

## UPPER CAMPANIAN CALCAREOUS NANNOFOSSILS FROM A CORE OF WELL 2-RSS-1, PELOTAS BASIN, BRAZIL

RODRIGO DO MONTE GUERRA

Laboratório de Micropaleontologia, UNISINOS, Av. Unisinos, 950, 93022-000, São Leopoldo, RS, Brasil.  
*rmguerra@unisinos.br*

LUCIO RIOGI TOKUTAKE

Departamento de Exploração, Setor de Sedimentologia e Estratigrafia, PETROBRAS, Unidade UN-ES, Av. Fernando Ferrari, 1000, 29075-973, Vitória, ES, Brasil. *tokutake@petrobras.com.br*

GERSON FAUTH

Laboratório de Micropaleontologia, UNISINOS, Av. Unisinos, 950, 93022-000, São Leopoldo, RS, Brasil.  
*gersonf@unisinos.br*

**ABSTRACT** – This study aimed to determine calcareous nannofossils associations and their standard biozones, taking into account a previous study for the Cretaceous of the Pelotas Basin conducted by Petróleo Brasileiro S.A. - PETROBRAS. Twenty-three slides from samples of a core from well 2-RSS-1 (depth interval of 4,480.35-4,487.70 m) were analyzed, drilled in the offshore portion of the basin. Thirty-two nannofossil species were recognized, with the most important being *Arkhangelskiella cymbiformis*, *Broinsonia parca constricta*, *Calculites obscurus*, *Eiffellithus turriseiffelii*, *Microrhabdulus decoratus*, *Micula decussata*, *Reinhardtites levis*, *Retecapsa crenulata*, *Tranolithus orionatus*, *Uniplanarius sissinghii* and *Uniplanarius trifidus*. The coexistence of the species *B. parca constricta* and *R. levis* in the slides indicates the interval between the international biozones CC22b and CC23a. According to the international zonation proposed for the Cretaceous, the interval studied seems to be deposited in the upper Campanian boundary.

**Key words:** calcareous nannofossils, Pelotas Basin, biostratigraphy, Cretaceous, Campanian.

**RESUMO** – Este trabalho enfoca a caracterização dos nanofósseis calcários da bacia de Pelotas e sua inserção nas respectivas biozonas internacionais, como refinamento a estudos prévios feitos nos depósitos cretáceos da bacia. Foram analisadas 23 lâminas de amostras procedentes do intervalo de 4.480,35 até 4.487,70 m de testemunho do poço 2-RSS-1, perfurado na porção offshore da bacia. O estudo reconheceu 32 espécies, das quais se destacam *Arkhangelskiella cymbiformis*, *Broinsonia parca constricta*, *Calculites obscurus*, *Eiffellithus turriseiffelii*, *Microrhabdulus decoratus*, *Micula decussata*, *Reinhardtites levis*, *Retecapsa crenulata*, *Tranolithus orionatus*, *Uniplanarius sissinghii* e *Uniplanarius trifidus*. A coexistência das espécies *R. levis* e *B. parca constricta* indica o intervalo entre as biozonas internacionais CC22b e CC23a. De acordo com o zoneamento internacional proposto para o Cretáceo, pode-se inferir que o intervalo estudado foi depositado durante o Campaniano superior.

