

# Correlation of sedimentary events during the Latest Cenomanian from the Basque Basin to the Castilian Ramp (Northern Spain)

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## ABSTRACT

*Sedimentologic, biostratigraphic and geochemical analyses of the Late Cenomanian - Early Turonian series of the deep Basque Basin and of the Navarre-Cantabrian distal Ramp and Castilian proximal Ramp, allow: 1) to correlate sedimentary events such as the sedimentation of thin layers of organic matter-bearing laminated black shales in the Basque Basin and as the formation of glauconitic-pyritic bioturbated hardgrounds on the Navarre-Cantabrian and Castilian Ramps, 2) to date these events from the Archaeocretacea Zone, 3) to interpret them as evidence of anoxia in the basin and hypoxia on the ramps, and as results of major marine deepening and transgression.*

**Key-words:** black shales, glauconitic hardgrounds, latest Cenomanian, anoxia, hypoxia, marine transgression and deepening, Basque Basin, Navarre-Cantabrian and Castilian Ramps

## RESUMEN

*Estudios sedimentológicos, bioestratigráficos y geoquímicos de series de edad Cenomanense superior - Turonense inferior de la Cuenca profunda Vasca, de la Rampa distal Navarro-Cantábrica y de la Rampa somera Castellana han permitido: 1) correlacionar la deposición de arcillas negras laminadas (black shales) en la Cuenca Vasca con la formación de superficies endurecidas (hardgrounds) glauconíticas en las Rampas Navarro-Cantábrica y Castellana, 2) situar estos eventos en la Zona de Archaeocretacea, 3) interpretar dichos depósitos como indicadores de anoxia en la cuenca profunda y de hipoxia sobre las rampas, resultado de una profundización y transgresión marina mayor.*

**Palabras clave:** arcillas negras laminadas, superficie endurecida, glauconita, Cenomanense final, anoxia, hipoxia, profundización y transgresión, Cuenca Vasca, Rampas Navarro-Cantábrica y Castellana

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## Aim and subject of the study

One of the aims of studies in sedimentary geology is to know whether various events recorded at the same moment in different deposits and depositional environments have a common origin. This feature is obviously necessary for any attempt to correlate events, particularly in sequence stratigraphy which is supposed to trace the same events across wide areas, at least from a basin to its margins.

Similarly, a study was carried out (Métais, 1995) on the formations deposited around the Cenomanian-Turonian boundary along a transect leading from the deep Basque Basin up to the epicontinental Castilian Ramp (Northern Spain, Fig. 1). The choice of the epoch was due to the fact that numerous studies have al-

ready shown that biosedimentary events had taken place quite everywhere around the Cenomanian-Turonian boundary (Arthur *et al.*, 1987; Schlanger *et al.*, 1987; Philip and Airaud-Crumière, 1991; Hancock, 1993; Ulicny *et al.*, 1993). The choice of the transect was motivated by the fact that the palaeogeographies corresponding to the biosedimentary series deposited during the Late Cenomanian and Early Turonian in the Basque-Cantabrian countries were known (Mathey, 1987; Floquet, 1991).

Three sections are described in order to represent the main deposits and corresponding depositional palaeoenvironments crossed by the transect: 1) the Iciar section, representative of the pelagic and oceanic deposits and palaeoenvironments of the deep Basque Basin, 2) the Sobrón

section, representative of the hemipelagic deposits and palaeoenvironments of the distal Navarre-Cantabrian Ramp, 3) the Rocamundo section, representative of the neritic deposits and palaeoenvironments of the proximal Castilian Ramp (Fig. 1 and 2).

## Main analytical results

### 1) Iciar section

This section is particularly interesting because, for the first time in the Basque Country, it provides black shale layers around the Cenomanian-Turonian boundary. The section shows 4 units, from base to top:

-Unit 1: 5 meters of limestones and marls with very abundant *Pithonella* sp. and planktonic foraminifera including

