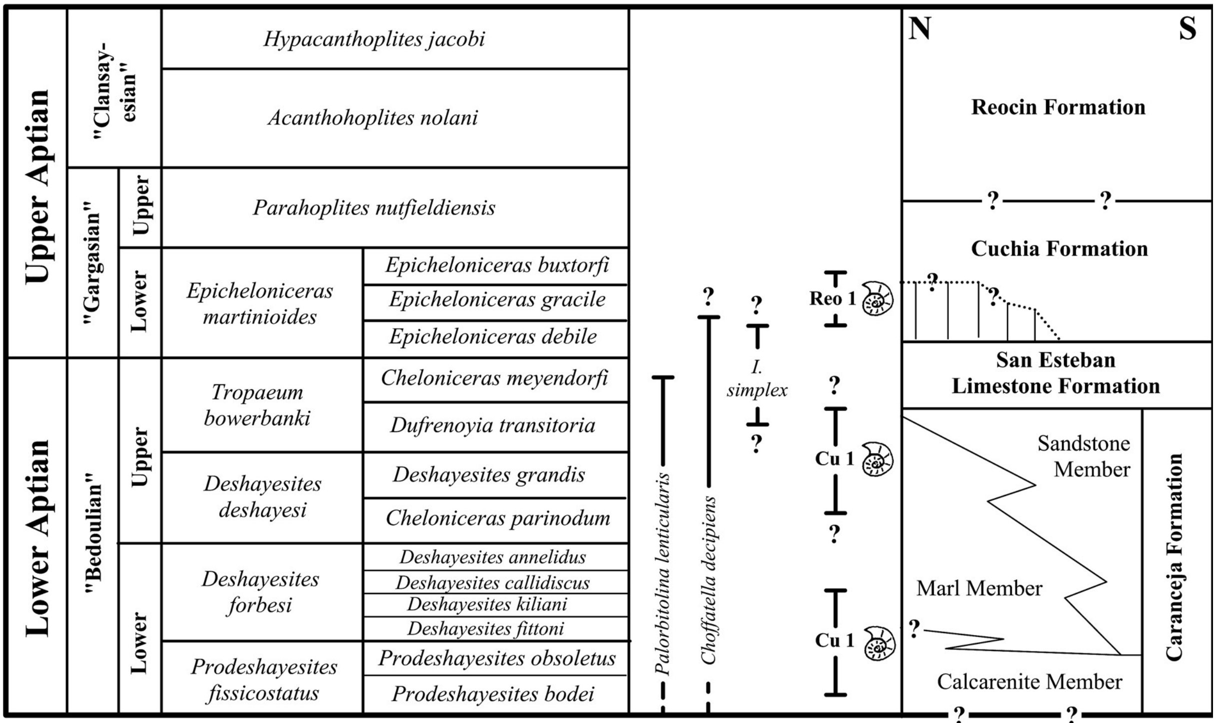


Fig. 3.– Ammonite biostratigraphy of the Aptian stage (compiled after Kemper, 1982; Erba, 1995; Casey *et al.*, 1998; Mutterlose, 1998; Masse, 2000) with indication of the ranges of some benthic foraminifera (after Pascal, 1985) and the ammonite levels Cuchía Cu1, Cu2 and Reocín Reo1 (cf. Collignon *et al.*, 1979). Furthermore, lithostratigraphic units (formations after García-Mondéjar, 1982) discussed in the text are shown according to their approximate chronostratigraphic positions.

Fig. 3.– Bioestratigrafía de Ammonites del Aptiense (recopilada de Kemper, 1982; Erba, 1995; Casey *et al.*, 1998; Mutterlose, 1998; Masse, 2000) con indicación de los rangos de distribución de algunos foraminíferos bentónicos(según Pascal, 1985) y de los niveles de ammonites Cu1 y Cu2 de Cuchía y Reo1 de Reocín (cf. Collignon *et al.*, 1979). Además, se muestran las unidades litoestratigráficas (Formaciones según García-Mondejar, 1982) que se discuten en el texto de acuerdo con sus posiciones cronoestratigráficas aproximadas

The biostratigraphy of the Caranceja Formation is based on ammonites and benthic foraminifera (see Fig. 3). The lower part of the Calcarenite Member yields *Palorbitolina lenticularis* (Pascal, 1985), indicating a latest Barremian to Early Aptian age (e.g., Gusic, 1981). Collignon *et al.* (1979) reported *P. lenticularis, Orbitolinopsis* gr. *cuvillieri-kiliani,* and *Choffatella decipiens* from the top beds of the Calcarenite Member, still indicating a terminal Barremian to Early Aptian age. The middle member of the Caranceja Formation includes two horizons with ammonites (cf. Collignon *et al.*, 1979). However, due to the poor outcrop conditions in the lowermost part of the Formation, the separation of the two levels it not easy because the fossils are washed down the badland slopes formed by the lower, soft part of the member (Fig. 2D).

The ammonite assemblage of the lower level (*Prodeshayesites fissicostatus, P. bodei, P.* cf. *lestrangei, Deshayesites euglyphus, D. forbesi, D. fittoni, D. punfieldensis and D. callidiscus*) indicates the early Early Aptian *fissicostatus* to *forbesi* zones (e.g., Casey, 1961, lower "Bedoulian" of Collignon *et al.*, 1979). The upper level yielded *Cheloniceras* (*C.*) *cornueli*, *C.* (*C.*) *crassum*, *C.* (*C.*) cf. *royeri* and *Vectisites hispanicus*, indicating the *deshayesi* to *bowerbanki* zones (late Early Aptian). It should be noted that the *Tropaeum bowerbanki* Zone is regarded by some authors (e.g., Kemper, 1982) already as part of the Lower "Gargasian" (= lower Upper Aptian according to Erba, 1995).

The top of the measured section (transition of Caranceja Formation and San Esteban Limestone Formation) still yields *Palorbitolina lenticularis* along with *Choffatella decipiens, Charentia* aff. *cuvillieri* and *Sabaudia minuta*, suggesting a late Early Aptian age (Collignon *et al.*, 1979; Pascal, 1985). The San Esteban Limestone Formation contains *Iraquia simplex*, according to Pascal (1985) indicating a latest Early to early Late Aptian age. The age of the top of the San Esteban Limestone Formation can be inferred only indirectly.They are capped in the study area by a subaerial erosion surface overlain by the lithologically variable lower Upper Aptian Cuchía Formation (Birkenhake, 1996).

In the Reocín section (Collignon *et al.*, 1979, see Fig. 1A), the San Esteban Limestone Formation is overlain by the Cuchía Formation comprising 50 m of marly

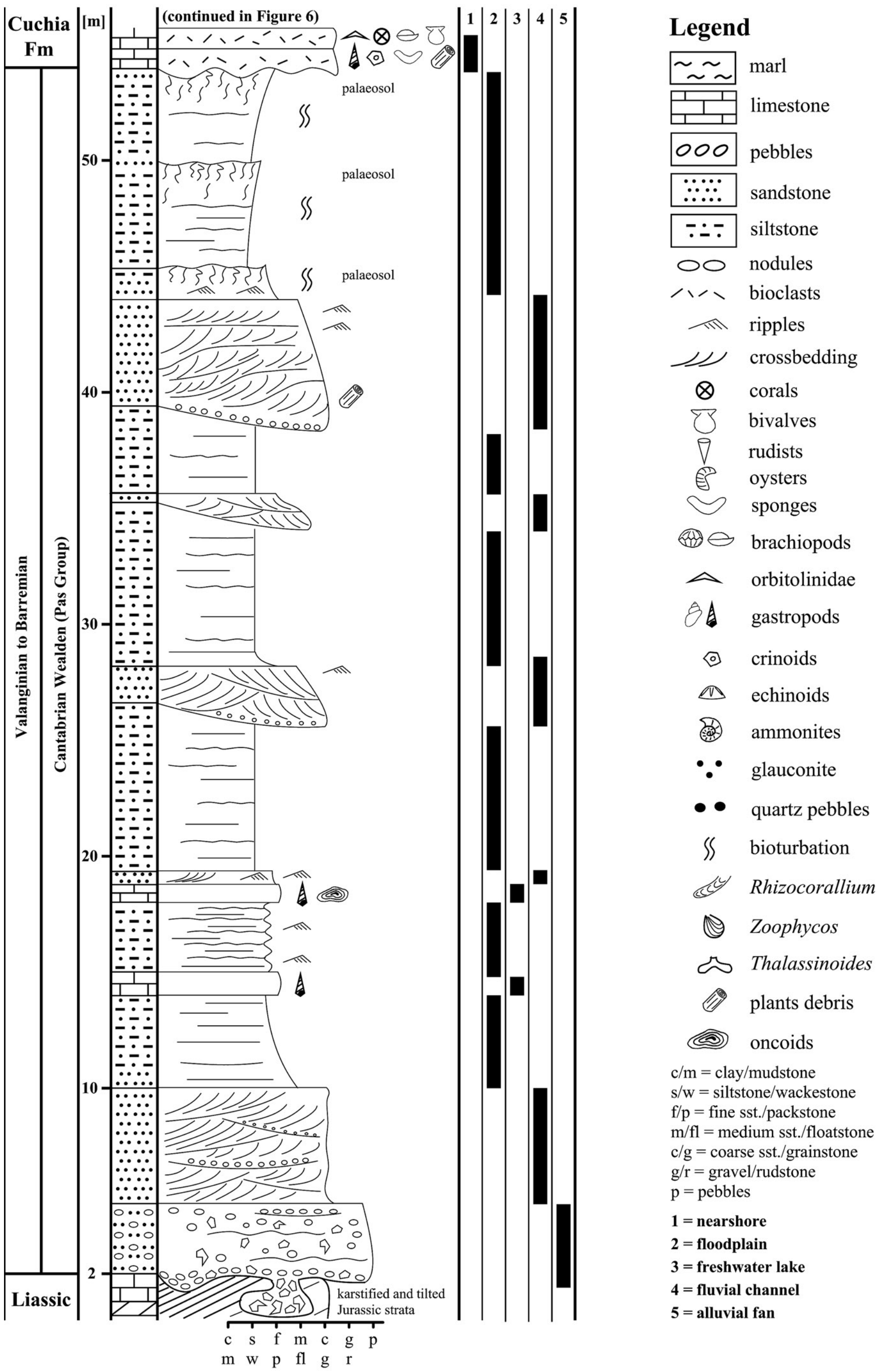


Fig. 4.– Log of the Cantabrian Wealden (Pas Group) at the Cuchía section with indication of depositional environments; legend applies for all figures.