**Palavras-chave:** manofósseis calcários, bacia de Pelotas, bioestratigrafia, Cretáceo, Campaniano.

### INTRODUCTION

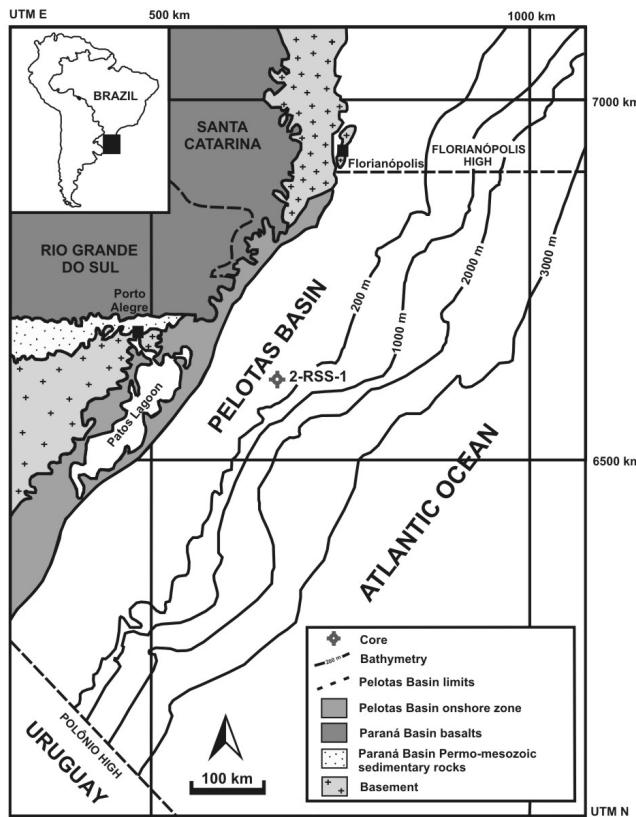
The deep wells drilled in the Pelotas Basin by PETROBRAS between the 1970s and 1980s represent a rare opportunity to understand the geological evolution of the region during the Cretaceous and Cenozoic. Refined biostratigraphic studies have been carried out aimed at better understanding the microfossil occurrence and distribution, as follow: Closs (1970), Thiesen (1977), Madeira-Falcetta *et al.* (1980), Koutsoukos (1982), Anjos (2004), Anjos & Carreño (2004) and Coimbra *et al.* (2009) regarding foraminifers; Sanguinetti (1980), Ornellas (1981), Carreño *et al.* (1997) and Ceolin & Fauth (2009) regarding ostracods; Gomide (1989) regarding calcareous nannofossils; and Regali *et al.* (1974),

Arai *et al.* (2006) and Premaor *et al.* (2007) regarding palynomorphs. Based on calcareous nannofossils, Gomide (1989) presented the biochronostratigraphy of the marine section between the Cretaceous and Miocene.

Located between latitudes 28°S and 34°S, the Pelotas Basin is bordered on the south by Polônio High, in Uruguay and on the north by the Florianópolis High (Bueno *et al.*, 2007). It occupies an area of approximately 210,000 km<sup>2</sup>, of which 40,000 km<sup>2</sup> are in the continental area (Dias *et al.*, 1994; Figure 1).

According to Milani *et al.* (1994) and Fontana (1996), the proximal portion of the Pelotas Basin overlaid on the continental crust (Paraná Basin), and basalt extruded in the beginning of the pre-rift phase, while the distal portion overlaid on the ocean floor.

Gonçalves *et al.* (1979) separated the northern portion of the Pelotas Basin, known as the Florianópolis Shelf, an intense volcanic zone featuring the earliest stages of the opening of



**Figure 1.** Simplified map of the Pelotas Basin showing its borders and well 2-RSS-1 (modified from Anjos & Carreño, 2004).

