

Österreichische Akademie der Wissenschaften
Schriftenreihe der Erdwissenschaftlichen Kommissionen

Band 15

Aspects of Cretaceous Stratigraphy and Palaeobiogeography

Proceedings of the 6th International Cretaceous Symposium
Vienna, 2000

edited by
Michael WAGREICH

OFFPRINT



Verlag der Österreichischen Akademie der Wissenschaften
Wien 2002

Österreichische Akademie der Wissenschaften
Schriftenreihe der Erdwissenschaftlichen Kommissionen

Band 15

Aspects of Cretaceous Stratigraphy and Palaeobiogeography

Proceedings of the 6th International Cretaceous Symposium
Vienna, 2000

edited by
Michael WAGREICH

OFFPRINT



Verlag der Österreichischen Akademie der Wissenschaften
Wien 2002

Calcareous nannofossils around the Coniacian/Santonian boundary interval in the Olazagutía section (N. Spain)

Mihaela C. MELINTE¹, Marcos A. LAMOLDA²

MELINTE, M. C. & LAMOLDA, M. A., 2002: Calcareous nannofossils around the Coniacian/Santonian boundary interval in the Olazagutía section (N. Spain). – In: WAGREICH, M. (Ed.): Aspects of Cretaceous Stratigraphy and Palaeobiogeography. – Österr. Akad. Wiss., Schriftenr. Erdwiss. Komm. 15: 351–364, 3 Figs., 1 Pl., Wien.

Abstract: The calcareous nannofossil content of the Upper Coniacian-Lower Santonian sediments of the Olazagutía section (Navarra Province, N Spain) was investigated. The analyzed samples yielded diversified nannofloral assemblages, belonging to Nannofossil Zones CC15 to CC16 of SISSINGH (1977) and UC10 to UC12 of BURNETT (1998) respectively. The following bioevents, in stratigraphic order, characterized the Coniacian/Santonian boundary interval in the studied section: successive FOs of nannofossils *Lithastrinus grillii* and *Lucianorhabdus cayeuxii* (Upper Coniacian); FO of nannofossil *Calculites obscurus*, including morphotypes (Uppermost Coniacian); FO of inoceramid *Platyceramus undulatopectatus* (Coniacian/Santonian boundary); FO of planktonic foraminifera *Dicarinella asymerica*, within the Lowermost Santonian, followed by the FO of planktonic foraminifera *Sigalia carpatica* (according to LAMOLDA et al., 1999); LO of nannofossil *Lithastrinus septenarius* (Lower Santonian).

Other nannofossil events observed in the analyzed succession are the high abundances of the *Lucianorhabdus* spp. and *Micula concava* (in the Coniacian-Santonian boundary interval), followed by the increasing abundance of *Calculites* (within the lowermost Santonian).

Keywords: Calcareous Nannofossils, Foraminifera, Biostratigraphy, Coniacian/Santonian Boundary, Olazagutía, Spain

1. INTRODUCTION

Pelagic and/or hemipelagic marine sediments, which yield rich and well preserved fossil associations, were deposited in the Navarro-Cantabrian Trough (N Spain) during the Upper Cretaceous. In particular, an exceptional preservation of the marine sediments covering the Coniacian/Santonian boundary is present. Previous biostratigraphical studies of the Coniacian-Santonian Interval from northern Spain have documented the presence in these sediments of diverse macro- and microfossils, as well as nannofossil assemblages typical of low-middle latitudes (LAMOLDA, 1984; RODRÍGUEZ & LAMOLDA, 1986; FLORES et al., 1987; SANTAMARÍA, 1992; MARTÍNEZ et al., 1996).

Among the sections with a continuous sedimentation across the Coniacian/Santonian boundary interval is that at Olazagutía, in the Navarra Province (N Spain). This section

¹ National Institute for Geology and Marine Geocology. Dimitrie Onciul 23–25, 70388 Bucharest, Romania, E-mail: melinte@geoecomar.ru

² Facultad de Ciencias-UPV, 48940 Lejona, España, E-mail: gpplapam@lg.ehu.es

was selected during the Second International Symposium on Cretaceous Stage Boundaries (Brussels, 1995) as one of the three candidates for the Coniacian/Santonian Boundary Stratotype Section. The other two proposed sections are Seaford Head (Sussex, England) and Ten Mile Creek (Dallas, USA).

Recently, the Santonian Working Group recommended two biomarkers for recognizing the Coniacian/Santonian boundary (LAMOLDA & HANCOCK, 1996):

- primary marker: the lowest occurrence of the inoceramid species *Platyceramus undulaticus* (ROEMER). This taxon is widespread (known from North America, Africa and central Asia) as well as being easily recognizable;
- secondary marker: the lowest occurrence of the planktonic foraminiferal species *Sigalia carpatica* SALAJ & SAMUEL, a taxon especially common in the Mediterranean region.

Both marker species, *Platyceramus undulaticus* (KANNENBERG, 1985; GRÄFE, 1994; GALLEMÍ et al., 1997), and *Sigalia carpatica*, have been identified in Olazagutia (LAMOLDA et al., 1999).

Former studies of the Upper Coniacian and Lower Santonian sediments from Olazagutia (LAMOLDA et al., 1999) identified some important additional bioevents, such as the first occurrence (FO) of the planktonic foraminiferal species *Dicarinella asymetrica* (SIGAL), slightly above the Coniacian/Santonian boundary and the FO of the nannofossil *Lithastrinus grillii* STRADNER, below the boundary. Further sampling of the Olazagutia section, during 1998 and 1999, allow us to present detailed qualitative and quantitative studies of the calcareous nannofloras.