Fig. 4.– Columna estratigráfica del Weald cantábrico (Grupo Pas) en la sección de Cuchía en la que se indican los ambientes sedimentarios; la leyenda es válida para todas las figuras.

sandstones followed by 40 m of dark, in part glauconitic marls with ammonites (*Cheloniceras mackesoni* and *Epicheloniceras gracile)*. The Reocín ammonite fauna is considered to be of early Late Aptian age (*martinioides* Zone, *gracile* Subzone, see Fig. 3). Thus, lower Urgonian carbonate deposition of the San Esteban Limestone Formation was terminated probably at the boundary Lower/Upper Aptian in response to differential tectonic movements of the Gargasian tectonic event (e.g., Pascal, 1985). This tectonic unconformity also forms the boundary between Urgonian sequences U1 and U2 of García-Mondéjar (1990) which is, in places, angular. According to this author, the terminal Early Aptian *Cheloniceras* (*C.*) *meyendorfi* occurs in sequence U1, placing the unconformity at the boundary to, or in the earliest parts of, the Late Aptian (*Epicheloniceras debile* Subzone?).

3.3. Log description

3.3.1. Cantabrian Wealden facies (Fig. 4)

The Wealden starts with 4 m of coarse conglomerates and poorly sorted pebbly sandstones unconformably overlying karstified and tilted Upper Triassic-Liassic carbonates (Figs. 2A, 5B). Cobble-sized quartzites may reach 30 cm in diameter and are well rounded. According to Birkenhake (1996), the basal Wealden rocks fill in a metre-scale palaeo-relief, and also karst cavities filled with limestone breccia, clay, sand, and speleothems occur in carbonates of the Carñiolas (Fig. 5A). The components are rounded quartzites and angular to subrounded limestones. These basal beds are followed by 6 m of coarse-grained immature sandstones with trough cross-bedding and fine-conglomeratic lenses.

Upsection, a succession of red siltstones and erosional, trough cross-bedded sandstone bodies up to 6 m in thickness predominates (Fig. 2B). The sandstones are sharp-based, show basal pebble lags, lateral accretion surfaces and contain wood fragments (Fig. 5C). The red siltstones display intercalated thin, fine-grained rippled sandstone beds and are punctuated by palaeosols, especially in the upper part of the succession (Fig. 5D). Bioturbation is represented by simple burrows such as *Scoyenia*. In the lower part, two thin (~1 m) beds of white micritic limestone with viviparid gastropods, ostracods, and stromatolites are developed.

3.3.2. Caranceja Formation (Fig. 6)

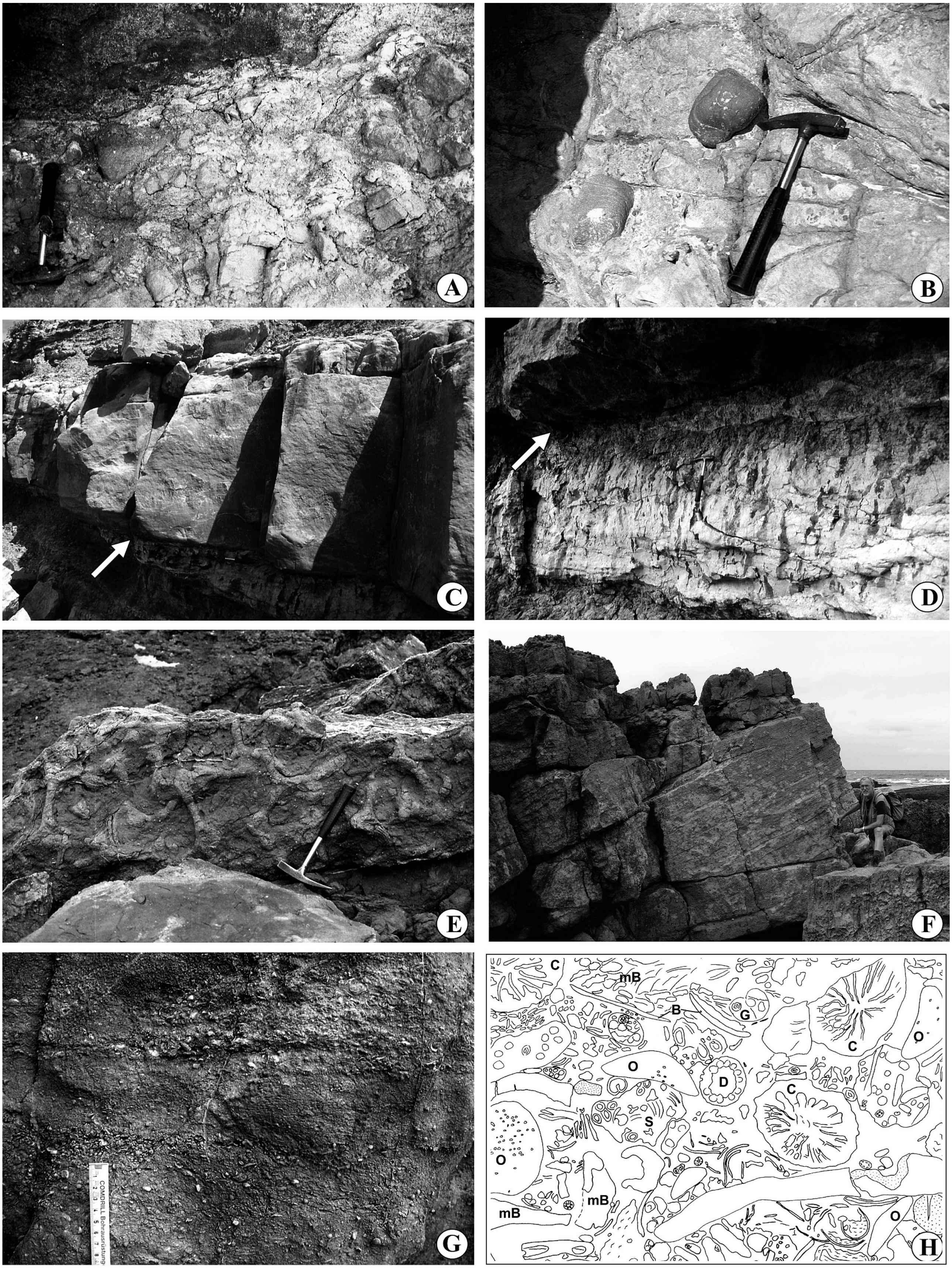
With strongly undulating erosive contact (Figs. 2C, 5D), the 25 m thick Calcarenite Member of the Caranceja Formation overlies the Wealden deposits. The basal two beds are massive bioclastic rudstones with abundant shallow marine biota (e.g., orbitolinids, corals, echinoderms, sponges, brachiopods, gastropods, and bivalves; Fig. 5H). They also yielded well-rounded, hazelnut-sized pebbles of milky quartz (Fig. 5G), and wood fragments. The following 20 m are characterized by thickly bedded to massive bioclastic limestones (mostly grain- and rudstones) showing large-scale trough cross-bedding (Fig. 5F). Laterally, the beds are of varying thickness and are separated by silty marls with abundant orbitolinids. Their top is frequently bioturbated by *Thalassinoides* burrows which are infilled with the overlying orbitolinid marls, generating a nodular fabric (Fig. 5E).

The microfacies is dominated by sparitic fabric types and well washed, moderately to poorly sorted, often cross-bedded bioclastic grain- and rudstones are the most common facies types (see Figs. 5H, 7). The most common components are larger agglutinated benthic foraminifera (orbitolinids and other large lituolids, Fig. 7A, B), molluscan and echinoderm fragments, solitary corals, and calcareous algae such as dasycladaceans and codiaceans (e.g., *Boueina*, Fig. 7E, F). Micritic envelopes around bioclasts are common and primary aragonitic components such as gastropods and corals are commonly recrystallized to neomorphic calcite spar; in that case, they are often outlined only by means of their micritic envelopes (Fig. 7A, B). Well rounded quartz grains up to 3 cm in diameter are common (Fig. 7A, E). Cementation of the pore space occurred with an isopachous fibrous rim cement (A) and a blocky sparite (B).

The limestones intercalated between cross-bedded grain- and rudstones are characterized by finer grain-size and a packstone fabric. Those bioclastic packstones contain echinoid debris, small lituolids, and angular, silt-sized quartz (Fig. 7C). A sharp-based bed with small, subspherical oncoids of up to 2 cm occurs in the lower part of the Calcarenite Member (Fig. 7D).

In the upper part of the Calcarenite Member, the facies changes drastically. The coarse calcarenitic bed at 20 m of the measured section (Fig. 6) is strongly bioturbated and capped by a slightly ferruginous firmground colonized by oysters. It is overlain by an up to three metres thick silty marl with plant debris. This marl appears to onlap the underlying cross-bedded rudstone in a northward direction (Fig. 2D). The top bed of the member is a strongly bioturbated, bio- and intraclastic pack- to grainstone, in the lower part strongly silty (bioclastic siltstone), and contains authigenic glauconite (Fig. 7G, H). It is rich in brachiopod and echinoderm debris and small lituolids. Euphotic elements such as calcareous green algae, occurring in the underlying limestones, are not recorded. The top of this bed is a ferruginous hummocky surface, encrusted by large oysters and mineralized by glauconite, forming the boundary to the Marl Member of the Caranceja Formation. Pascal (1985, p. 437, fig. 107) reports a massive increase in Zn, Cu, and Fe from this surface. The following ca. 30 cm thick silty marl and a thin (~20 cm), strongly bioturbated calcareous-bioclastic sandstone with spreiten burrows form the lowermost beds of the hanging Marl Member.

The Marl Member of the Caranceja Formation, abruptly overlying the sediments of the Calcarenite Member (Fig. 2D), is 55 m thick and starts with silty marls grading into dark-grey, soft clayey marls ('marnes bleues'). Unfortunately, the basal parts of the formation are usually covered with sediment washed down the badland slopes. In this part, the two ammonite horizons are intercalated


A
B
C
D
E
F
G
H
C
mB
B
G
C
O
O
D
C
S
O
mB
mB
O

(see chapter biostratigraphy). Additional faunal elements are echinoid spines, serpulids and small oysters. Upsection, the silt content of the marls increases gradually. Between 60 and 70 m, some sandy, bioclastic limestones beds are intercalated. Usually, they show a nodular fabric due to bioturbation. The prominent bed between 67-68 m yields abundant bivalves (*Pterotrigonia* sp., *Neithea* sp., *Icanotia pennula*), irregular echinoids (*Toxaster* sp.), terebratulid brachiopods (*Sellithyris* sp.), orbitolinids, and wood fragments. thin (<10 cm) fine sandstone beds with parallel lamination and faint grading are intercalated towards the top.

At 80 m of the measured section, the boundary to the Sandstone Member of the Caranceja Formation is drawn at a level from which sandy sediments prevail upsection. The thickness of the member is ca. 26 m albeit a normal fault occurs in the south-eastern part of the Playa de los Caballos (see Fig. 2E). However, the beds could be confidentially correlated across the fault. The member includes mica-rich, bioturbated sandstones, trough-cross-bedded sandstones, and heterolithic intervals comprising thin, fine-grained, lenticularly or ripple bedded sandstone beds with mud drapes, and dark clays (Fig. 2F). The heterolithic beds as well as the sandstones are strongly bioturbated and conspicuous *Ophiomorpha nodosa* burrows occur (Fig. 8B1/B2); sandstone beds frequently show convolute bedding (Fig. 8A1/A2) and flaser bedding may occur. Wood fragments prevail throughout the succession (Fig. 8C) which shows a general thickening and coarsening upward trend.