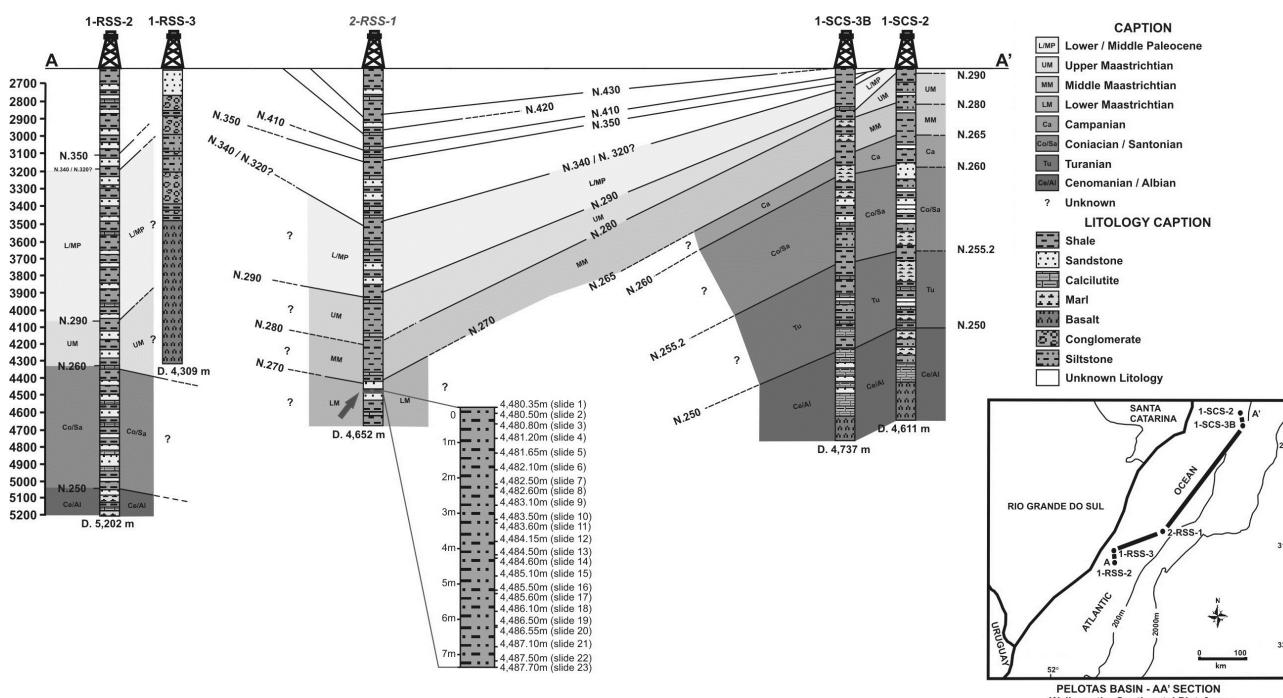
the South Atlantic Ocean, forming an igneous rock barrier named the Florianópolis High, which isolated the Pelotas Basin from the northern evaporitic basins. The Florianópolis High blocked the ocean circulation favoring a large restricted environment to the north represented by evaporitic layers (Azevedo, 2004). This lock remained with a low sedimentation rate until the Aptian. During the lower Albian, the Florianópolis Shelf sedimentary record becomes more substantial due to the open marine waters between the Santos and Pelotas basins (Gonçalves *et al.*, 1979).

The interval studied in this work belongs to the Imbé Formation which consists of shales with rare intercalations of turbidite sandstones deposited in deep marine environments, aged from the Turonian to Recent (Dias *et al.*, 1994).