One aim of this paper is to describe the detailed biostratigraphy of the Coniacian/Santonian boundary interval, based on the nannofloral distribution from Olazagutia. To

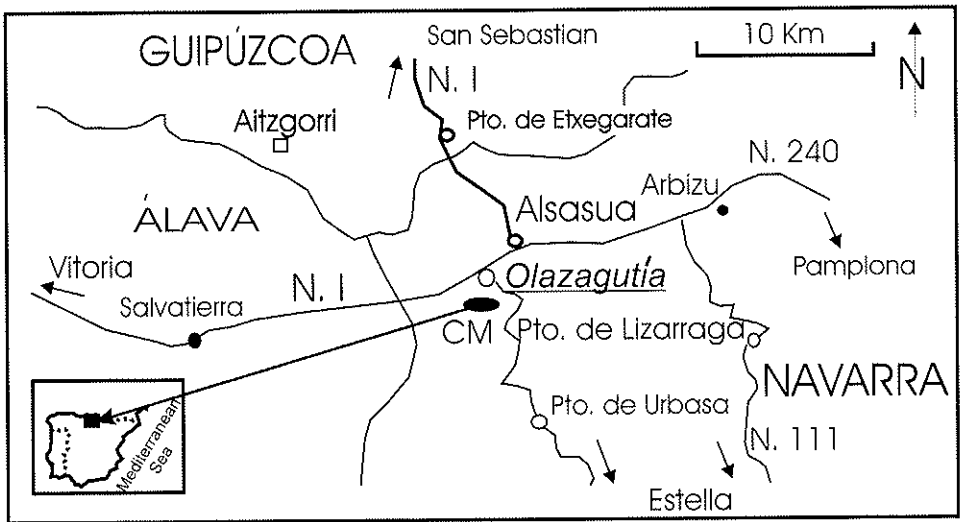


Fig. 1: Study area: the Olazagutia section (Navarra, NE Spain). CM = Cantera de Margas (Marl Quarry).

obtain an integrated biozonation of this interval, the nannofloral events were correlated with the macro- and microfaunal ones. A comparison of the nannofossil events observed in the Olazagutía section, around the Coniacian/Santonian boundary interval, with those recorded in other representative sections of the same interval, was also undertaken.

2. STUDY AREA

The Olazagutía section is located in the Eguibil Marl Quarry, Navarra Province, northern Spain (Fig. 1). The entire sequence exposed covers the Coniacian to Campanian. The Coniacian/Santonian boundary interval crops out along the access ramp to the main quarry face and constitutes a durable and periodically maintained exposure. The key interval is characterized lithologically by predominantly marly sedimentation, with some intercalations of marly limestones. The upper part of the succession studied is dominated by limestones.

The most abundant macrofossils are echinoids, represented by species of the genera *Micraster*, *Hemiaster*, *Cardiaster* and *Offaster* (GALLEMI et al., 1997; GALLEMI et al., 2000). Within the Coniacian/Santonian boundary interval, several biohorizons containing the inoceramid species *Platyceramus undulatoplicatus* were identified. The oldest occurrence of this taxon marks the Coniacian/Santonian boundary in this section. Ammonites are not particularly abundant. The first texanitid identified so far occurs 120m above the FO of *Platyceramus undulatoplicatus*. The Coniacian/Santonian boundary interval also yields diverse planktonic and benthic foraminiferal assemblages. The FO of the planktonic foraminifera *Dicarinella asymetrica* was observed slightly above (1.8m) the FO of *Platyceramus undulatoplicatus*, followed by the FO of *Sigalia carpatica* (LAMOLDA et al., 1999).

3. MATERIAL AND METHODS

A total of 30 samples, covering 46m of sediments, were investigated for their calcareous nannofossil content. Preparation of smear-slides for light microscope study followed the technique described in LAMOLDA et al. (1994). The distributions of the taxa listed in Fig. 2 were determined by light microscope techniques (normal light and crossed-nicols). Bibliographical references for the taxa recognized are given in PERCH-NIELSEN (1985) and BOWN (1998).

Both qualitative and quantitative studies of calcareous nannofossils were performed. For each slide at least 500 specimens were counted in randomly distributed longitudinal transverses. Species counts are expressed as a percentage of the total count for each assemblage. The diversity index is the number of taxa found in each sample.

The preservation of the observed nannofloral assemblages is moderate to good. Only a few specimens showed slight to moderate overgrowth. Partial dissolution of some taxa with delicate structures, such as *Corollithion exiguum* and *Corollithion signum*, was also observed.