3.3.3 San Esteban Limestone Formation

Only the lower part of this unit was investigated. It starts with 5 m of sandy to marly, bioclastic, nodular limestones rich in orbitolinids including *P. lenticularis* (Collignon *et al.*, 1979; Pascal, 1985). Wood fragments and corals occur. This part of the formation weathers softly and retreats in the cliff (Fig. 2F). Upsection, pure, micritic, thickly bedded limestones with abundant rudists (*Toucasia* and *Requienia*) forming biostromes and bioclastic floatstones prevail (Figs. 8D, 9). The matrix is a miliolid wackestones further containing orbitolinids and calcareous algae. Rare corals are also reported from this unit by Pascal (1985) and Birkenhake (1996).

3.4. Interpretation

The Wealden facies documents deposition in a continental setting and shows a general fining-upward. The basal conglomerates are interpreted as proximal alluvial fans deposited close to a palaeorelief. Also karst-collapse breccias occur in Upper Triassic-Lower Jurassic carbonates (Carñiolas). The following sediments document alluvial deposition grading from braided rivers in the lower part (coarse-grained trough cross-bedded sandstones with conglomeratic lenses) to streams of moderate sinuosity in the upper part (e.g., Miall, 1996). The middle and upper Wealden succession is dominated by red siltstones and intercalated sandstone bodies forming fining-upward sequences (‘point bar sequences’ of Allen, 1970). The

Fig. 5.– (opposite page) Field aspects of the Wealden and the Calcarenite Member of the Caranceja Formation at the lectostratotype. A. Poorly sorted karst cavity fill at the base of the Wealden section consisting of angular to sub-rounded carbonates, sand, and greenish clays. B. Well rounded quartzite pebbles in coarse-grained sandstone, lower part of the Wealden (cf. Fig. 2A). C. Sharp-based (arrow), erosional channel sandstone (ca. 1.5 m thick) in the upper part of the Wealden (cf. Fig. 2B). D. Rooted palaeosol in the uppermost part of the Wealden section; arrow marks the base of the Caranceja Formation, Calcarenite Member (see Fig. 2C; hammer in centre for scale). E. Large *Thalassinoides* burrows in orbitolinid-rich marl separating thickly bedded calcarenite beds from a fallen block of the Calcarenite Member of the Caranceja Formation at the Punta de Umbrera. F. Large-scale cross-bedding in the upper part of the Calcarenite Member at the Punta de Umbrera (F.T. Fürsich gives scale). G. Coarse-grained, poorly sorted fabric of a cross-bedded bioclastic rudstone of the Calcarenite Member; the light-grey components are well rounded milky quartz grains (scale in cm). H. Line drawing of the principal microfacies of the Calcarenite Member: poorly sorted bioclastic rudstone with corals (c), orbitolinids (o), serpulids (s), dasycladaceans (d), gastropods (g), and micritized bioclasts (mB) (after a photomicrograph, width is 25 mm).

Fig. 5.– (página opuesta) Aspectos de campo del Weald y del Miembro calcarenítico de la Formación Caranceja en el lectoestratotipo. A. Material de relleno de una cavidad cárstica mal seleccionado que aparece en la base de la sección del Weald, está compuesto por clastos carbonatados de angulosos a subredondeados, arena, y arcillas verdosas. B. Cantos de cuarcita bien redondeados en areniscas de grano grueso, parte inferior del Weald (cf. Fig. 2ª). C. Cuerpo canalizado de arenisca (aprox.1,5 m de espesor) con base neta erosional (flecha) en la parte superior del Weald (cf. Fig. 2B). D. Paleosuelo con huellas de raíces en la parte más alta de la sección del Weald; la flecha señala la base de la Formación Caranceja, Miembro calcarenítico (ver Fig. 2C; un martillo de escala en el centro). E. Grandes galerías de *Thalassinoides* en margas ricas en orbitolínidos que separan las calcarenitas estratificadas en capas potentes de un bloque caido del Miembro calcarenítico de la Formación Caranceja en la Punta de Umbrera. F. Estratificación cruzada a gran escala en la parte superior del Miembro Calcarenítico en la Punta de Umbrera (F.T. Fürsich de escala). G. Fábrica mal seleccionada en una caliza rudstone bioclástica de grano grueso con estratificación cruzada correspondiente al Miembro calcarenítico; los componentes de tono gris claro son granos de cuarzo lechoso bien redondeados (escala en cm). H. Dibujo de las microfacies principales del Miembro calcarenítico: caliza rudstone bioclástica mal seleccionada con corales (c), orbitolínidos (o), serpúlidos (s), dasicladáceas (d), gasterópodos (g), y bioclastos micritizados (mB) (a partir de una microfotografía, la anchura es 25 mm).

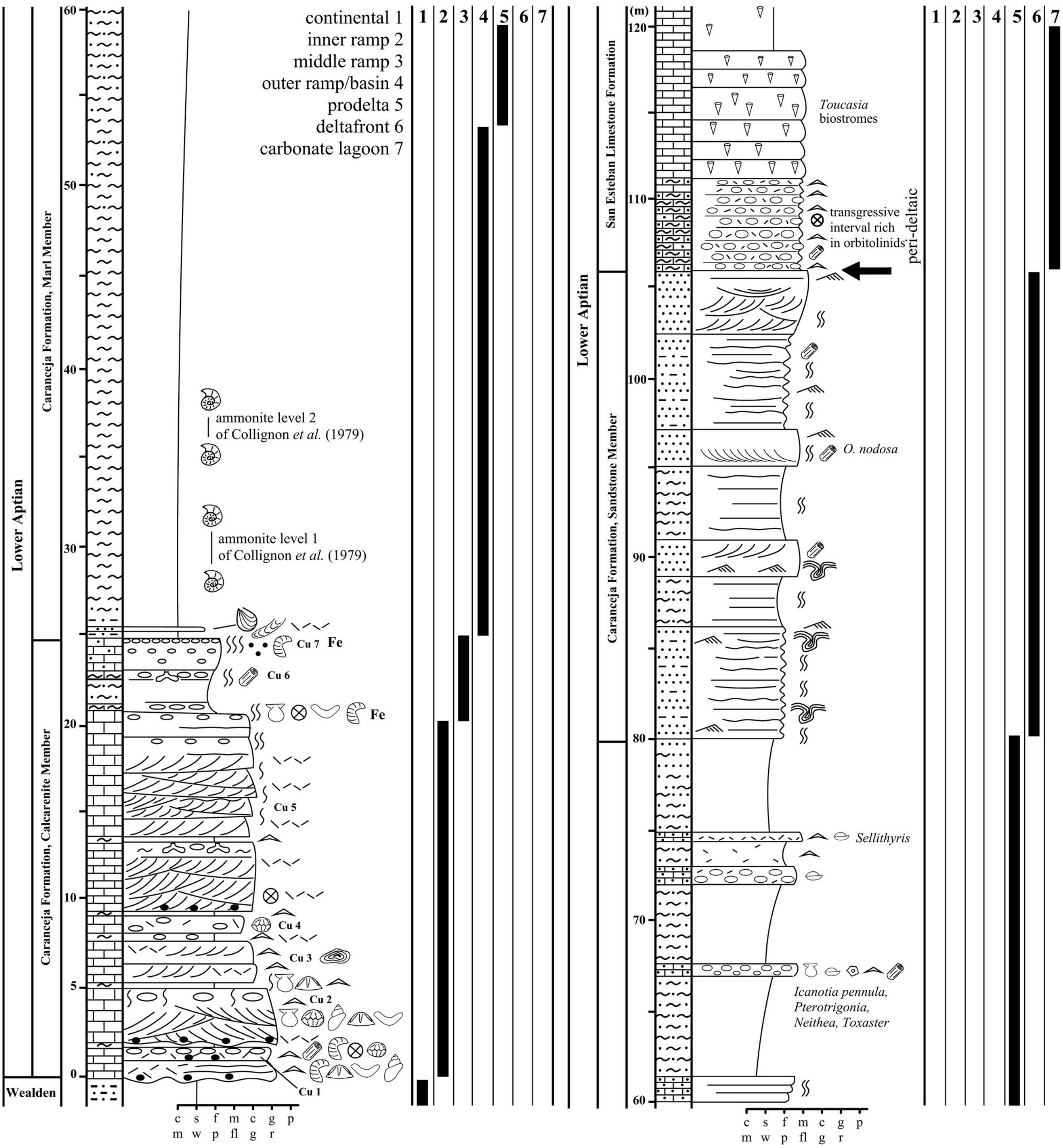


Fig. 6.– Log of the lectostratotype of the Caranceja Formation and the lower part of the San Esteban Limestone Formation at Playa de los Caballos, eastern margin of the Ria de Suances, with indication of depositional environments (see Fig. 1B); for legend see Figure 4.

Fig. 6.– Columna estratigráfica del lectoestratotipo de la Formación Carnceja y de la parte inferior de la Formación calizas de san Esteban en la Playa de los Caballos, margen oriental de la Ría de Suances, en la que se indican los ambientes sedimentarios (ver Fig. 1B); para la leyenda ver Figura 4.

red siltstones are interpreted as representing flood plain sediments deposited under semi-arid climatic conditions (e.g., Farrell, 1987; Willis and Behrensmeyer, 1994). As most of the sandstones are more or less lenticular, they very likely represent channel deposits of rivers of low to moderate sinuosity (e.g., Galloway, 1981; Miall, 1996). The two limestone beds in the lower to middle part of the succession suggest the presence of shallow lakes on the flood plain, also indicated by freshwater molluscs and ostracods (e.g., Picard and High, 1972). In the uppermost part of the succession, repeated palaeosol development took place in a floodplain environment.

The erosive base of the Caranceja Formation, Calcarenite Member, represents a major transgressive surface. The overlying bioclastic and large-scale trough cross-bedded limestones indicate deposition in a highly agitated and fully marine nearshore environment. They most likely represent shallow subtidal sandwaves in an inner carbonate ramp setting (e.g., Burchette and Wright, 1991); areas between active bars were somewhat sheltered and sites of orbitolinid marl and fine-bioclastic, silty packstone deposition as well as infaunal activity. Abandoned bars were rapidly colonized by burrowing organisms such as *Thalassinoides*-producing crustaceans, causing the often nodular fabric of their tops. The coarse infill in the formerly open burrow system may represent 'tubular tempestites' *sensu* Tedesco and Wanless (1991).

Oncoid-rich layers indicate reduced accumulation rates and somewhat varying energy levels; they might represent deposition tidal channels dissecting the inner ramp (Buchanan *et al.*, 1972, reported recent oncoids with a sub-spherical shape and a diameter of 1.5 to 3 cm completely covering the bottom of a roughly 2 m deep tidal channel on the Great Bahama Bank). Plant fragments and siliciclastic input indicate prevailing terrigenous input and the vicinity of vegetated land. The carbonate facies of the Calcarenite Member shows a mixed biofacies of subordinate chloralgal and predominating foramol associations (*sensu* Lees and Buller, 1972; Lees, 1975; or 'photozoan' and 'heterozoan' carbonates of James, 1997).