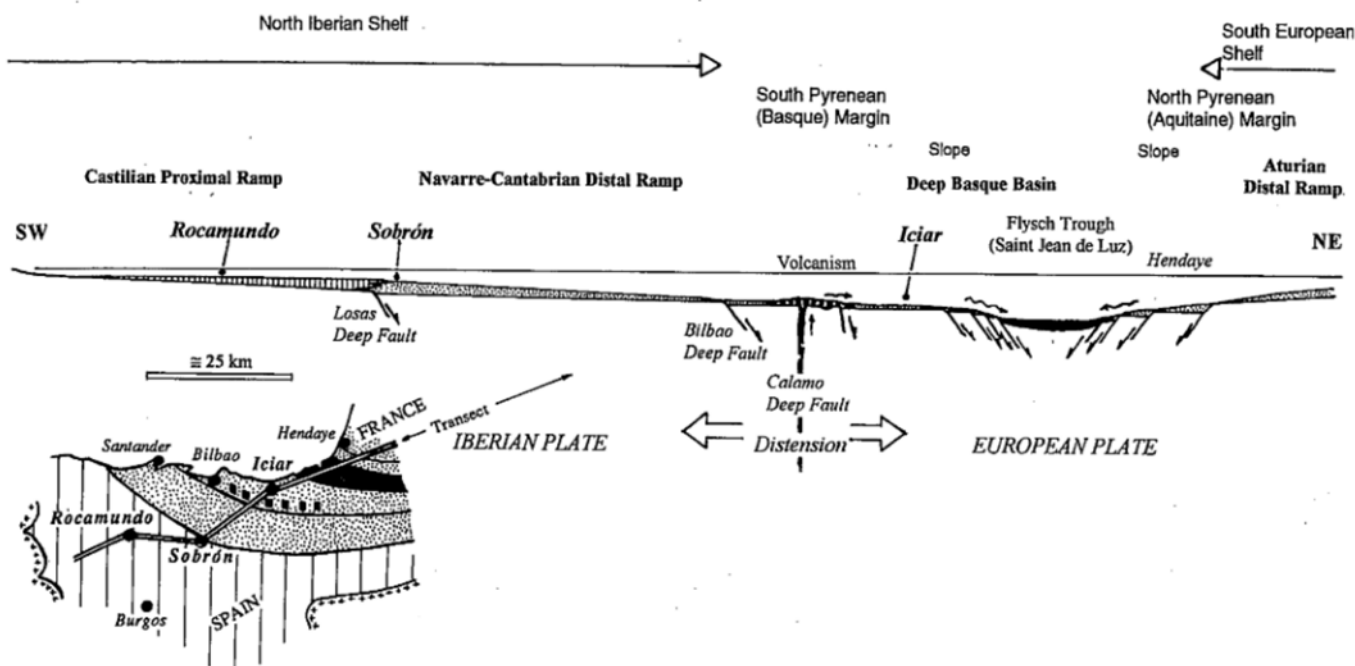


Fig. 1.- Location of the sections on a schematic transect and palaeogeography showing the main depositional environments from the Castilian Ramp (North-Iberian) to the Aturian Ramp (South-European) during the Late Cenomanian.

Fig. 1.- Localización de los cortes sobre un perfil esquemático y paleogeografía regional mostrando los medios de depósitos desde la Rampa Castellana (Noribérica) hasta la Rampa Aturiana (Sureuropea) durante el Cenomanense superior.

*Rotalipora cushmani*, *R. deckei*, *R. greenhornensis*, *Praeglobotruncana stephani*.

-Unit 2: 1 meter of alternate argillaceous limestones beds and layers of laminar and fissile dark clays (black shales) bearing organic matter (about 3%). The calcareous beds as well as the black shales contain some laminae of volcanic microlites. The black shales enclose only dwarf and indeterminate planktonic foraminifera. The two basal calcareous beds of unit 2 contain some *Rotalipora cushmani* which disappear definitely in the upper beds.

-Unit 3: about 4 meters of argillaceous limestones with very plentiful planktonic foraminifera including *Praeglobotruncana cf. praeaelvetica*, *Whiteinella aprica*, *W. baltica*, *Dicarinella cf. hagni*, *D. sp.*

-Unit 4: 5 meters of limestones including some thin turbidites (thickness ranging from 0,5 to 3 centimeters) consisting of volcanoclastic grains. *Margino-truncana pseudolinneiana* and *M. sigali* appear from the base and *M. coronata* around the top.

The  $\delta^{13}\text{C}$  values (on whole rock) range from +1‰ to +2‰ with a general trend to increase upward. However, the values are highly variable in unit 2 (black shales) with a negative shift (+1,1‰) at

the base, a positive shift (+3‰) in the middle and a negative one (+1,9‰) at the top.

The  $\delta^{18}\text{O}$  values (on whole rock) are highly negative and fluctuating from -6,4‰ to -7,7‰ with a well marked variation in unit 2 (black shales) from -7,23‰ to -6,7‰ and then up to -7,6‰.