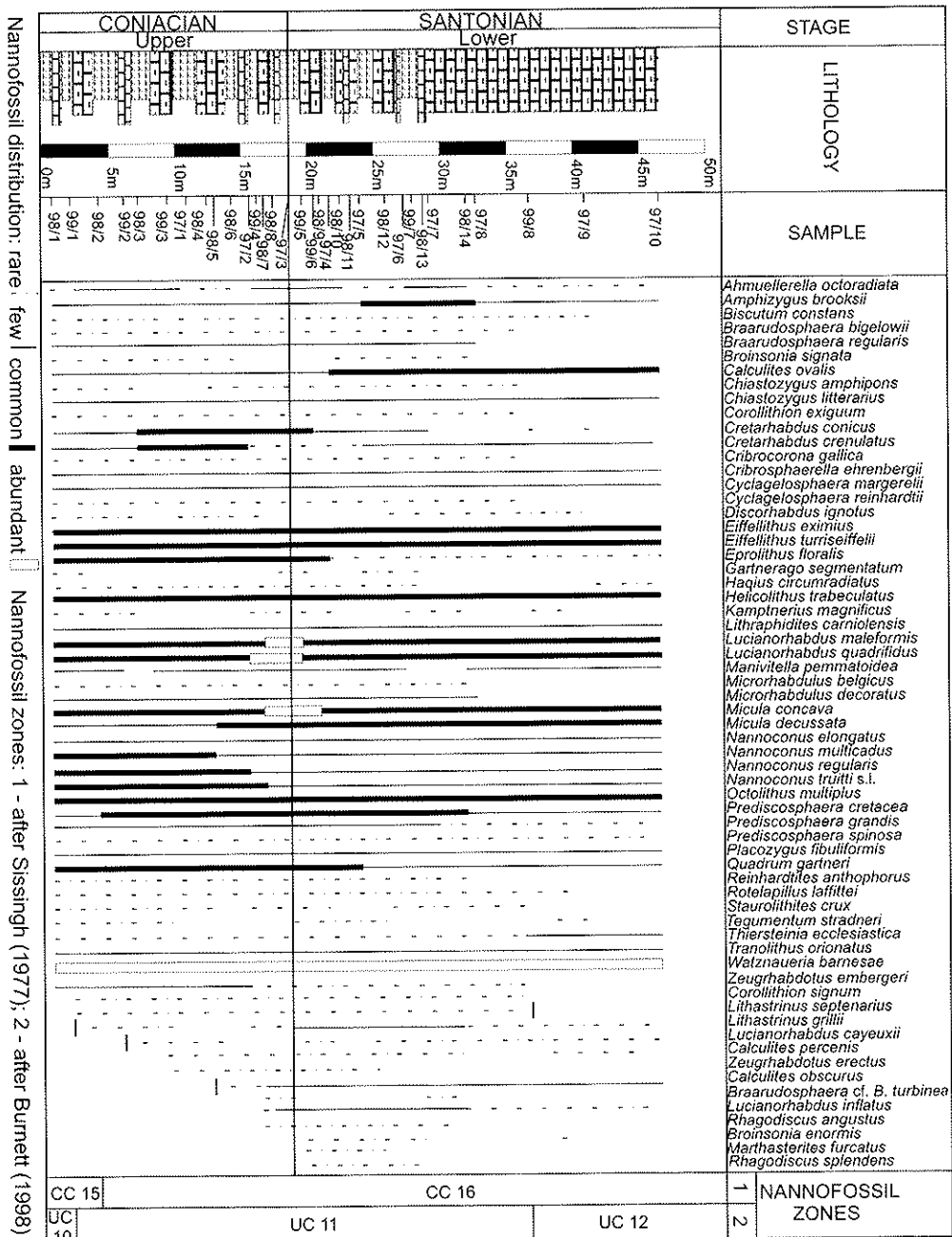


Fig. 2: Range-chart of nannofossil species in the Olazagutia section. Abundances were recorded as follows: A-abundant, >1specimen/field of view (FOV); C-common, 1 specimen/2-10 FOV; F-few, 1 specimen/11-20FOV; R-rare, 1 specimen/>20 FOV.

4. RESULTS

4.1. Diversity

The marly carbonate-rich sediments of the Coniacian/Santonian boundary interval from Olazagutía contain highly diverse nannofloral assemblages. In all, 63 different taxa were encountered in the succession studied (Fig. 2). Species diversity (number of species/sample) declines up-section, from about 50 species in the Upper Coniacian to about 40 species in the Lower Santonian. Relatively minor changes in diversity occur in the Upper Coniacian, whereas Lower Santonian samples show frequent shifts in diversity, especially near the Coniacian/Santonian boundary and in the lowermost Santonian.

The nannofossil assemblages are dominated by the long-ranging taxa *Watznaueria barnesae*, *Chiastozygus* spp., *Cretarhabdus* spp., *Eiffellithus* spp., *Prediscosphaera* spp. and *Tranolithus orionatus*. A high diversity of the Polycyclolithaceae, represented by the taxa *Eprolithus floralis*, *Lithastrinus grillii*, *Lithastrinus septenarius*, *Micula decussata*, *Micula concava* and *Quadrum gartneri* was also observed. *Prediscosphaera grandis* and *Cribracorona gallica*, taxa with their FOs within the Coniacian/Santonian boundary interval (BURNETT, 1998) are also present, but relatively rare.

A distinct component of the nannofossil assemblages is represented by holococcoliths. Commonly, *Lucianorhabdus maleformis*, *Lucianorhabdus inflatus*, *Lucianorhabdus quadrifidus* and *Lucianorhabdus cayeuxii*, as well as *Calculites ovalis*, *Calculites perennis* and several morphotypes of *Calculites obscurus* were identified.

Note that in Fig. 2 all the morphotypes of *Calculites obscurus* encountered in the studied section have been included in this taxon. Note further that these morphotypes (transitional forms from *Calculites ovalis* to *Calculites obscurus*), were first described from the Late Coniacian to Early Santonian sediments of the Gosau Group in Austria (WAGREICH, 1991).

Nannoconids, including: *Nannoconus truitti* s.l., *N. multicaudus*, *N. regularis* and *N. elongatus*, are also present throughout the succession.

Besides taxa having a continuous and consistent occurrence in the section, some species, such as *Biscutum ellipticum*, *Broinsonia signata*, *Gartnerago segmentatum*, *Marthasterites furcatus* and *Kamptnerius magnificus*, occur sporadically, especially in the Lower Santonian.

4.2. Abundance

Several calcareous nannofossil taxa from the Olazagutía section were selected for quantitative analysis. These include *Watznaueria barnesae*, *Micula concava*, *Micula decussata*, *Lucianorhabdus* spp., *Calculites* spp., *Nannoconus* spp. and *Eiffellithus* spp. (Fig. 3).

Watznaueria barnesae is abundant in all the samples. It is well known that this taxon is resistant to dissolution and diagenetic alteration and was the most abundant Cretaceous nannofossil. Dominance of this species is regarded as indicating diagenetic alteration. Associations in which *W. barnesae* exceeds 40% indicate strong dissolution according to ROTH & KRUMBACH (1986). However, other authors considered *W. barnesae* to be an eurytopic species (MUTTERLOSE, 1991) and to indicate diagenetic alteration only when it