However, true hermatypic corals do not occur, and the biofacies is dominated by heterotrophic organisms (such as oysters, brachiopods, echinoids, solitary corals). The beige-brown colour of the rocks indicates a relatively high iron content of the rocks. In combination with the terrigenous input (siliciclastics, plant debris) this suggests rather pronounced fluvial input and concomitant increased nutrient levels (meso- to eutrophic conditions; see, e.g., Friedman, 1969; Brasier, 1995). Thus, it appears that the more 'temperate' carbonate facies of the Calcarenite Member was controlled by elevated nutrient levels rather than temperature (cf. Lees, 1975; Hallock and Schlager, 1986; Carranante *et al.*, 1988). A similar observation was obtained by Gischler *et al.* (1994) for the Santonian *Lacazina* Limestones of the Basque-Cantabrian and Iberian basins.

In the upper part of the Calcarenite Member, a fundamental change in deposition is indicated by the onlap of silty marls of deeper water affinity (Figs. 2D, 10). These sediments are interpreted as syn-drowning sediments. The onlapping marls pinch out towards the north, indicating a northward backstepping of the shallow water carbonate system and a concomitant north-directed onlap onto the Liencres High (see Fig. 1D). The following terminal limestone is finer, strongly silty and bioturbated, and contains authigenic glauconite, indicating reduced accumulation rates and incipient condensation (e.g., Odin and Matter, 1981).

The abrupt transition into the overlying clayey marls of the Marl Member of the Caranceja Formation marks the complete submergence of the formerly shallow water depositional environment into a quiet basinal setting well below fair wheather wave base. The top surface of the Calcarenite Member indicates condensation during this interval (hardground development, mineralization, enrichment of Fe, Cu, Zn) and terminates the syn-drowning phase of the drowning sequence (cf. Ehrlich *et al.*, 1990) starting four metres below (Fig. 10). It is interesting to note that the drowning was accompanied by increased terrigenous input of angular, mainly silt- and fine sand-sized quartz. The ammonite-bearing lower part of the Marl Member of the Caranceja Formation is interpreted as basinal post-drowning sediment (Fig. 10). Apart from a few horizons in the upper part, the fauna is of low diversity and dominated by ammonites.

The upper part of the Marl Member is characterized by increasing silt content, indicating increasing fluvial input of suspended siliciclastic material. This part is interpreted as prodelta as also evidenced by plant debris and the presence of thin, graded sandstone beds (prodelta turbidites, see Wright, 1985). The upper Sandstone Member of the Caranceja Formation shows a constant thickening- and coarsening-upward. The changes in grain size, bed thicknesses, sedimentary structures, and bioturbation are characteristic of delta front deposits (Wright and Coleman, 1974; Wright, 1985; Elliott, 1986). The sandstones represent a high energy environment of shifting substrate and high rates of sedimentation, probably mouth bar deposits of distributary channels.

This interpretation is supported by large amounts of plant debris and sediment convolution attributed to high sedimentation rates. The occurrence of *Ophiomorpha nodosa* burrows likewise indicates instable, shifting substrates (Bromley, 1996). The heterolitic sediments record tidal influence by means of mud drapes, lenticular and flaser bedding and most probably represent deposition in interdistributary bays (e.g., Elliot, 1974; Wright, 1985). These observations allow a classification as a 'tide-dominated delta' *sensu* Galloway (1975), and the name 'Cuchía Delta' is proposed herein.

The transition into the San Esteban Limestone Formation again indicates a major change in the sedimentary environment attributed to a flooding event and the withdrawal of the terrigenous sources. At the base, sandy limestones with abundant orbitolinids suggest a nearshore environment with deltaic influence (e.g., Reitner, 1987). In the Cenomanian of the NCB, similar, *Orbitolina*-rich horizons are often associated with early transgressive intervals of 3rd- order depositional and 4th-order high-frequency sequences (Wilmsen, 1997, 2000).

These *Orbitolina* horizons are paucispecific, somewhat condensed biogenic accumulations that can be correlated across the basin. Comparable transgressive "*Orbitolina* episodes" are known from the Lower Aptian of southern Spain (Vilas *et al.*, 1995).

Upsection, micritic limestones with rudists and benthic foraminifera indicate deposition within a sheltered, lagoonal environment without terrigenous influence. The biofacies is dominated by rudistid bivalves forming patch-like and biostromal primary biogenic accumulations, and miliolid and orbitolinid foraminifera. The top of the San Esteban Limestone Formation represents an interregional unconformity, separating the first from the second biosedimentary system of Pascal (1982). In the study area, the top is a reworked, iron-stained, locally karstified erosion surface (Birkenhake, 1996) overlain by the lithologically very variable beds of the Cuchía Formation (Fig. 8E). Pascal (1985, p. 294-295) reports stromatolitic linings with desiccation cracks from this surface at Suances.

The deposition of limestone conglomerates with pebbles derived from the underlying San Esteban Limestone Formation (Fig. 8E) suggests nearby uplift and erosion. This Gargasian event was associated with the fragmentation of the "Bedoulian" platforms in the Basque-Cantabrian realm, development of local angular unconformities, and the progradation of deltaic sediments into the basins due to source area rejuvenation (e.g., Pascal, 1985; Reitner, 1987; García-Mondéjar, 1990). The Gargasian event was probably caused by a tectonic pulse in the evolving Biscay Ocean (onset of spreading in the western Biscay area). Tectonic movements around the Early/Late Aptian boundary are also known from other parts of Europe (e.g., England; Casey, 1961).

4. Reocín section

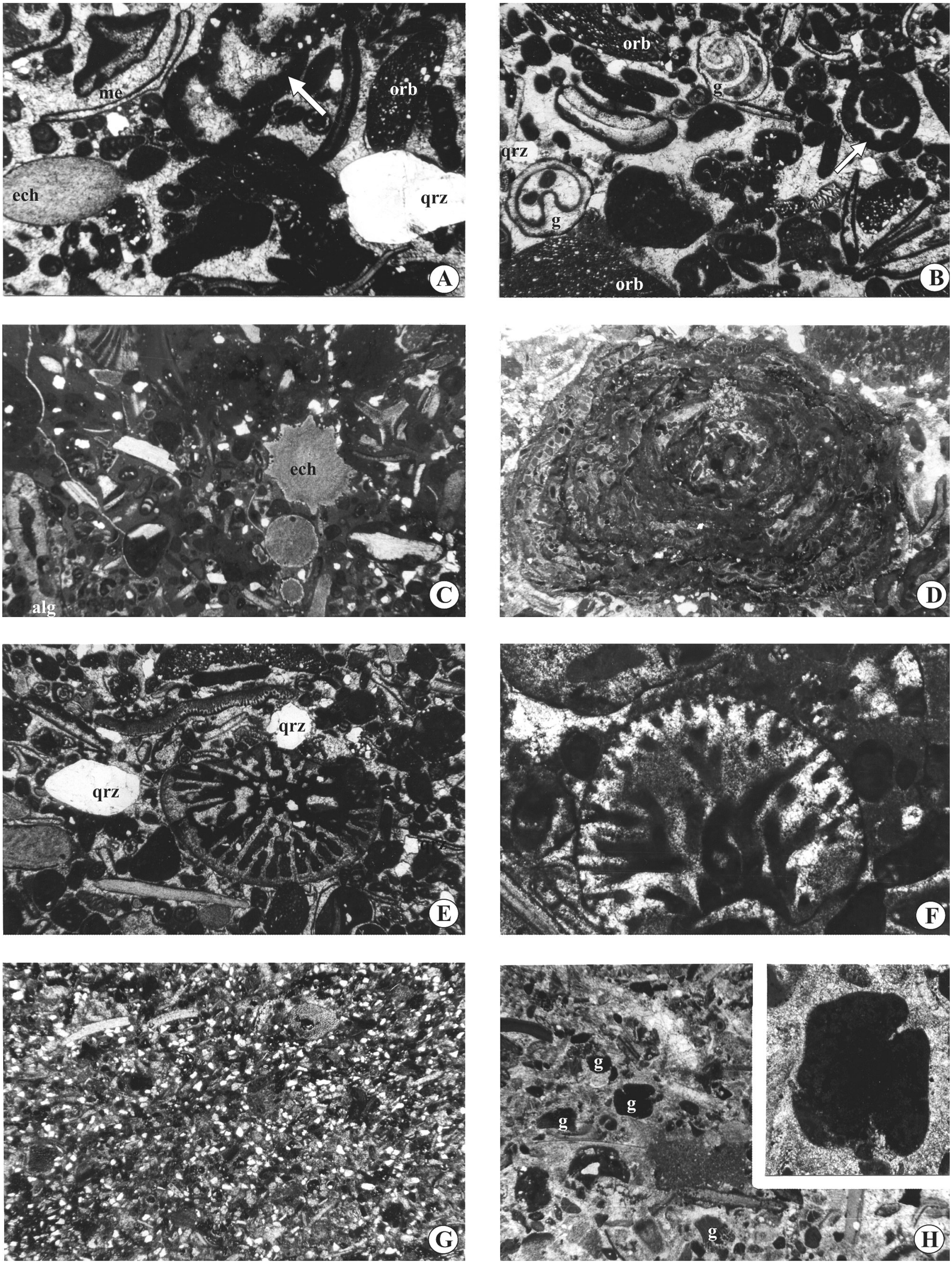
The village of Reocín is located ca. 12 km to the SSW of Cuchía east of Torrelavega (Fig. 1A). It was described by Rat (1959) and Collignon *et al.* (1979), and their descriptions are briefly re-evaluated here. The section (see Fig. 11) starts with a "Lower terrigenous formation" of 120 m thickness (sandstones with mica and subordinate clay alternating with bivalve-bearing sandy marls, orbitolinids and plant debris). In its lower part it includes a 10-12 m thick biointrasparite with *P. lenticularis* which is interpreted as lateral equivalent of the Lower Aptian Calcarenite Member of the Caranceja Formation. The facies suggests a delta front environment.