Trace element values (on whole rock) range from 430ppm to 1700ppm for Mn, from 1393ppm to 4650ppm for Fe, from 584ppm to 3007ppm for Sr and from 1020ppm to 9410ppm for Mg. The Mn values slightly decrease from unit 1 to unit 3, with a negative shift in unit 2, then distinctly increase in unit 4. The Fe values generally decrease from units 1 to 4, with a positive shift and a negative one in unit 2. The Sr values don't vary a lot but a positive shift in unit 2. The Mg values generally decrease from units 1 to 4, with a very positive shift in unit 2.

#### 2) *Sobrón* section

The section shows 6 units, from base to top:

-Unit 1: 7 meters of thick bedded limestones separated by thin bedded marls sometimes dark coloured. The last two calcareous beds have distinctly bioturbated and partially hardened surfaces. Facies are bioclastic and bioturbated wackestones - packstones, glauconitic and pyritic, with numerous *Pithonella* sp. and

rare planktonic foraminifera including *Heterohelix* sp. and *Praeglobotruncana stephani*.

-Unit 2: 4 meters of a marly and calcareous sequence. The marls contain many foraminifera, 30% of which are planktonic and include *Hedbergella delrioensis*, *Whiteinella aprica*, *W. sp. aff. baltica*, *W. cf. brittonensis*, *Praeglobotruncana stephani*, *Dicarinella* sp. The limestones are bioclastic and bioturbated wackestones - packstones.

-Unit 3: 5 meters of marls containing the same microfauna as seen previously plus *Ammobaculites* sp., *Dicarinella algeriana* and many ostracods.

-Unit 4: 5 meter-thick bed of argillaceous limestone, bioturbated and nodular, especially at its top. Textures are bioclastic wackestones and packstones, the remains coming from echinoderms, lamellibranchs (including prodissococonchs), sponges, bryozoans, benthonic and planktonic foraminifera including *Heterohelix* sp., *Hedbergella* sp., *Praeglobotruncana* sp., *Pithonella* sp. cf. *sphaerica* (up to 50% of the biophase). Glauconite is present.

-Unit 5: 8 meters of argillaceous limestones and marls, including a bed of nodular limestone with framboidal pyrite, glauconite, remains of corals encrusted by serpulids, in the lower half. A biotur-