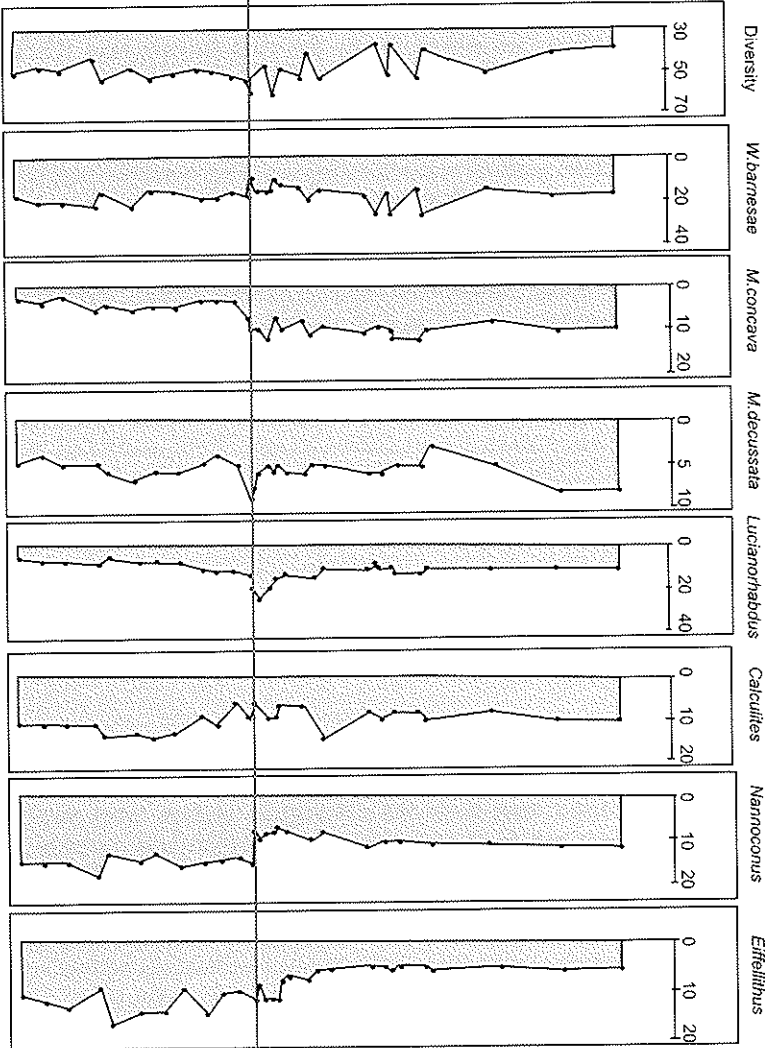
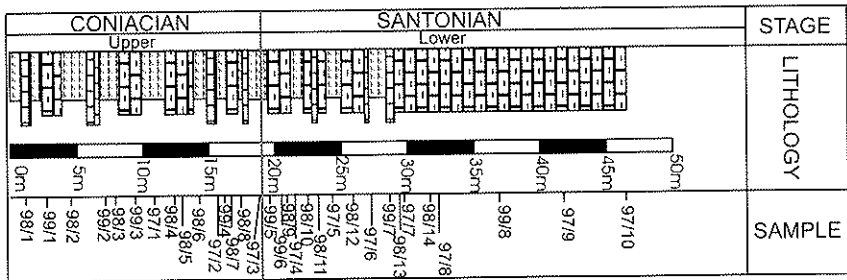


Fig. 3: Taxonomic diversity and fluctuations (in percentages) of selected calcareous nannofossil taxa in the Olazagutia section

forms more than 70% of the nannoflora (WILLIAMS & BRALOWER, 1995). In the Olazagutía section, *W. barnesae* represents between 9–26% of the total nannofloral assemblage, with the highest value in the Lower Santonian. Highest percentages of *W. barnesae* coincide with a low diversity and *vice-versa* (Fig. 3). This pattern, which is similar to that reported by ROTH & KRUMBACH (1986), indicates an inverse relationship between specific diversity and percentage of *W. barnesae* and is well known from Upper Cenomanian-Lower Turonian localities in northern Spain and southern England (LAMOLDA et al., 1994; LAMOLDA and GOROSTIDI, 1996; PAUL et al., 1999).

Other taxa selected for quantitative analyses are *Micula concava* and *Micula decussata*. The percentages of *Micula concava* vary between 2–12%, whereas *Micula decussata* represents 4–8% of the total nannofloral assemblage. There is also a positive correlation between *M. concava* and *M. decussata*, both species having the highest abundance at the top of the Coniacian. A similar abundance pattern to that shown by *M. concava* and *M. decussata* has been observed in the Upper Coniacian-Lower Santonian deposits of western Alava Province, northern Spain (GOROSTIDI et al., 1990).

The abundance of the *Lucianorhabdus* group (which includes *L. maleformis*, *L. quadrididus* and *L. cayeuxii*) varies from 6% to 21% of the total nannofloral assemblage, indicating a significant fluctuation through the section. This also correlates positively with the pattern for *Micula* spp. Note that the highest abundance of *Lucianorhabdus* was observed in the uppermost Coniacian, only a few centimeters below the FO of *Platyceramus undulatopicatus*.

The *Calculites* group (including *C. ovalis*, *C. percenis* and *C. obscurus*) represents between 7 and 15% of the total assemblage, with low values throughout the Coniacian/Santonian boundary, and a short and significant recovery in the lowermost Santonian.

The abundance of the *Nannoconus* group (including *N. elongatus*, *N. multicadus*, *N. regularis* and *N. truitti* s.l.) decreased up-section, varying between 7 and 18% of the total identified nannoflora. A sharp decrease was observed slightly below the Coniacian/Santonian boundary. A negative correlation between the abundance of *Lucianorhabdus* and *Nannoconus* was usually recorded.

Another analyzed group was *Eiffellithus* (which includes *E. turriseiffelii* and *E. eximius*). The abundance of this group decreased progressively up the succession. The highest recorded value is 18% of the total assemblage, in the Upper Coniacian, whereas the lowest is 5%, in the Lower Santonian.