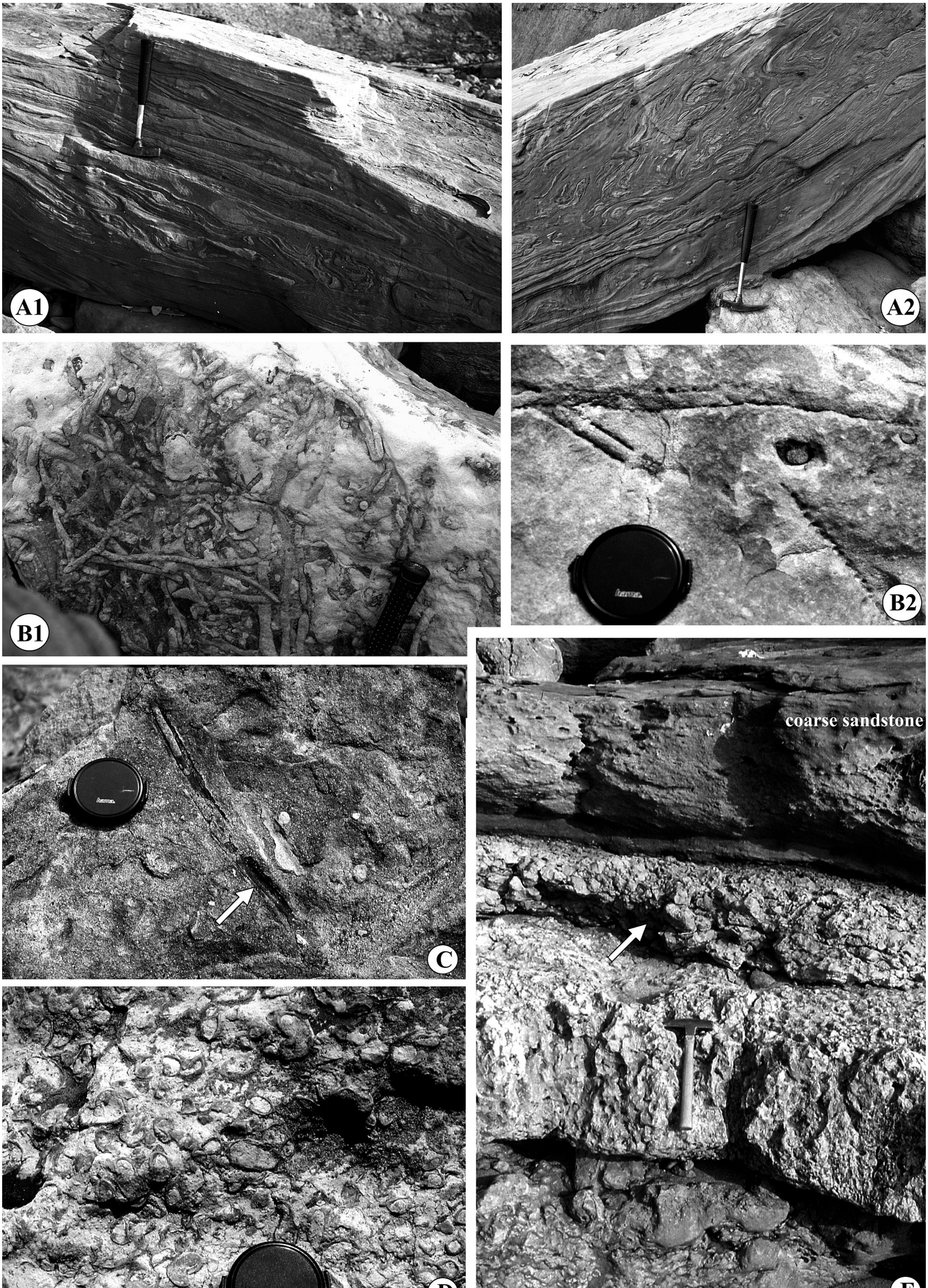
The Lower terrigenous formation is followed by the 60 m thick San Esteban Limestone Formation which starts, as in Cuchía, with a sandy-marly calcareous level rich in foraminifera (*P. lenticularis, Choffatella decipiens, Orbitolinopsis* cf. *debelmasi*). Upsection, *Toucasia* beds of metric thickness yielding *Iraquia simplex, Simplorbitolina praesimplex, Nautiloculina bronnimanni, Sabaudia* ex gr. *minuta*, miliolids and calcareous algae are developed. Their age is considered as late Early Aptian.

The San Esteban Limestone Formation is overlain by an "Upper terrigenous formation" (i.e., Cuchía Formation) of marly, deltaic sandstones (50 m) followed by dark, in part glauconitic marls (40 m) with large oysters, sponge spicules, ostracods, planktonic foraminifera and ammonites. Collignon *et al.* (1979) recorded *Cheloniceras mackesoni* and *Epicheloniceras gracile*, indicating the early Late Aptian (*martinioides* Zone, *gracile* Subzone). Above these marls, upper Upper Aptian ("Clansayesian") to lower Lower Albian platform carbonates occur (Reocín Formation, 'Upper Urgonian limestones').

Fig. 7.– Microfacies of the Calcarenite Member of the Caranceja Formation at the lectostratotype; width of photomicrographs is 10 mm if not otherwisely stated. A. Bioclastic rudstone with echinoid spine (ech), orbitolinid foraminifera (orb), large lituolid (arrow), micritized bioclasts (me), and well rounded quartz grains (qrz); sample Cu2. B. Bioclastic grainstone with gastropods (g, with micritic envelopes, arrowed.): orbitolinids (orb), and several micritized bioclasts (bahamite peloids); sample Cu2. C. Silty, bioclastic packstone with small lituolids and echinoid spines (ech); sample Cu4. D. Small subspherical oncoid; sample Cu3. E. Coral-rich bioclastic rudstone (compare with Figs. 5G, H) with well rounded quartz grains (qrz), orbitolinids, miliolids (upper left), and micritized bioclast; sample Cu5. F. *Boueina* sp.; sample Cu5, width of photomicrograph is 2.5 mm. G. Bioclastic siltstone from the drowning sequence. The dark components represent glauconite grains or glauconitized bioclasts; sample Cu6. H. Terminal bed of the Calcarenite Member: bio- and intraclastic grain-/packstone with abundant brachiopod and echinoderm debris. G = glauconite grains; note the desiccation cracks in the enlarged grain (ca. 0.8 mm in diameter) suggesting that it is authigenic; sample Cu7.

Fig. 7.– Microfacies del Miembro calcarenítico de la Formación Caranceja en el lectoestratotipo; la anchura de las microfotografías es 10 mm si no se indica otra cosa. A. Caliza rudstone bioclástica con espina de equínido (ech), foraminífero orbitolínido (orb), lituólido grande (flecha), bioclastos micritizados (me), y granos de cuarzo redondeados (qrz); muestra Cu2. C. Caliza packstone bioclástica limosa con pequeños lituólidos y espinas de equínidos (ech); muestra Cu4. D. Pequeño oncoide subesférico; muestra Cu3. E. Caliza rudstone bioclástica rica en corales (comparar con Figs. 5G, H) con granos de cuarzo redondeados (qrz), orbitolínidos, miliólidos (arriba a la izquierda), y bioclastos micritizados; muestra Cu5. F. *Boueina* sp.; sample Cu5, la anchura de microfotografía es 2,5 mm. G. Limolita bioclástica de la secuencia de inundación. Los componentes oscuros corresponden a granos de glauconita o bioclastos glauconitizados; muestra Cu6. H. Capa terminal del Miembro calcarenítico: caliza grainstone/packestone con abundantes fragmentos de braquiópodos y equinodermos. G = granos de glauconita; obsérvese las grietas de desecación en el grano ampliado (aprox. 0,8 mm de diámetro) que sugieren su carácter autigénico; muestra Cu7.


me
orb
ech
qrz
A
orb
g
qrz
g
orb
B
ech
alg
C
D
qrz
qrz
E
F
G
g
g
g
g
H


A1
A2
B1
B2
C
D
coarse sandstone
E

5. Discussion

According to the bio-/lithostratigraphic and sedimentologic data presented above, a correlation of the Cuchía and Reocín sections is proposed (Fig. 11). In the lower part of the sections, a major, latest Barremian-earliest Aptian transgression is indicated by the deposition of the shallow marine Calcarenite Member of the Caranceja Formation above continental siliciclastics of the Cantabrian Wealden facies. The Calcarenite Member also occurs ca. 8 km to the southeast of Cuchía, south of Oruña in the valley of the Rio Pas, where it reaches a thickness of ca. 30 m (Pascal, 1985, p. 286). The transgression probably proceeded from N to S or NE to SW (see also Pascal, 1985). At the more distal Cuchía section, basinal sediments (Marl Member) were deposited after the drowning of the carbonate system of the Calcarenite Member in the early Early Aptian.

In the proximal Reocín section, deltaic sedimentation prevailed, probably fed from the S by the uplifted Cabuerniga Ridge. Finally, this delta prograded towards the north (Cuchía). A subsequent flooding of the delta system (Cuchía Delta) established a carbonate platform represented by the San Esteban Limestone Formation. At the transition from the Early to the Late Aptian, the platform was fragmented and (at least partially) subaerially exposed in response to tectonic activity of the Gargasian event. The overlying beds of the Cuchía Formation record renewed delta progradation and differential subsidence by rapid lateral facies and thickness changes (see Birkenhake, 1996). Ammonites from the Reocín section indicate an early Late Aptian age for these beds (Collignon *et al.*, 1979).

Above, the homogenous, micritic platform carbonates of the Reocín Formation spread across much of the NCB. The proposed correlation suggests a predominant siliciclastic input from the S for the Caranceja Formation (i.e., the Marl Member is replaced by a thicker Sandstone Member in the south, Fig. 11). Also in the type area west of Torrelavega and south of Oruña (see Fig. 1A), the upper parts of the formation are predominantly sandy and characterized by a deltaic environment (delta front to delta plain).

Despite warm water conditions as indicated by the occurrence of corals, calcareous algae, micritic envelopes, and suggested by the subtropical palaeolatitude between 25-30°N (e.g., Masse, 2000), the carbonate facies of the Calcarenite Member is rather ‘temperate’, i.e., heterozoan-dominated (abundance of suspension-feeding and

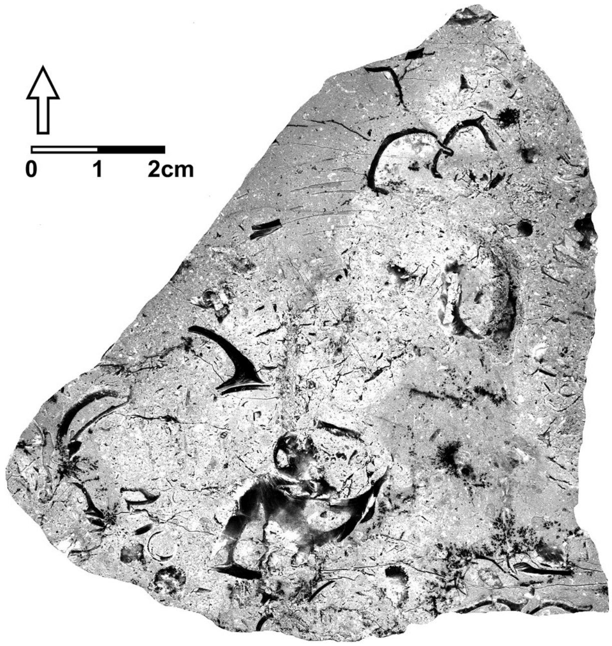


Fig. 9.– Polished slab of a bioclastic rudistid floatstones with a miliolid wackestone matrix, San Esteban Limestone Formation at Playa de los Caballos.