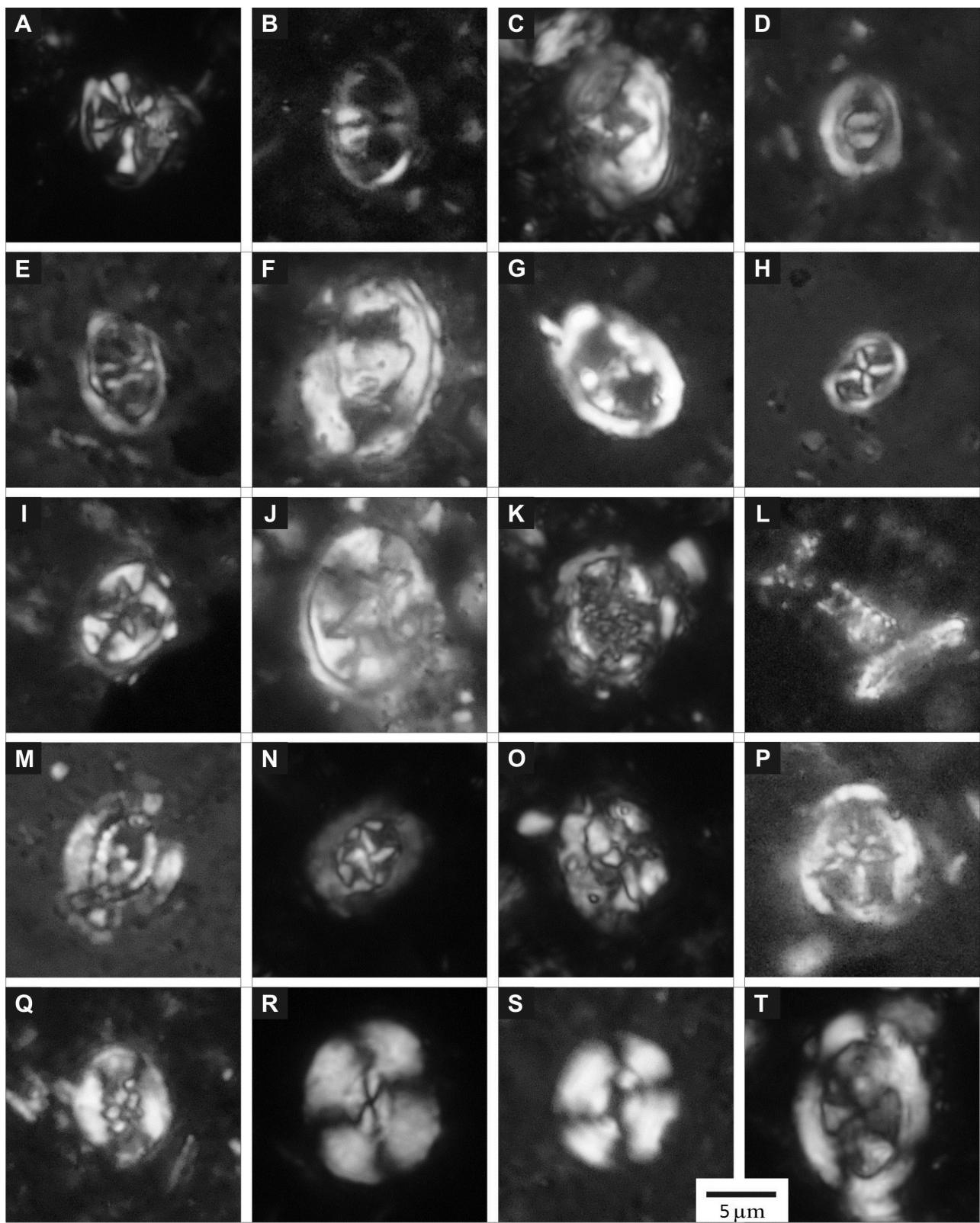
## MATERIAL AND METHODS

Twenty-three samples of a core from well 2-RSS-1, drilled in the offshore portion of the Pelotas Basin, were analyzed. They come from the depth interval 4,480.35-4,487.70 m, with a sampling interval ranging between 10 and 55 cm (Figure 2). Lithologically, the range (about 7.35 m) is composed of dark-gray micaceous siltstones.

The preparation of the slides was undertaken at the Laboratório de Micropaleontologia at the Universidade do Vale do Rio dos Sinos (UNISINOS), according to the method proposed by Antunes (1997). The species identified herein are reported in Appendix 1 and illustrated in Figures 3 and 4. The taxonomy follows Bown & Young (1997). Perch-Nielsen (1985) and Burnett (1998) were widely consulted for help in the identification of species and biozones.



**Figure 2.** Detail of the interval studied in core 2-RSS-1, following the AA' section of Gomide (1989). The arrow indicates the interval studied. Dotted lines and question marks indicate areas where it was not possible to define the extent of the biozone (modified from Gomide, 1989).



**Figure 3.** **A**, *Ahmuellerella octoradiata*, slide 2/4,480.50 m; **B**, *Tranolithus orionatus*, slide 11/4,483.60 m; **C**, *Reinhardtites levius*, slide 10/4,483.50 m; **D**, *Zeugrhabdotus bicrescenticus*, slide 1/4,480.35 m; **E**, *Zeugrhabdotus diplogramus*, slide 10/4,483.50 m; **F**, *Zeugrhabdotus embergeri*, slide 1/4,480.35 m; **G**, *Zeugrhabdotus sigmoides*, slide 22/4,487.50 m; **H**, *Chiastozygus* sp., slide 17/4,485.60 m; **I**, *Eiffellithus gorkae*, slide 1/4,480.35 m; **J**, *Eiffellithus turriseiffelii*, slide 7/4,482.50 m; **K**, *Cribrosphaerella ehrenbergii*, slide 10/4,483.50 m; **L**, *Tetrapodorhabdus decorus*, slide 5/4,481.65 m; **M**, *Biscutum magnum*, slide 17/4,485.60 m; **N**, *Prediscosphaera cretacea*, slide 20/4,486.55 m; **O**, *Prediscosphaera spinosa*, slide 13/4,484.50 m; **P**, *Cretarhabdus conicus*, slide 7/4,482.50 m; **Q**, *Retecapsa crenulata*, slide 16/4,485.50 m; **R**, *Watznaueria barnesiae*, slide 1/4,480.35 m; **S**, *Watznaueria fossacincta*, slide 1/4,480.35 m; **T**, *Arkhangelskiella cymbiformis*, slide 20/4,485.55 m.