5. DISCUSSION

5.1. Nannofossil occurrences, bio-events and biostratigraphy

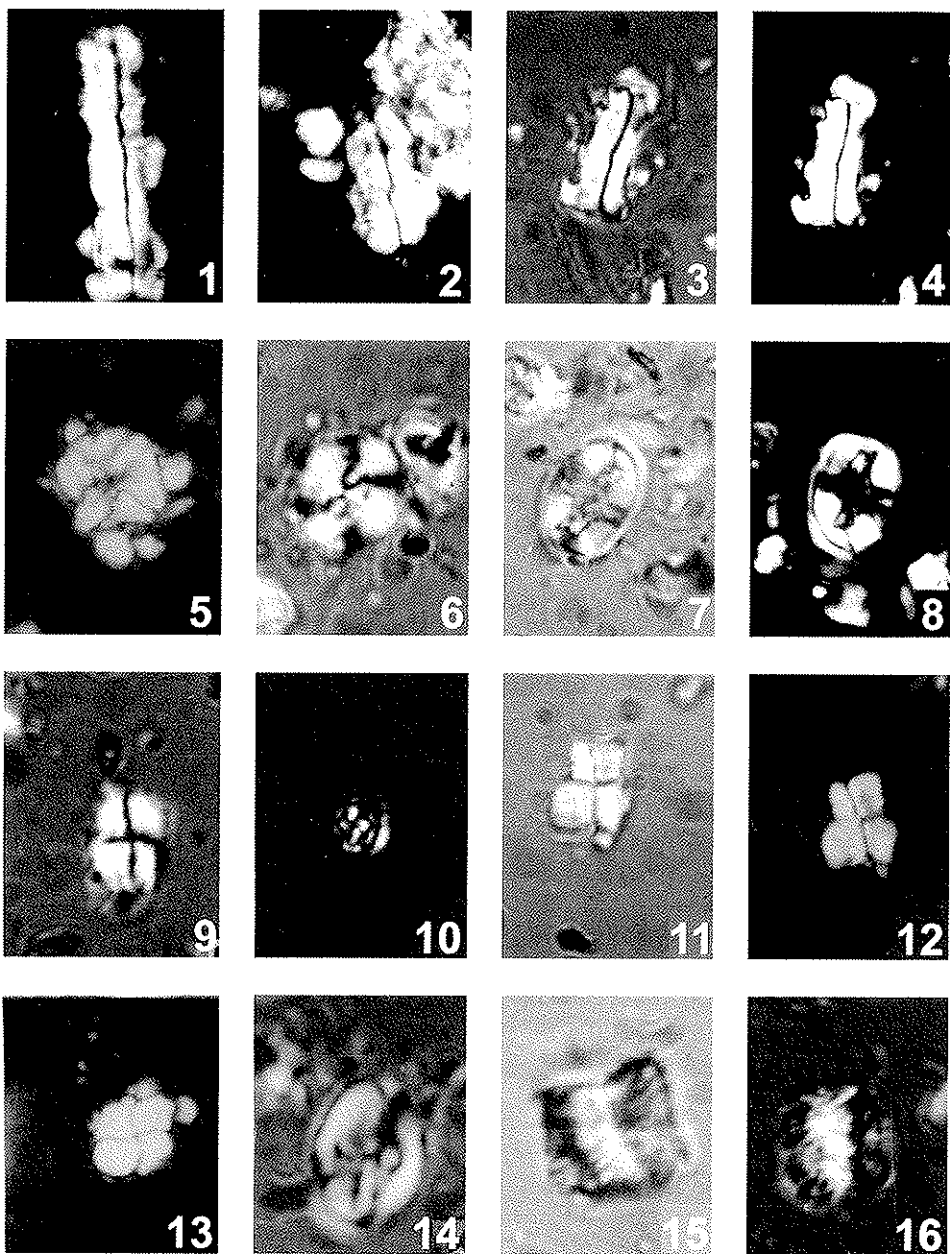
Over the last few decades several biozonation schemes based on calcareous nannofossils have been produced for the Upper Cretaceous (MANIVIT, 1971; SISSINGH, 1977; VERBEEK, 1977; PERCH-NIELSEN, 1985; BURNETT, 1998). MANIVIT (1971), studying the historical stratotype of the Santonian (from Saintes, W France) assigned to this stage one nannozone, using the FOs of *Kamptnerius magnificus* and *Broinsonia parca parca*. However, later studies revealed that *K. magnificus* had its FO in the Turonian, whereas the FO of *B. parca parca* is a Campanian event (ROTH, 1978; PERCH-NIELSEN, 1985). SISSINGH (1977) also

Plate 1

Light microscope, magnification x 3200

Figs. 1–2, 4–5, 8, 10, 12–12: cross polarized light. Figs. 3, 6–7, 9, 11, 14–15: phase contrast.

- Fig. 1: *Lucianorhabdus maleformis* REINHARDT, sample 97/3
Fig. 2: *Lucianorhabdus cayeuxii* DEFLANDRE, sample 98/4
Figs. 3, 4: *Lucianorhabdus quadrifidus* FORCHHEIMER, sample 97/5
Fig. 5: *Micula decussata* VEKSHINA, sample 97/3
Fig. 6: *Watznaueria barnesae* (BLACK) PERCH-NIELSEN, sample 97/5
Figs. 7 and 8: *Eiffellithus eximius* (STOVER) PERCH-NIELSEN, sample 99/1
Fig. 9: *Calculites ovalis* (STRADNER) PRINS & SISSINGH, sample 97/3
Fig. 10: *Prediscosphaera spinosa* (BRAMLETTE & MARTINI) GARTNER, sample 97/4
Figs. 11 and 12: *Quadrum gartneri* PRINS & PERCH-NIELSEN, sample 97/4
Fig. 13: *Calculites obscurus* (DEFLANDRE) PRINS & SISSINGH, sample 97/10
Fig. 14: *Thiersteinia ecclesiastica* WISE & WATKINS, sample 98/10
Fig. 15: *Nannoconus truitti rectangularis* DERES & ACHERITEGUY, sample 99/5
Fig. 16: *Nannoconus truitti truitti* BRÖNNIMANN, sample 98/7



investigated the Santonian of the same region of France (Saintes and adjacent areas) and divided this stage into two nannozones: CC15 and CC16, based on the FOs of *Reinhardtites anthophorus* and *Lucianorhabdus cayeuxii*, respectively. In his zonation, the boundary between the Coniacian and Santonian stages appeared to coincide with the base of CC15. Recent studies (BURNETT, 1998) showed that the index species of CC15 Nannozone first occurred in the Turonian. The same author (BURNETT, 1996) recalibrated the CC Nannozones of SISSINGH (1977) and put CC15 into the Upper Coniacian to Middle Santonian interval.