Fig. 9.– Sección pulida de calizas floatstones bioclásticas de rudístidos con matriz de caliza wakestone con miliólidos, Formación calizas de San Esteban en la Playa de los Caballos.

Fig. 8.– Field aspects of the Sandstone Member of the Caranceja Formation, the San Esteban Limestone Formation, and the Cuchía Formation. A1, A2. Convoluted sandstone beds from the Sandstone Member of the Caranceja Formation (fallen blocks at the base of the cliff). B1, B2. Intense bioturbation by *Ophiomorpha nodosa* (note the pelletoid lining in B2) from the Sandstone Member of the Caranceja Formation (lens cap is 65 mm in diameter). C. Large wood fragment (arrow) in coarse-grained, mica-rich, bioturbated sandstone; Sandstone Member of the Caranceja Formation. D. Primary biogenic accumulation of rudistid bivalves (?*Requienia*) from the San Esteban Limestone Formation, top of the cliff south of Playa de los Caballos. E. Erosional conglomerate (arrow) in the lower part of the Cuchía Formation at Playa de Cuchía (see Fig. 1B) overlain by coarse-grained sandstone. The poorly to moderately rounded pebbles consist of micritic limestone, probably derived from the San Esteban Limestone Formation.

Fig. 8.– Aspectos de campo del Miembro de areniscas de la Formación Caranceja, de la Formación calizas de San Esteban, y de la Formación Cuchía. A1, A2. Capas de arenisca con estratificación convoluta de Miembro de areniscas de la Formación Caranceja (bloques caídos en la base del acantilado). B1, B2. Intensa bioturbación de *Ophiomorpha nodosa* (obsérvese la envuelta de peloides en B2) en el Miembro de areniscas de la Formación Caranceja (el diámetro de la tapa del objetivo es de 65 mm). C. Fragmento de tronco de tamaño grande (flecha) en arenisca de grano grueso micácea bioturbada; Miembro de areniscas de la Formación Caranceja. D. Acumulación biogénica primaria de bivalvos rudístidos (*Requienia*?) de la Formación calizas de San Esteban, parte superior del acantilado meridional de la Playa de los Caballos. E. Conglomerado erosional (flecha) el la parte inferior de la Formación Cuchía (ver Fig. 1B) sobre el que se apoyan areniscas de grano grueso. Los cantos poco o moderadamente redondeados son de caliza micrítica, posiblemnte procedentes de la Formación calizas de San Esteban.

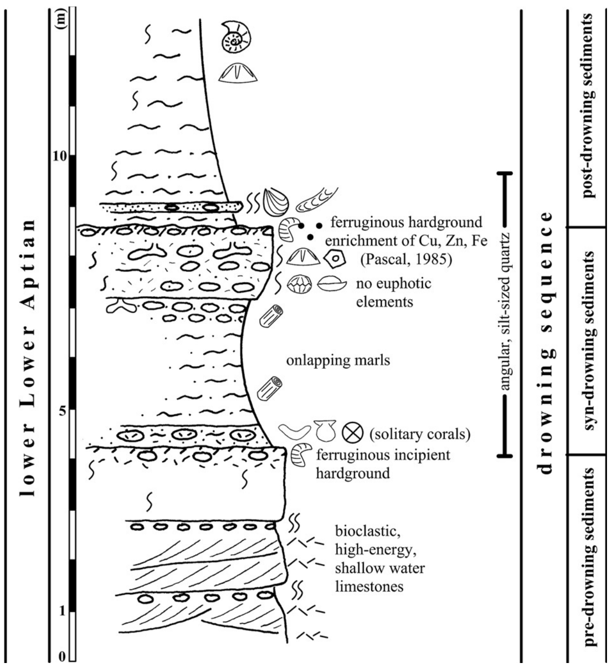


Fig. 10.– Detailed log of the early Early Aptian drowning sequence at the transition of the Calcarenite Member to the Marl Member of the Caranceja Formation; legend as in Figure 4.

Fig. 10.– Columna estratigráfica detallada de la secuencia de inundación del Aptiense inferior temprano en la transición del Miembro calcarenítico al Miembro margoso de la Formación Caranceja; ver leyenda en la Figura 4.

deposit-feeding organisms). This fact is attributed to a nutrient surplus which suppressed photozoan communities adapted to stable, oligotrophic conditions (e.g., Lees, 1975; Hallock and Schlager, 1986; Brasier, 1995). The nutrients were introduced into the marine system by fluvial input as suggested by high siliciclastic input and plant debris. According to Rat (1989) and García-Mondéjar (1990), the climate during the Early Aptian was wet subtropical. The depositional setting was a homoclinal carbonate ramp, and the Calcarenite Member represents high-energy inner ramp sandwaves, somewhat sheltered inter-sandwave areas, and tidal channels.

The shallow water sediments of the Calcarenite Member are capped by a mineralized (Fe, glauconite) incipient hardground encrusted by oysters and are onlapped by deeper water marls with ammonites. The abrupt facies change suggests a drowning of the juvenile shallow water carbonate system. However, the drowning sequence started already below with the onlap of silty marls (cf. Figs. 2D, 11). Euphotic (i.e., shallow water) elements such as calcareous green algae flourishing in the upper, light-saturated part of the water column (e.g., Liebau, 1984), are absent from the last limestone bed of the member. Instead, suspension- and deposit-feeding organisms (oysters, brachiopods, echinoids) occur abundantly. The drowning of the carbonate ramp represented by the Calcarenite Member of the Caranceja Formation is attributed to a combination of effects, i.e., synsedimentary tectonics associated with an eustatic sea-level rise and environmental perturbations:

The Calcarenite Member transgressed across a flat-lying coastal plain in the NCB represented by the upper part of the Cantabrian Wealden facies. No significant facies differentiation appeared to exist in a S-N direction between Reocín and Cuchía during the deposition of the Calcarenite Member. A change occurred in the uppermost part of the member when deeper water marls (Marl Member) started to accumulate in Cuchía, onlapping towards the N (Liencres High), whereas deltaic sediments spread in the Reocín area. These observations can best be explained by a rotation and differential subsidence of the Santander Block (see Fig. 1D). The carbonate ramp stepped back onto the Liencres High and finally drowned, whereas from the S (Cabuerniga Ridge), siliciclastic sediments were shed into the NCB. Later on, the basin was filled with (pro-) deltaic sediments of the northward prograding Cuchía Delta, and the San Esteban Carbonate Platform could spread across a levelled area. According to Agirrezabala and García-Mondéjar (1992), synsedimentary tectonics was the main controlling factor for relative sea-level changes during the Aptian in the Aulesti area in the northeastern Basque-Cantabrian region.

The growth potential of the Calcarenite Member carbonate ramp was obviously not high enough to compensate the relative sea-level rise resulting from increased subsidence and eustatic rise during the early Early Aptian (see also Pascal, 1987). According to the ammonite faunas, however, this drowning event is also coincident with the oceanic anoxic event (OAE) Ia (Early Aptian *fissicostatus* to *forbesi* zones; see, e.g., Bralower *et al.*, 1994). During the Barremian-Aptian interval, eruption of large igneous provinces combined with peaking sea-floor spreading rates caused a pronounced sea-level rise and severe environmental perturbations (increasing rainfall and temperature, marine eutrophication due to increased continental weathering and introduction of hydrothermal trace metals such as Fe, Ni, Cu, Zn; see Larson and Erba, 1999; Leckie *et al.*, 2002).

The drowning of the juvenile carbonate system of the Calcarenite Member of the Caranceja Formation can also be related to these environmental perturbations as indicated by a drastic increase in Fe, Cu, and Zn contents in the drowning sequence (Pascal, 1985); these hydrothermal metals are known as biolimiting elements triggering primary productivity (e.g., Behrenfeld and Kolber,

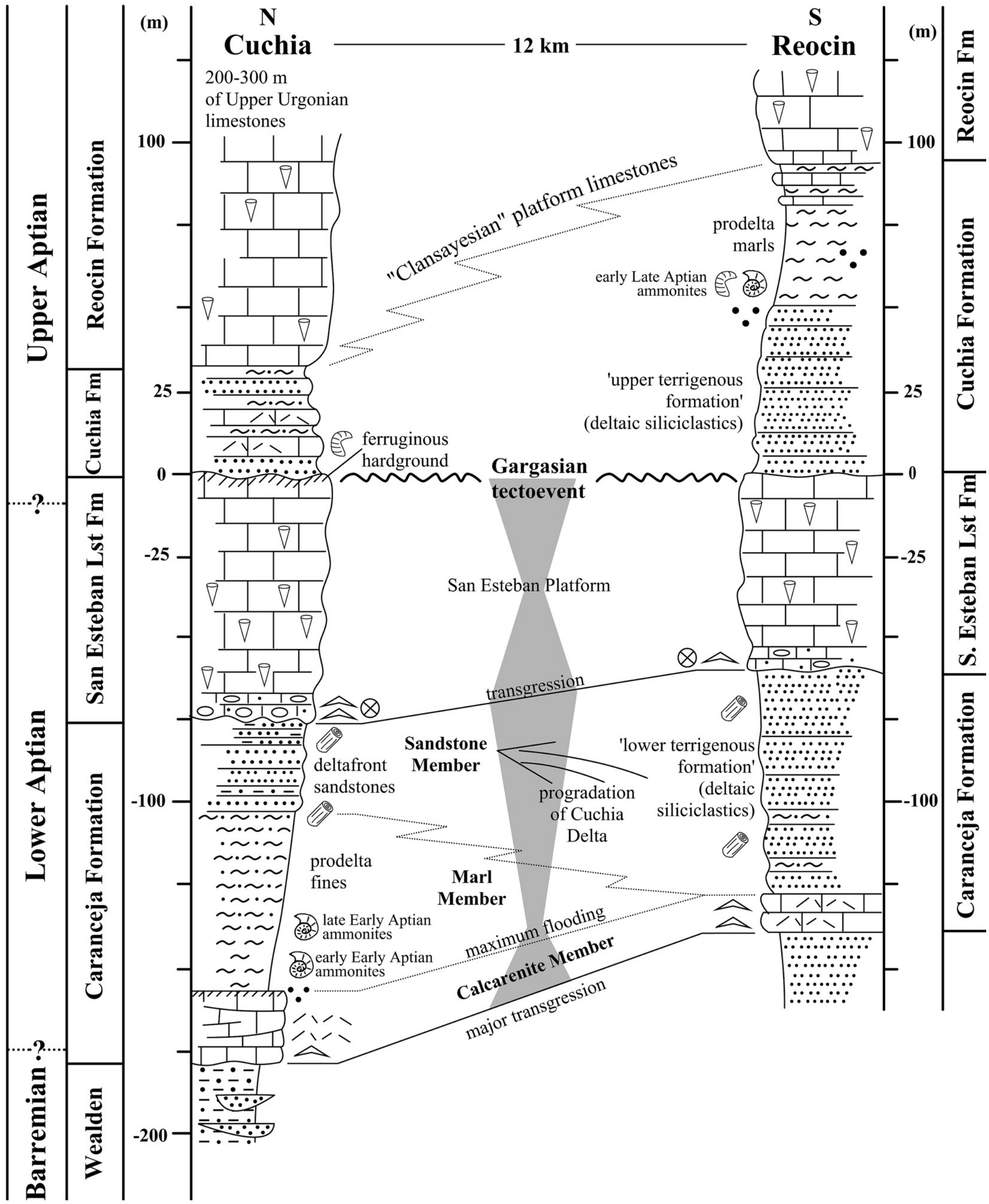


Fig. 11.– Proposed correlation between the sections at Cuchía and at Reocín (partly after data from Collignon *et al.*, 1979, and Birkenhake, 1996); legend as in Figure 4.