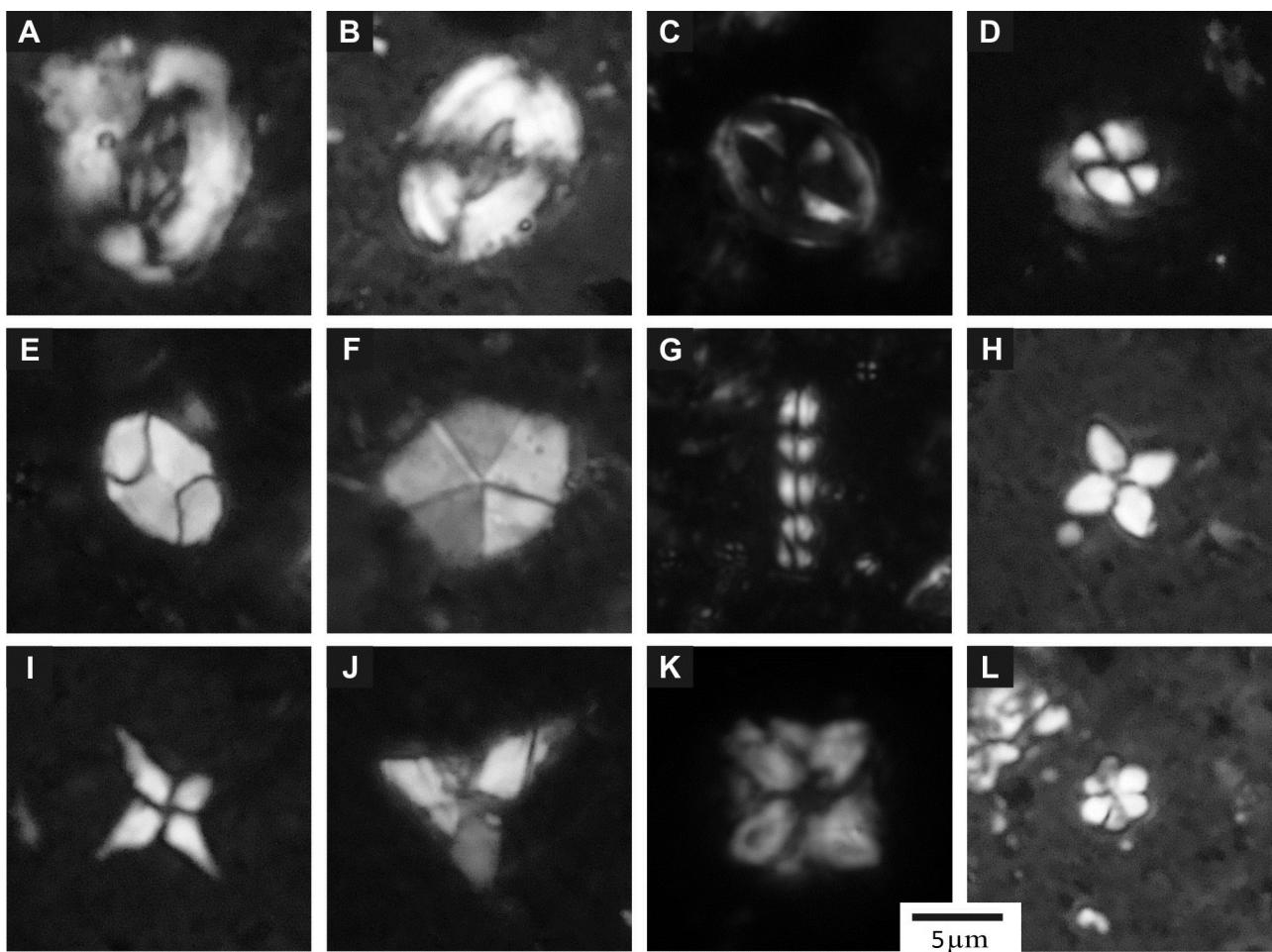
## BIOSTRATIGRAPHY

The calcareous nannofossils are considered excellent biostratigraphic tools. These planktonic organisms had rapid speciation throughout their geological history, leaving modified descendants. The short time range, wide geographical distribution, and the facility to prepare the samples make calcareous nannofossils one of the most effective biostratigraphic tools since the Lower Jurassic. The stratigraphic distribution of calcareous nannofossils during the Cretaceous is fairly well known. Several authors have used different combinations of species distribution to establish biozones in different regions of the earth (Perch-Nielsen, 1985). The main cosmopolitan zonations, using Cretaceous calcareous nannofossils were established by Sissingh (1977), Roth (1978), Perch-Nielsen (1985), and Burnett (1998).