Since *Reinhardtites anthophorus*, the index species of the CC15 Nannozone, is easily affected by overgrowth and dissolution, WAGREICH (1992) considered that it is inappropriate to use this taxon as a marker species. In the Olazagutía section, *R. anthophorus* is present frequently from the base of the studied sequence.

Lithastrinus grillii is another nannofossil with a biostratigraphical value present in the succession. The FO of *L. grillii* occurs in the Upper Coniacian according to BURNETT (1998). This bio-event defines the base of her UC11 Nannozone and occurs within the *Micraster coranguinum* Echinoid Zone. VAROL (1992) also placed the FO of *L. grillii* in the upper part of the Coniacian. It is noteworthy that WAGREICH (1992) found the FO of *L. grillii* in the *Tridorsatum* Ammonite Zone (Middle Coniacian) in the Gosau Group of Austria, i.e. approximately at the same level as the FO of *Micula decussata*.

In the Olazagutía section, the FO of *Lithastrinus grillii* lies 15m below the Coniacian/Santonian boundary (Fig. 2). This bio-event occurs within the *Dicarinella concavata* Planktonic Foraminiferal zone. Note that a continuous and persistent occurrence of *L. grillii* was previously recognized close to the Coniacian/Santonian boundary, slightly below the boundary between the *Dicarinella concavata* and *Dicarinella asymetrica* Planktonic Foraminiferal Zones (LAMOLDA et al., 1999). However, new sampling has revealed older occurrences (sample 99-1), as cited above. Nevertheless, the condition of the exposures and the length of the section studied may not be sufficient to allow the accurate location of the oldest record of *L. grillii* in the Olazagutía Quarry. Thus the FO of *L. grillii*, as shown in Fig. 2, may not be a definitive level.

The next bioevent recorded in the Upper Coniacian deposits from Olazagutía is the occurrence of *Lucianorhabdus cayeuxii*, approximately 3m above the FO of *Lithastrinus grillii*. In contrast, note that in most Upper Cretaceous nannofossil studies, the FO of *Lucianorhabdus cayeuxii* has been recorded in the Santonian (SISSINGH, 1977; PERCH-NIELSEN, 1985; WAGREICH, 1992; SVABENICKA, 1992). BURNETT (1998) correlated this nannofloral event with macrofaunal ones, dating the FO of *L. cayeuxii* as of latest Coniacian age, older than previously reported. This evidence agrees with our record. Based on the FO of *L. cayeuxii*, the boundary between the CC15/CC16 SISSINGH's Zones could be recognized in the Olazagutía section, within the Uppermost Coniacian.

The youngest Coniacian nannofossil event observed in the studied section is the FO of *Calculites obscurus* (including its morphotypes), at 3.5m below the Coniacian/Santonian boundary. Within the Lower Santonian of Olazagutía, at the end of the occurrence interval of the inoceramid *Platyceramus undulatoplicatus*, the LO of the nannofossil *Lithastrinus septenarius* was recorded. This event marked the boundary between UC11/UC12 Nannozones of BURNETT (1998).

5.2. Palaeobiogeography

The Late Coniacian-Early Santonian was characterized by a low nannofossil provincialism, in comparison to other intervals of the Late Cretaceous (e.g. the Campanian stage, when the differences between nannofloras related to low-middle latitudes and to high-northern ones became more pronounced – BURNETT, 1990; SVABENICKÁ, 1995; MELINTE & ODIN, 2001).

Most of the nannofossils occurring around the Coniacian/Santonian boundary interval herein are cosmopolitan taxa, although a small number of them are more related to low-latitudes than to high ones. A significant component of the nannofloras from the Olazagutía section is *Watznaueria barnesae* the most abundant Cretaceous cosmopolitan nannofossil. THIERSTEIN (1981) indicated that this taxon shows a latitudinal distribution pattern: it is more common at low latitudes, becoming decreasingly common towards higher latitudes, although it is still an important component of high-latitude nannofloral assemblages.

The presence of nannofossils *Lithastrinus grillii* and *Lithastrinus septenarius*, both identified in the Olazagutía section, indicates, according to VAROL (1992), warm to temperate waters of low-mid latitudes.

Another important component of the assemblages identified in the studied section is the *Nannoconus* genus, which reached, at certain levels, >15% of the nannoflora (Fig. 3). Note that the Upper Cretaceous nannoconids are also believed to be more related to low-middle latitudes, than to high ones.

In contrast, *Kamptnerius magnificus* and *Gartnerago segmentatum*, recorded infrequently and discontinuously in samples from Olazagutía, and which are mainly restricted to the Lowermost Santonian, are usually common to abundant at high latitudes (THIERSTEIN, 1976), although THIERSTEIN (1981) reported *K. magnificus* as common also at low latitudes. SVABENICKÁ (1995) cited the above mentioned taxon as a cold water species. It is present in the Tethyan Realm, but infrequently, often related to cold water incursions into lower latitudes (e.g. in the Romanian Carpathians, where a similar distribution pattern has also been recorded for *Reinhardtites anthophorus* – MELINTE, 1999).

Note also the high abundance of holococcoliths in the section studied. These taxa are believed to be more abundant in nearshore and epicontinental areas than in open ocean ones (THIERSTEIN, 1976; PERCH-NIELSEN, 1985). This observation is consistent with the palaeogeographical setting of the Olazagutía section, situated in the Navarro-Cantabrian Basin, with sediments deposited on a rapidly sinking shelf.