Fig. 11.– Correlación propuesta entre las secciones de Cuchía y de Reocín (parcialmente a partir de datos de Collignon *et al.*, 1979, y Birkenhake, 1996); ver leyenda en Figura 4.

1999). Eutrophic conditions are also suggested by the abundance of heterotrophic organisms and an increase in siliciclastic content (angular, silt-/fine sand-sized quartz) in the drowning sequence (cf. Brasier, 1995). Carbonate systems usually react with strongly reduced accumulation rates to these environmental perturbations and are, thus, prone to drowning even by moderate sea-level rises (e.g., Hallock and Schlager, 1986; Weissert *et al.*, 1998).

Above the terminal drowning unconformity, Lower Aptian basinal marls with ammonites of 'English' (Boreal) affinities (see Casey, 1961; Casey *et al.*, 1998) and silty prodelta marls accumulated in Cuchía whereas to the south (Reocín, Oruña, Caranceja, see Fig. 1A), deltafront and delta plain sediments were deposited. During the late Early Aptian, this delta system (the 'Cuchía Delta') prograded northwards and became the locus of shallow water carbonate deposition later on (upper Lower Aptian San Esteban Limestone Formation). The retrograding of the delta system is indicated by the onlap of sandy-marly ('peri-deltaic') limestones rich in orbitolinids; comparable transgressive "*Orbitolina*" beds are known from the Lower Aptian of southern Spain (Vilas *et al.*, 1995) and the Cenomanian of the NCB (Wilmsen, 1997, 2000).

The evolving carbonate platform was predominantly characterized by 'muddy' carbonates (miliolid wackestones, bio-floatstones, rudistid bafflestones) which were deposited in a lagoonal setting of an attached (coastal) platform. However, terrigenous input was very low, suggesting more distant sources and/or a somewhat dryer climate during the later Early to early Late Aptian (Rat, 1989, suggested a cooler climate during the early late Aptian). The sedimentary cycle of the Lower Aptian was terminated at the Gargasian unconformity, caused by enhanced tectonic activity in the Biscay Ocean (e.g., Pascal, 1982; Wiedmann *et al.*, 1983). The Gargasian event caused a fragmentation of the juvenile coastal platform of the San Esteban Limestone Formation. The correlation between Cuchía and Reocín (Fig. 11) suggest differential subsidence, limestone conglomerates indicate uplift and erosion. Reports of tectonic movements from this interval also from the Isle of Wight, England (Casey, 1961, pp. 500-501) support the inter-regional significance of the tectonic event.

6. Conclusions

The litho- and biostratigraphy as well as the (bio-)facies development of the Lower Aptian in the central part of the North Cantabrian Basin (NCB) are re-evaluated and the following conclusions were obtained:

(1) The Lower Aptian Caranceja Formation (García-Mondéjar, 1982a) is described and formalized herein. It consists of a lower Calcarenite Member (shallow marine limestones), a middle Marl Member (basinal-prodeltaic marls), and an upper Sandstone Member (deltafront sediments). A lectostratotype is designated and figured, and a sedimentological interpretation is presented. A correlation to Reocín near Torrelavega (12 km to the SSW) is suggested, outlining the distribution and lateral facies changes of the Caranceja Formation.

(2) In response to a pronounced transgression, a latest Barremian-earliest Aptian carbonate ramp depositional system was established in the central North Cantabrian Basin, overlying continental deposits (Wealden facies). This system is documented by the Calcarenite Member of the Caranceja Formation, representing the early developmental stages of the Urgonian system in the NCB. The biofacies of the Calcarenite Member is clearly predominated by heterozoans albeit water temperatures were probably sufficient to support the deposition of coralgal carbonates. A strong terrigenous nutrient input under wet-subtropical climate is held responsible for the deposition of rather 'temperate' carbonates.

(3) Shortly after its establishment, the 'juvenile' carbonate ramp system was drowned in the early Early Aptian *fissicostatus* to *forbesi* zones. The drowning sequence culminated in the development of a condensed, mineralized hardground capping the Calcarenite Member, overlain by ammonite-bearing deep water marls. Stratigraphical, sedimentological, biofacies, and geochemical data suggest that the drowning occurred in response to synsedimentary tectonics, eustatic sea-level rise, and environmental perturbations associated with the Early Aptian oceanic anoxic event OAE Ia.

(4) The Calcarenite Member is overlain by deep water marls of the Marl Member of the Caranceja Formation. Two ammonite levels indicate an early Early and a late Early Aptian age, respectively (Collignon *et al.*, 1979). Up-section increasing terrigenous input and the transition to the deltafront siliciclastics of the Sandstone Member of the Caranceja Formation indicate the progradation of a delta system into the central NCB during the late Early Aptian. The correlation with Reocín suggests that this presumably tide-dominated 'Cuchía Delta' prograded from the south.

(5) A renewed flooding of the NCB during the latest Early Aptian established a shallow marine carbonate platform represented by the uppermost Lower Aptian San Esteban Limestone Formation. The San Esteban Limestone Formation was deposited in a lagoonal setting of an attached platform nearly complete lacking terrigenous input. The San Esteban Platform was fragmented by inter-regional tectonic movements associated with the Gargasian event (Early to Late Aptian boundary interval).

Acknowledgements

Reviews by J. Lehmann (Bremen) and an anonymous reviewer are gratefully acknowledged. F. Birkenhake (Berlin), B. Niebuhr (Würzburg) and F. Wiese (Berlin) are thanked for joint fieldwork. Many thanks to the editorial team of Journal of Iberian Geology for the Spanish translations of Abstract and Figure captions.

References

Agirrezabala, L.M., García-Mondéjar, J. (1992): Tectonic origin of carbonate depositional sequences in a strike-slip setting (Aptian, northern Iberia). *Sedimentary Geology*, 81(3-4): 163-172.

Allen, J.R.L. (1970): Studies in fluviatile sedimentation: A comparision of fining upwards cyclothems with special reference to coarse-member composition and interpretation. *Journal of Sedimentary Petrology*, 40: 298-323.

Behrenfeld, M.J., Kolber, Z.S. (1999): Widespread iron limitation of phytoplankton in the South Pacific Ocean. *Science*, 283: 840-843.

Birkenhake, F. (1996): Erläuterungen zur geologischen Kartierung bei Miengo (Provinz Kantabrien, N-Spanien). *Diploma thesis, FU Berlin*: 54 p. (unpublished).

Brasier, M.D (1995): Fossil indicators of nutrient levels. 1: Eutrophication and climatic change. In: D.W. Bosence, P.A. Allison (eds.): *Marine palaeoenvironmental analysis from fossils*. Geological Society of London Special Publication, 83: 113-132.

Bromley, R.G. (1996): *Trace fossils – Biology, taphonomy and applications*, 361 p., 2nd edition, Chapman and Hall, London.

Buchanan, H., Streeter, S.S., Gebelein, C.D. (1972): Possible living algal-foraminiferal consortia in nodules from modern carbonate sediments of Great Bahama Bank. *American Association of Petroleum Geologists Bulletin*, 56: 606.

Burchette, T.P., Wright, V.P. (1992): Carbonate ramp depositional systems. *Sedimentary Geology,* 79: 3-57.

Carranante, G., Esteban, M., Milliman, J.D., Simone, L. (1988): Carbonate lithofazies as paleolatitude indicators: problems and limitations. *Sedimentary Geology*, 60: 333-346.

Casey, R. (1961): The stratigraphical palaeontology of the Lower Greensand. *Palaeontology*, 3: 487-621.

Casey, R., Bayliss, H.M., Simpson, M.I. (1998): Observations on the lithostratigraphy and ammonite succession of the Aptian (Lower Cretaceous) Lower Greensand of Chale Bay, Isle of Wight, UK. *Cretaceous Research*, 19: 511-533.

Collignon, M., Pascal, A., Peybernès, B., Rey, J. (1979): Faunes d' ammonites de l'Aptien de la région de Santander (Espagne). *Annales de Paléontologie (Invertébrés)*, 65: 139-156.

Dunham, R.J. (1962): Classification of carbonate rocks according to depositional texture. In: W.E. Ham (ed.): *Classification of carbonate rocks*. American Assocociation of Petroleum Geologists Memoir, 1: 108-121, AAPG, Tulsa.

Ehrlich, R.N., Barrett, S.F., Ju, G.B. (1990): Seismic and geologic characteristics of drowning events on carbonate platforms. *American Assocociation of Petroleum Geologists Bulletin*, 74 (10): 1523-1537.

Elliott, T. (1974): Interdistributary bay sequences and their genesis. *Sedimentology*, 21: 611-622.

Elliott, T. (1986): Deltas. In: H.G. Reading (ed.): *Sedimentary environments and facies*, 113-154, Blackwell, Oxford.

Embry, A.F., Klovan, J.E. (1972): Absolute water depth limits of Late Devonian paleoecological zones. *Geologische Rundschau*, 61: 672-686.

Erba, E. (1995): The Aptian Stage. *Bulletin de l' Institut Royal des Sciences Naturales de Belgique (Sciences de la Terre),* 66: 31-43.

Farrell, K.M. (1987): Sedimentology and facies architecture of overbank deposits of the Mississippi River, False River Region, Louisiana. In: F.G. Ethridge, R.M Flores, M.D. Harvey (eds.): *Recent developments in fluvial geology*. Society of Economic Paleontologists and Mineralogists Special Publication, 39: 111-120, Tulsa.

Feuillée, P. (1967): Le Cénomanien des Pyrénées basques et Asturies. *Mémoirs de la Société géologique de France, nouvelle série*, 46: 1-343.

Feuillée, P. (1971): Les calcaires biogéniques de l'Albien et du Cénomanien Pyrénéo-Cantabrique: problèmes d'énvironment sèdimentaires. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 9: 277-311.

Feuillée, P., Rat, P. (1971): Structures et paléogéographies pyrénéo-cantabriques. In: J. Debyser, X. Le Pichon, L. Montadert (eds.): *Colloque de l'Histoire du Golfe de Gascogne*, 2: 1-45, Edition Technip, Paris.

Folk, R.L. (1959): Practical petrographic classification of limestones. *American Association of Petroleum Geologists, Bulletin*, 43: 1-38.