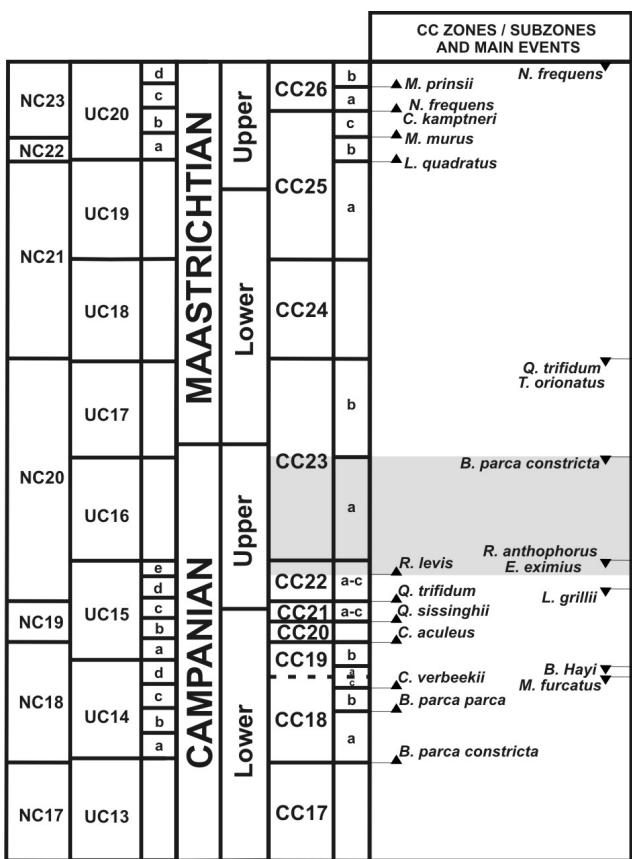
During the taxonomic study, the abundance of the species *Arkhangelskiella cymbiformis* (Figure 3T), *Broinsonia parca constricta* (Figure 4B), *Calculites obscurus* (Figure 4E), *Eiffellithus turriseiffelii* (Figure 3J), *Microrhabdulus decoratus* (Figure 4G), *Micula decussata* (Figure 4K),

*Reinhardtites levis* (Figure 3C), *Retecapsa crenulata* (Figure 3Q), *Tranolithus orionatus* (Figure 3B), *Uniplanarius sissinghii* (Figure 4I) and *Uniplanarius trifidus* (Figure 4J) was examined, and these species were considered Cretaceous biomarkers following Perch-Nielsen (1985). According to Sissingh (1977) and Perch-Nielsen (1985), the presence of *B. parca constricta* and *R. levis* together define the interval between the international biozones CC22b to CC23a. The CC22 zone, upper Campanian in age, is defined by the first occurrence of *Quadrum trifidum* (=*Uniplanarius trifidus*) until the last occurrence (LO) of *Reinhardtites anthophorus*. Sissingh (1977), however, suggested the division of the CC22 zone by the first occurrence of *R. levis*. The CC23 zone, upper Campanian/lower Maastrichtian in age, is defined by the LO of *R. anthophorus* until the LO of *Tranolithus orionatus* (=*Tranolithus phacelosus*). The LO of *Broinsonia parca* (=*Aspidolithus parcus*) subdivides the CC23 zone (Sissingh, 1977).

Burnett (1998) suggested a new biozonation using Cretaceous calcareous nannofossils. According to the author, many bioevents used to define the Perch-Nielsen (1985) CC biozones are inappropriate for a global context (Figure 5).



**Figure 4.** A, *Broinsonia parca*, slide 11/4,483.60 m; B, *Broinsonia parca constricta*, slide 18/4,486.10 m; C, *Gartnerago segmentatum*, slide 18/4,486.10 m; D, *Markalius inversus*, slide 22/4,487.50 m; E, *Calculites obscurus*, slide 2/4,480.50 m; F, *Braarudosphaera bigelovii*, slide 14/4,484.60 m; G, *Microrhabdulus decoratus*, slide 7/4,482.50 m; H, *Uniplanarius gothicus*, slide 22/4,487.50 m; I, *Uniplanarius sissinghii*, slide 5/4,481.65 m; J, *Uniplanarius trifidus*, slide 7/4,482.50 m; K, *Micula decussata*, slide 4/4,481.20 m; L, *Hexolithus gardetiae*, slide 18/4,486.10 m.