6. CONCLUSIONS

This study of calcareous nannofossil from the Upper Coniacian-Lower Santonian sediments in the Olazagutía section (N Spain) revealed diverse assemblages, which can be assigned to CC15 to CC16 of SISSINGH'S (1977) Biozonation and to UC10 to UC12 in BURNETT'S (1998) scheme.

The Coniacian/Santonian Boundary thus falls into the CC16 and UC11 Nannozones respectively.

The stratigraphic order of integrated events is:

- FO of nannofossil *Lithastrinus grillii* – Upper Coniacian;
- FO of nannofossil *Lucianorhabdus cayeuxii* – Upper Coniacian;
- FO of nannofossil *Calculites obscurus* (including morphotypes) – Uppermost Coniacian;
- FO of inoceramid *Platyceramus undulatoPLICATUS* (Coniacian/Santonian boundary);
- FO of planktonic foraminifera *Dicarinella asyMETRICA* – Lowermost Santonian (according to LAMOLDA et al., 1999);
- FO of planktonic foraminifera *Sigalia carpatICA* – Lower Santonian (according to LAMOLDA et al., 1999);
- LO of nannofossil *Lithastrinus septenarius* – Lower Santonian.

The section studied is characterized by a high frequency and moderate diversity of *Lucianorhabdus* taxa, as well as by a significant increase of *Micula concava* abundance. Within the lowermost Santonian, an increasing abundance of *Calculites* spp. has also been observed.

Acknowledgements: The authors would like to thank Dr. Jackie Burnett-Lees (University College London) and Dr. Michael Wagreich (University of Vienna), who reviewed this paper and made valuable comments and suggestions. Fieldwork to establish a stratigraphic column and for stable isotope sampling was undertaken in collaboration with Professor C.R.C. Paul (University of Liverpool). Prof. Paul also improved an earlier draft of this manuscript. The financial support of the Spanish Ministry of Education and Culture (Project PB95-0505-C02-01, DGEsIC) is gratefully acknowledged.

References

- BOWN, P. R. (Ed.), 1998: *Calcareous Nannofossil Biostratigraphy*. – 314 pp. British Micropalaeont. Soc. Publ. Series (Chapman & Hall Ltd./Kluwer Academic Press).
- BURNETT, J. A., 1990: New nannofossil zonation scheme for the Boreal Campanian. – *INA Newsl.* 12: 67–70.
- BURNETT, J. A., 1996: Nannofossils and Upper Cretaceous (sub-) stage boundaries – State of the art. – *J. Nannoplankton Res.* 18: 23–32.
- BURNETT, J. A., 1998: Upper Cretaceous. – In: BOWN, P. R. (Ed.): *Calcareous Nannofossil Biostratigraphy*. – British Micropalaeont. Soc. Publ. Series: 132–199, (Chapman & Hall Ltd/Kluwer Academic Press).
- FLORES, J. A., GOROSTIDI, A. & LAMOLDA, M. A., 1987: Nannoflora y bioestratigrafía del paso Coniaciense-Santoniese en Álava noroccidental. – *Paleontología i Evolució* 20: 151–163.
- GALLEMI, J., KÜCHLER, T., LAMOLDA, M., LÓPEZ, G., MARTÍNEZ, R., MUÑOZ, J., PONS, J. M. & SOLER, M., 1997: The Coniacian-Santonian boundary in Northern Spain: the Olazagutía section. – *Mineralia Slovaca* 29: 311.
- GALLEMI, J., KÜCHLER, T., LÓPEZ, G., MARTÍNEZ, R., MUÑOZ, J., PONS, J. M. & SOLER, M., 2000: Macrofaunal distribution around the Coniacian/Santonian Boundary interval in the Olazagutía section (Northern Spain). – 6th Int. Cret. Symp. Vienna. Abstracts: 33.
- GOROSTIDI, A., FLORES, J. A. & LAMOLDA, M. A., 1990: Aspectos tafonómicos y paleoecológicos de la nannoflora calcárea del Cretácico superior de Álava Occidental. – In: CIVIS, J. & FLORES, J. A. (Eds): *Actas de Paleontología* 68: 159–171.
- GRÄFE, K-U., 1994: Sequence Stratigraphy in the Cretaceous and Paleogene (Aptian to Eocene) of the Basco-Cantabrian Basin (N Spain). – *Tübinger Geowiss. Arb. A* 18: 1–418.
- KANNENBERG, M., 1985: Stratigraphische Arbeiten in der Kreide der westlichen Barranca in Navarra/Nordspanien und statistische Untersuchungen der Echiniden-Gattung *Micraster* im Steinbruch Olazagutía (Coniac-Campan). – Diploma Thesis, FU Berlin, 100pp.