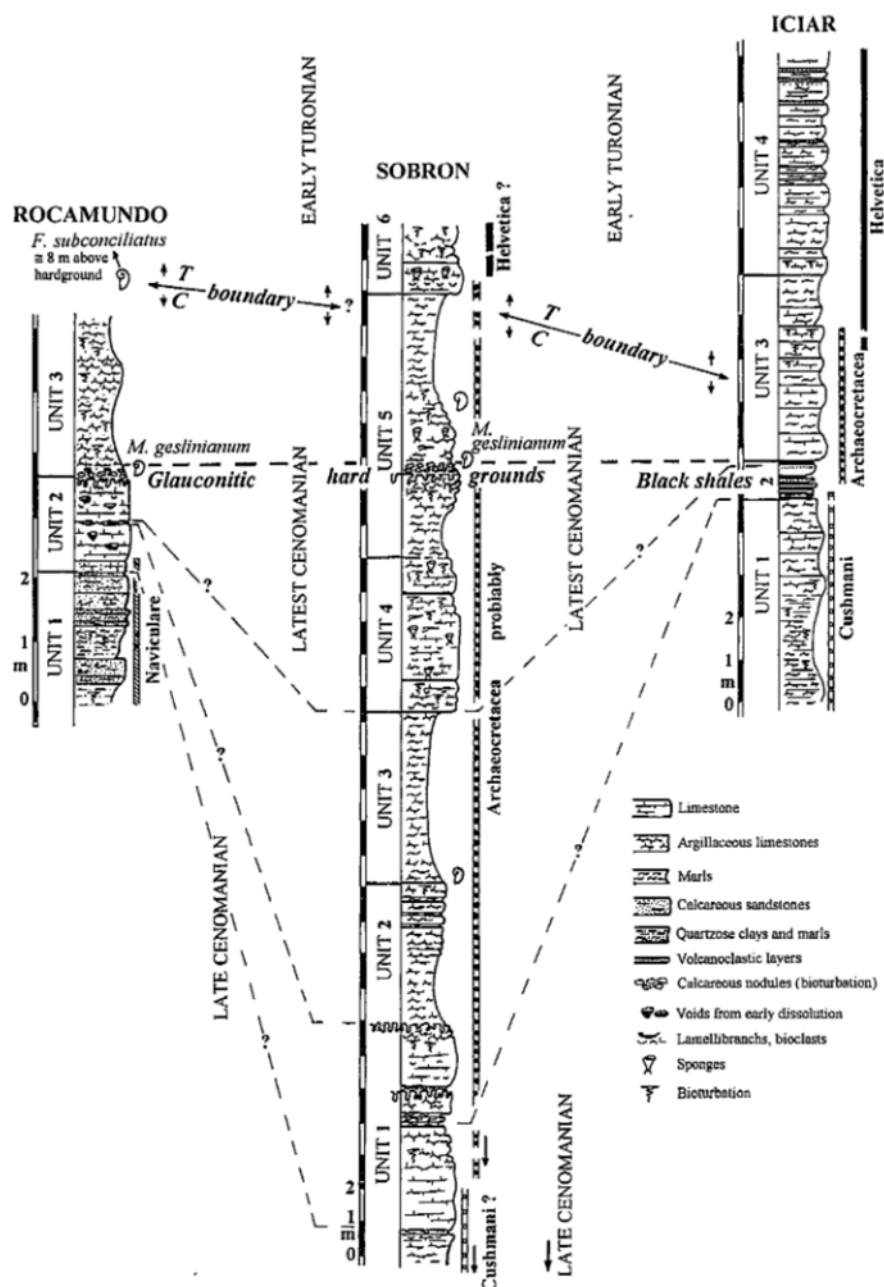


Fig. 2.- Tentative correlation of the Late Cenomanian - Early Turonian unconformities and lithostratigraphic units from the section of the deep Basque Basin (Iciar) to the sections of the Navarre-Cantabrian distal Ramp (Sobron) and Castilian proximal Ramp (Rocamundo).

Fig. 2.- Ensayo de correlación de las discontinuidades y de las unidades litoestratigráficas de edad Cenomanense final y Turonense inferior entre los cortes de la Cuenca profunda Vasca (Iciar), de la Rampa distal Navarro-Cantábrica (Sobron) y de la Rampa somera Castellana (Rocamundo).

bated and bored hardground ends this bed. The walls of the burrows and borings are made green by a glauconitic coating. Two fragments of ammonites were found over this surface: despite their poor preservation, they are recognized as *Metoicoceras* sp. cf. *geslinianum*. Ostracods, benthonic and planktonic foraminifera

are abundant and varied. *Praeglobotruncana gibba*, *Dicarinella hagni* and *D. imbricata* are frequent in the upper marls.

-Unit 6: about 10 meters of bioturbated argillaceous limestone, bioclastic packstone with glauconitic peloids, remains from pycnodontids, inoceramids, sponges, bryozoans, serpulids, echinoderms,

foraminifera including *Heterohelix* sp., *Praeglobotruncana gibba*, *Dicarinella hagni*, *D. imbricata* and *Whiteinella* sp. among the planktonic ones.

The carbon isotopic curve has a general trend decreasing with  $\delta^{13}\text{C}$  values ranging from +4,5‰ to +1,5‰. A negative shift takes place on the whole of unit 5 comprising the lowest value of +1,5‰.

The  $\delta^{18}\text{O}$  values range from -6,4‰ to -3,8‰ and are less negative than those recorded from the Iciar section. The oxygen isotopic curve has a trend decreasing from the base to the top and reveals the lowest value at the glauconitic hardground of unit 5.

Trace element values range from 104ppm to 248ppm for Mn (except for an anomalous value of 1604ppm in dark marls of the unit 1) and with a peak at 221ppm from the glauconitic hardground of unit 5; from 1574ppm to 3865ppm for Fe, with a peak at 2871ppm from the glauconitic hardground of unit 5 and the minima at 1581ppm and 1574ppm from samples located 2 and 3 meters above this hardground; from 306ppm to 518ppm for Sr (except for an anomalous value of 3156ppm in dark marls of unit 1); from 3120ppm to 5352ppm for Mg. With regard to the mean values noticed at Iciar, the mean values calculated at Sobron are respectively considerably lower for Mn, lower for Fe and Sr, clearly higher for Mg.

### 3) Rocamundo section

The section shows 3 units, from base to top:

-Unit 1: 2 to 2.5 meters of quartzose marls and of argillaceous-quartzose and bioclastic limestones, with glauconite. Bioclasts proceed from lamellibranchs, gastropods, echinoderms, green algae, corals. The microfauna includes some foraminifera, solely benthonic, and ostracods. The macrofauna comprises *Costa-gyra olisiponensis*, *Rhynchostreon suborbiculatum*, *Strombus* sp. mainly.