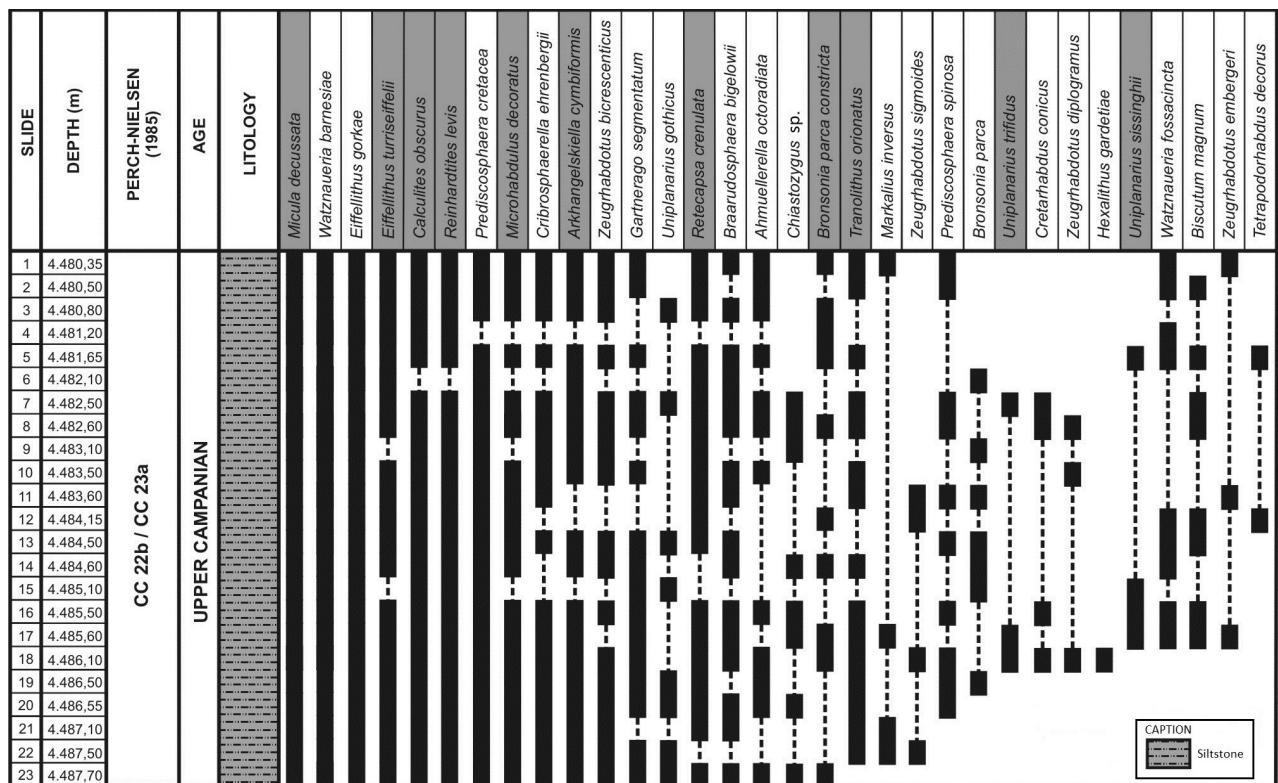


**Figure 5.** Correlation between the biozones of Roth (1978) (NC), Burnett (1998) (UC) and Perch-Nielsen (1985) (CC). The area in gray shows the interval studied herein (modified from Burnett, 1998).

The species *B. parca constricta* and *R. levis* studied in this paper were also of great importance in the biozone proposed by Burnett (1998). According to the author, in the Tethyan-intermediate zone (Thethyan=45°N-10°S/intermediate=10-35°S), *R. levis* had its first occurrence in the UC14d zone, and *B. parca constricta* had its last occurrence in UC16. In the Boreal-intermediate zone (Boreal=>50°N/intermediate=50-45°N), *R. levis* appeared in the UC15b zone, and *B. parca constricta* was extinguished in the UC16. For the Austral zone (>35°S), it was not possible to detect the first occurrence of *R. levis*, but the extinction of *B. parca constricta* was also indicated in UC16. It is important to remark that the author did not use samples from the South Atlantic in general (Brazil), but rather only the extreme South Atlantic (Argentine shelf).