- LAMOLDA, M. A., 1984: Foraminíferos planctónicos del Cretácico Superior Vasco-Cantábrico: distribución y bioestratigrafía. – Cuadernos de Geología Ibérica **8** (1982): 111–123.
- LAMOLDA, M. A. & GOROSTIDI, A., 1996: Calcareous Nannofossils at the Cenomanian-Turonian Boundary Event in the Ganza section, Northern Spain. – In: SAHNI, A. (Ed.): Cretaceous Stratigraphy and Paleoenvironments. – Geol. Soc. India Mem. **37**: 251–265.
- LAMOLDA, M. A., GOROSTIDI, A. & PAUL, C. R. C., 1994: Quantitative estimates of calcareous nannofossil changes across the Plenus Marls (latest Cenomanian), Dover, England: implications for the generation of the Cenomanian-Turonian Boundary Event. – Cretaceous Res. **15**: 143–164.
- LAMOLDA, M. A. & HANCOCK, J. M., 1996: The Santonian stage and substages. – Bull. l'Institut Royal Sci. Natur. Belg. Sci. Terre, Suppl. **66**: 95–102.
- LAMOLDA, M. A., MELINTE, M. C. & PERYT, D., 1999: Datos micropaleontológicos preliminares sobre el límite Coniaciense/Santonense en Olazagutía (Navarra, España). – Rev. Esp. Micropaleont. **31**: 337–345.
- MANIVIT, H., 1971: Nannofossiles calcaires du Crétacé français (Aptien-Maastrichtien). Essai de Biozonation appuyée sur les stratotypes. – Thèse de Doctorat, Université de Paris, 387pp.
- MARTÍNEZ, R., LAMOLDA, M. A., GOROSTIDI, A., LÓPEZ, G. & SANTAMARÍA, R., 1996: Bioestratigrafía integrada del Cretácico superior (Cenomaniense superior-Santonense) de la Región Vasco-cantábrica. – Rev. Esp. Paleont., No. extraord.: 160–171.
- MELINTE, M., 1999: Turonian-Coniacian nannofossil events in the East and South Carpathians (Romania). – Rev. Esp. Micropaleont. **31**: 369–377.
- MELINTE, M. & ODIN, G., 2001: Optical study of the calcareous nannofossils from Tercis-les-Bains (Landes, France) at the Campanian-Maastrichtian boundary. – In: ODIN, G. S. (Ed.): The Campanian-Maastrichtian Boundary. 301–309 (Elsevier).
- MUTTERLOSE, J., 1991: Das Verteilungs- und Migrationsmuster des kalkigen Nannoplanktons in der borealen Unterkreide (Valangin bis Apt) NW Deutschlands. – Palaeontographica **B 221**: 27–152.
- PAUL, C. R. C., LAMOLDA, M. A., MITCHELL, S. F., VAZIRI, M. R., GOROSTIDI, A. & MARSHALL, J. D., 1999: The Cenomanian-Turonian boundary at Eastbourne (Sussex, UK): a proposed European reference section. – Palaeogeogr. Palaeoclimat. Palaeoecol. **150**: 83–121.
- PERCH-NIELSEN, K., 1985: Mesozoic calcareous nannofossils. – In: BOLLI, H. M., SAUNDERS, J. B. & PERCH-NIELSEN, K. (Eds): Plankton Stratigraphy, 329–426, Cambridge (Cambridge Univ. Press).
- RODRÍGUEZ J. & LAMOLDA, M., 1986: Ecoestratigrafía de los ostrácodos del Coniaciense y Santoniense de la Cuenca Vasco-cantábrica occidental. – In: VILLAS, E. (Coord): Mem. Jorn. Paleont., 210–219.
- ROTH, P. H., 1978: Cretaceous nannoplankton biostratigraphy and oceanography of the Northwestern Atlantic Ocean. – Initial Rep. DSDP **44**: 731–759.
- ROTH, P. H. & KRUMBACH, K. R., 1986: Middle Cretaceous calcareous nannofossil biostratigraphy and preservation in the Atlantic and Indian oceans: implications for paleoceanography. – Mar. Micropaleont. **10**: 235–266.
- SANTAMARÍA, R., 1992: Los Ammonoideos del Cenomaniense superior al Santoniense de la plataforma nord-castellana y la cuenca navarro-cántabra. Parte I. Bioestratigrafía y sistemática: *Phylloce-ratina*, *Ammonitina* (*Desmocerataceae* y *Hoplitaceae*) y *Ancyloceratina*. – Treballs Museu Geologia Barcelona, **2**: 171–268.
- SISSINGH, W., 1977: Biostratigraphy of Cretaceous calcareous nannoplankton. – Geol. Mijnb. **56**: 37–65.
- SVÁBENICKÁ, L., 1992: Upper Cretaceous Nannofossils from the Klement Formation (Flysch Belt of the West Carpathians, Czechoslovakia). – Knihovnicka ZPN, **14a/1**: 189–205.
- SVÁBENICKÁ, L., 1995: Common occurrences of the ecologically restricted nannofossils in the Campanian sediments of the Zdánice Unit and Waschberg Zone, West Carpathians. – Proc. XVth Congr. Carpatho-Balkan. Geol. Ass. (Geol. Soc. Greece Spec. Publ.) **4**: 282–287.
- THIERSTEIN, H. R., 1976: Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. – Mar. Micropaleont. **1**: 325–362.

- THIERSTEIN, H. R., 1981: Late Cretaceous nannoplankton and the change at the Cretaceous/Tertiary boundary. – *SEPM Spec. Publ.* **32**: 355–394.
- VAROL, O., 1992: Taxonomic revision of the Polycyclolithaceae and its contribution to Cretaceous biostratigraphy. – *Newsl. Stratigr.* **27**: 93–127.
- VERBEEK, J. W., 1977: Calcareous nannoplankton biostratigraphy of Middle and Upper Cretaceous deposits in Tunisia, southern Spain and France. – *Utrecht Micropaleont. Bull.* **16**: 157pp.
- WAGREICH, M., 1991: Holococcoliths and the biostratigraphy of the Late Turonian-Early Campanian of the Gosau Group of Austria. – In: YOUNG, J. R. (Ed.): Abstracts of the 4th INA Conference Prague 1991.– *INA Newsl.* **13/2**: 71–72.
- WAGREICH, M., 1992: Correlation of Late Cretaceous calcareous nannofossil zones with ammonites and planktic foraminifera: the Austrian Gosau sections. – *Cretaceous Res.* **15**: 505–516.
- WATKINS, D. K., WISE, S. W., POSPHICAL, J. J. & CRUX, J., 1996: Upper Cretaceous calcareous nannofossil biostratigraphy and paleoceanography of the Southern Ocean. – In: MOGUILVSKY, A. & WHATLEY, R. (Eds.): *Microfossils and oceanic environments*. 351–381, University of Wales, Aberystwyth (Aberystwyth Press).
- WILLIAMS, J. R. & BRALOWER, T. J., 1995: Nannofossil assemblages, fine fraction stable isotopes and the paleoceanography of the Valanginian-Barremian (Early Cretaceous) North Sea Basin. – *Paleoceanography* **10**: 815–839.