-Unit 2: 1.5 meter-thick bed of bioturbated and glauconitic limestones. Textures are bioclastic wackestones - packstones, the remains proceeding from the same organisms as seen above plus some small planktonic foraminifera and *Pithonella* sp. Some voids from early dissolution, centimetric in size, are filled with micrite enriched in *Pithonella* sp., *Heterohelix* sp. and small *Globotruncanidae*. The top of the bed is very irregular hardground or firmground, clearly bored or bioturbated, nodular. The infillings of the burrows or borings as well as the nodules or intraclasts are markedly glauconitic and pyritic.

-Unit 3: 3 meters of bioturbated and nodular argillaceous limestones. Macrofauna is condensed in the basal nodules directly originating from the underlying calcareous bed and includes: *Hemiasper verneuli*, *Phaseolina phaseolina*, *Tylosoma* sp., *Pycnodonte* cf. *vesiculosum*, *Rhynchostreon* sp., *Metoicoceras* cf. *geslinianum*. Ostracods and benthic foraminifera are present as well as *Pithonella* sp. and *Heterohelix* sp.

The carbon isotopic curve has a general trend increasing with the  $\delta^{13}\text{C}$  values ranging from +1.16‰ to +4.9‰, that is to say similar to those noticed at Sobrón, and with the maximum negative shift (+1.16‰) just above the glauconitic hardground.

The  $\delta^{18}\text{O}$  values range from -7.28‰ to -4.12‰ with a general trend to decrease from the base to the top.

Mn values vary from 114ppm to 286ppm and, on the whole, decrease from the base to the top, except for a slight positive shift around the glauconitic hardground. Fe values are very high, ranging from 2157ppm to 6370ppm and, generally speaking, decreasing from the base to the top except for a positive shift around the glauconitic hardground like Mn values. Sr values, ranging from 193ppm to 358ppm, gently increase. Mg values are highly variable, from 18250ppm (the highest value from basal dolomitic facies) to 3369ppm.

#### Correlation of events

1) The biostratigraphic data, essentially proceeding from the planktonic foraminifera and ammonites and, at a lesser degree, from ostracods, enable to date the black shale layers found in the Iciar section as well as the various glauconitic and pyritic hardgrounds found in the Sobrón and Rocamundo sections, from the Archaeocretacea Zone of the Latest Cenomanian (*Metoicoceras geslinianum* appears together with *Neocardioceras*

*juddii* in the Cassis section, SE France, P. Jolet, personal communication and thesis in progress). In any case, the Cenomanian - Turonian boundary is located above the sedimentary events demonstrated here (Fig. 2).

2) The events were linked to a low rate of sedimentation around the Cenomanian - Turonian boundary, namely: a very low rate in the deep Basque Basin (Iciar) which appears to have been starved, a low rate, too, on the Castilian proximal Ramp (Rocamundo) where sedimentary hiatuses seem important, a relatively higher rate on the distal and subsident Navarre-Cantabrian Ramp (Sobrón) which could accumulate sediments.

3) The events were also linked to oxygen deficiency in the depositional environments: likely anoxia in the Basque Basin and momentary hypoxia on the Navarre-Cantabrian and Castilian Ramps.

4) Correlative anomalies in the curves of carbon and oxygen isotopic values and in the curves of trace element values underline the sedimentary events, even though these geochemical values appear to be different according to the distinct depositional and diagenetical environments.

5) Biological events seem to have been connected to the sedimentary events: 1) the disappearance of *Rotalipora cushmani* in the Basque Basin, at the base of the black shale layers (probably because of anoxia), 2) also the possible disappearance of *Rotalipora cushmani* on the Navarre-Cantabrian Ramp (undiscovered in the units described at Sobrón, whereas it was found in the underlying depositional sequence in the same section), 3) the bloom of *Pithonella* and *Heterohelix* on the Navarre-Cantabrian and Castilian Ramps whereas some benthonic foraminifera, rudistids and additional fauna or flora characteristic of the previous depositional sequences disappeared (Floquet, 1991).

#### Common causes of the events

The events which occurred at the same time, i. e. during the Archaeocretacea Zone of the Latest Cenomanian, on the whole Basque-Cantabrian passive margin and its Iberian hinterland, namely: 1) the deposition of the black shale beds and the formation of the glauconitic and pyritic hardgrounds, 2) the low sedimentation rate, 3) the anoxia or hypoxia, 4) the geochemical shifts, 5) the biological extinctions, are regarded as the results of an abrupt and marked marine transgression (and of the corresponding deepening of the depositional environments) demonstrated in previous works by palaeogeographical reconstruction.

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