Friedman, G.M. (1969): Trace elements as possible environmental indicators in carbonate sediments. In: G.M. Friedman (ed.): *Depositional environments in carbonate rocks*. Society of Economic Paleontologists and Mineralogists Special Publication, 14: 193-198, Tulsa.

Galloway, W.E. (1975): Process framework for describing the morphologic and stratigraphic evolution of deltaic depositional systems. In: M.L. Broussard (ed.): *Deltas: Models for Exploration*, 87-98, Houston Geological Society, Houston.

Galloway, W.E. (1981): Depositional architecture of Cenozoic Gulf coastal plain fluvial systems. In: F.G. Ethridge, R.M. Flores (eds.): *Recent and ancient nonmarine depositional environments: models for exploration*. Society of Economic Paleontologists and Mineralogists Special Publication, 31, 127-155, Tulsa.

García-Mondéjar, J. (1982a): Aptiense y Albiense. In: Grupo Español de Trabajo Proyecto n.o 58 Mid-Cretaceous Events: *El Cretacico de España*, 63-84, Universidad Complutense, Madrid.

García-Mondéjar, J. (1982b): Tectónica sinsedimentaria en el Aptiense y Albiense de la región Vasco-Cantábria occidental. *Cuadernos de Geología Ibérica*, 8: 23-36.

García-Mondéjar, J. (1989): Strike-slip subsidence of the Basque-Cantabrian Basin of Northern Spain and its relationship to Aptian-Albian opening of the Bay of Biscay. In: A.J. Tankard, H.R. Balkwill (eds.): *Extensional tectonics and stratigraphy of the North Atlantic margins*. American Association of Petroleum Geologists, Memoir, 46: 395-409, AAPG, Tulsa.

García-Mondéjar, J. (1990): The Aptian-Albian carbonate episode of the Basco-Cantabrian Basin (N-Spain): general characteristics, controls, and evolution. In: M.E. Tucker, J.L. Wilson, P.D. Crevello, J.F. Sarg, J.F. Read (eds.): *Carbonate Platforms*. International Association of Sedimentologists Special Publication, 9: 291-323, Blackwell, Oxford.

Gischler, E., Gräfe, K.-U., Wiedmann, J. (1994): The Upper Cretaceous *Lacazina* Limestone in the Basco-Cantabrian and Iberian Basins of Northern Spain: Cold water grain associations in warm-water environments. *Facies*, 30: 209-246.

Gusic, I. (1981): Variation range, evolution, and biostratigraphy of *Palorbitolina lenticularis* (Blumenbach) (Foraminiferida, Lituolacea) in the Lower Cretaceous of the Dinaric Mountains in Yugoslavia. *Paläontologische Zeitschrift*, 55 (3-4): 191-208.

Hallock, P., Schlager, W. (1986): Nutrient excess and the demise of coral reefs and carbonate platforms. *Palaios*, 1: 389-398.

James, N.P. (1997): The cool-water carbonate depositional realm. In: N.P. James, J.A.D. Clarke (eds.): *Cool-water carbonates*. Society Of Economic Paleontologists And Mineralogists Special Publication, 56: 1-20, Tulsa.

Kemper, E. (1982): Zur Gliederung der Schichtfolge der Apt-Unter Alb. *Geologisches Jahrbuch (A*) 65: 21-33.

Kemper, E. (1987): Das Klima der Kreidezeit. *Geologisches Jahrbuch* (A) 96: 5-185.

Larson, R.L., Erba, E. (1999): Onset of the mid-Cretaceous greenhouse in the Barremian-Aptian: Igneous events and the biological, sedimentary, and geochemical responses. *Paleoceanography*, 14 (6): 663-678.

Leckie, Bralower, T.J., Cashmann, R. (2002): Oceanic anoxic events and plankton evolution: Biotic response to tectonic forcing during the mid Cretaceous. *Paleoceanography*, 17(3): 13/1-13-29.

Leeder, M.R. (1995): Continental rifts and proto-oceanic rift troughs. In: C.J. Busby, R.V. Ingersoll (eds.): *Tectonics of sedimentary basins*, 119-148, Blackwell, Oxford.

Leeder, M.R., Gawthorpe, L.R. (1987): Sedimentary models for extensional tilt-block/half-graben basins. In: M.P. Coward, J.F. Dewey, P.L. Hancock (eds.): *Continental extensional tectonics*. Geological Society Special Publication, 28: 139-152, Geological Society, London.

Lees, A. (1975): Possible influence of salinity and temperature on modern shelf carbonate sedimentation. *Marine Geology*, 19: 159-198.

Lees, A., Buller, A.T. (1972): Modern temperate water and warm water shelf carbonate sediments contrasted. *Marine Geology*, 13: 1767-1773.

Liebau, A. (1984): Grundlagen der Ökobathymetrie. *Paläontologische Kursbücher*, 2: 149-184.

Masse, J.-P. (2000): Early Aptian (112-114 Ma). In: J. Dercourt, M. Gaetani, B. Vrielynck, E. Barrier, B. Biju-Duval, M.F. Brunet, J.P. Cadet, S. Crasquin, M. Sandulescu (eds.): *Atlas Peri-Tethys palaeogeographical maps*, 119-127, Gauthier-Villars, Paris.

Mengaud, L. (1920): Recherches géologiques dans la région cantabrique. *Bulletin de la Societé Histoire naturelle de Toulouse*, 48: 73-272.

Miall, A.D. (1996): *The geology of fluvial deposits: sedimentary facies, basin analysis and petroleum geology*, 582 p., Springer, Berlin.

Mutterlose, J. (1998): The Barremian-Aptian turnover of biota in northwestern Europe: evidence from belemnites. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 144: 161-173.

Odin, G.S., Matter, A. (1981): De glauconarium origine. *Sedimentology*, 28: 611-641.

Olivet, J.L. (1996): La cinématique de la Plaque Ibérique (Kinematics of the Iberian Plate). *Bulletin des Centres de Recherche Exploration-Production Elf Aquitaine*, 20 (1): 131-195.

Pascal, A. (1982): Evolution des systèmes biosédimentaires urgoniens en Espagne du Nord. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 165 (1): 77-86.

Pascal, A. (1985): Les systèmes biosédimentaires urgoniens (Aptien-Albien) sur la marge Nord Ibérique. *Mémoires géologiques de l'Université de Dijon*, 10: 1-569.

Pascal, A. (1987): Effets combinés de la téctonique regionale et de l'eustatisme dans les oscillations de la mer urgonienne en Espagne du Nord (Aptien-Albien). *Mémoires géologiques de l'Université de Dijon*, 11: 203-212.

Picard, M.D., High, L.R. Jr. (1972): Criteria for recognizing lacustrine rocks. In: J.K. Rigby, W.K. Hamblin (eds.): *Recognition of ancient sedimentary environments*. Society of Economic Paleontologists and Mineralogists Special Publication, 16: 108-145, Tulsa.

Pujalte, V. (1981): Sedimentary succession and paleoenvironments within a fault-controlled basin: the "Wealden" of the Santander area, northern Spain. *Sedimentary Geology*, 28: 293-325.

Ramirez del Pozo, J. (1971): Bioestratigrafía y microfacies del Jurásico y Cretácico del Norte de España (Region Cantábrica). *Memoria del Instituto Geologico y Minero de España*, 78: 1-357.

Rat, P. (1959): Les pays crétacés basco-cantabrique (Espagne). *Publications de l'Université de Dijon*, 18: 1-525.

Rat, P. (1989): The Iberian Cretaceous: Climatic implications. In: J. Wiedmann (ed.): *Cretaceous of the Western Tethys*. Proceedings 3rd International Cretaceous Symposium, Tübingen 1987: 17-25, Schweizerbart, Stuttgart.

Reitner, J. (1987): Mikrofazielle, palökologische und paläogeographische Analyse ausgewählter Vorkommen flachmariner Karbonate im Basko-Kantabrischen Strike Slip Fault-Becken-System (Nordspanien) an der Wende von der Unterkreide zur Oberkreide. *Documenta naturae*, 40: 1-239 p.

Salvador, A. (ed.) (1994): *International stratigraphic guide. A guide to stratigraphic classification, terminology and procedure*, 214 p., 2nd edition, Geological Society of America, Boulder.

Tedesco, L.P., Wanless, H.R. (1991): Generation of Sedimentary Fabrics and Facies by Repetitive Excavation and Storm Infilling of Burrow Networks, Holocene of South Florida and Caicos Platform, B.W.I. *Palaios*, 6 (3): 326-343.

Vilas, L., Masse, J.-P., Arias, C. (1995): *Orbitolina* episodes in carbonate platform evolution: the Early Aptian model from SE Spain. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 119: 35-45.

Weissert, H., Lini, A., Föllmi, K.B., Kuhn, O. (1998): Correlation of Early Cretaceous carbon isotope stratigraphy and platform drowning events: a possible link? *Palaeogeography, Palaeoclimatology, Palaeoecology*, 137: 189-203.

Wiedmann, J., Reitner, J., Engeser, T., Schwentke, W. (1983): Plattentektonik, Fazies- und Subsidenzgeschichte des baskokantabrischen Kontinentalrandes während Kreide und Alt-Tertiär. *Zitteliana*, 10: 207-244.

Wiese, F. (1995): Das mittelturone *Romaniceras kallesi*-Event im Raum Santander (Nordspanien): Lithologie, Stratigraphie, laterale Veränderung der Ammonitenassoziationen und Paläobiogeographie. *Berliner geowissenschaftliche Abhandlungen*, E 16 (1): 61-77.

Wiese, F., Wilmsen, M. (1999): Sequence stratigraphy in the Cenomanian to Campanian of the North Cantabrian Basin (Cantabria, N-Spain). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 212 (1-3): 131-173.

Willis, B.J., Behrensmeyer, A.K. (1994): Architecture of Miocene overbank deposits in northern Pakistan. *Journal of Sedimentary Research*, B64, 60-67.

Wilmsen, M. (1997): Das Oberalb und Cenoman im Nordkantabrischen Becken (Provinz Kantabrien, Nordspanien): Faziesentwicklung, Bio- und Sequenzstratigraphie. *Berliner geowissenschaftliche Abhandlungen*, E 23: 1-167.

Wilmsen, M. (2000): Evolution and demise of a mid-Cretaceous carbonate shelf: The Altamira Limestones (Cenomanian) of northern Cantabria (Spain). *Sedimentary Geology*, 133: 195-226.

Wilmsen, M., Wiese, F., Ernst, G. (1996): Facies development, events and sedimentary sequences in the Albian to Maastrichtian of the Santander depositional area, northern Spain. *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg*, 77: 337-367.

Wright, L.D., Coleman, J.M. (1974): Mississippi river mouth processes: Effluent dynamics and morphologic developments. *Journal of Geology*, 82: 751-778.

Wright, L.D. (1985): River deltas. In: R.A. Davies (ed.): *Coastal sedimentary environments*. 1-76, Springer, New York.