The species pointed out by Perch-Nielsen (1985) as Cretaceous (*Micula decussata*, *Watznaueria barnesiae*, and *Eiffellithus gorkae*) occur in almost all samples of the interval, have a homogeneous distribution along the profile, and are the most frequent in the material studied. Though *Hexolithus gardetiae* occurred only in one sample with a depth of 4,486.10 m (Figure 6).

Well 2-RSS-1 was studied previously by Gomide (1989) who proposed a framework using calcareous nannofossils, as previously mentioned. For the same depth analyzed in the present study, this author attributed a lower Maastrichtian age. Instead, based on data obtained in our study, associated with the Perch-Nielsen (1985) and Burnett (1998) biozones, we consider that the depth interval between 4,480.35-4,487.70 m was deposited in the upper Campanian boundary.



**Figure 6.** Distribution of calcareous nannofossil species in well 2-RSS-1. The species marked in gray are the Cretaceous calcareous nannofossil markers proposed by Perch-Nielsen (1985). Dotted lines indicate just inferred occurrence.

## FINAL CONSIDERATIONS

Taking into account the analyses carried out in the interval between 4,480.35-4,487.70 m of well 2-RSS-1, drilled in the offshore portion of the Pelotas Basin, thirty-two species of calcareous nannofossils were identified (Appendix 1). Eleven of them are present in the range of the Cretaceous biostratigraphic markers proposed by Sissingh (1977) and Perch-Nielsen (1985): *A. cymbiformis*, *B. parca constricta*, *C. obscurus*, *E. turriseiffelii*, *M. decoratus*, *M. decussata*, *R. levis*, *R. crenulata*, *T. orionatus*, *U. sissinghii* and *U. trifidus*. *Broinsonia parca constricta* and *R. levis* are the most important species observed. These species had a short time range and wide geographic distribution. Their occurrences throughout the material studied indicate that the strata was deposited in the upper Campanian boundary.

## ACKNOWLEDGMENTS

The authors are grateful to J.C. Coimbra for allowing the use of the samples for this study, as well as R.L. Antunes, F.H.O. Lima and A. Concheyro for discussions, and the staff of the Laboratório de Micropaleontologia (UNISINOS) for all the support.

## REFERENCES

- Anjos, G.S. 2004. *Bioestratigrafia (Foraminíferida) do Mioceno-Plioceno da Plataforma de Florianópolis, porção setentrional da Bacia de Pelotas*. Programa de Pós-graduação em Geociências, Universidade Federal do Rio Grande do Sul, M.Sc. thesis, 80 p.
- Anjos, G.S. & Carreño, A.L. 2004. Bioestratigrafia (Foraminíferida) da sondagem 1-SCS-3B, Plataforma de Florianópolis, Bacia de Pelotas, Brasil. *Revista Brasileira de Paleontologia*, **7**(2):127-138.
- Antunes, R.L. 1997. *Introdução ao estudo dos nanofósseis calcários*. Rio de Janeiro, Instituto de Geociências da UFRJ, 115 p.
- Arai, M.; Masure, E. & Lemos, V.B. 2006. Occurrence of a high-diversity Aptian microphytoplanktonic assemblage in Pelotas Basin (Southern Brazil): its implication for the Early Cretaceous history of the South Atlantic. In: SIMPÓSIO DO CRETÁCEO DO BRASIL, 7/SIMPÓSIO DO TERCIÁRIO DO BRASIL, 1, 2006. *Boletim de Resumos*, São Pedro, UNESP, p. 12.
- Azevedo, R.L.M. 2004. Paleoceanografia e a evolução do Atlântico Sul no Albiano. *Boletim de Geociências da Petrobras*, **12**(2):231-249.
- Bown, P.R. & Young, J.R. 1997. Mesozoic calcareous nannoplankton classification. *Journal of Nannoplankton Research*, **19**:21-36.
- Bueno, G.V.; Zacharias, A.A.; Oreiro, S.G.; Cupertino, J.A.; Falkenheim, F.U.H. & Martins Neto, M.A. 2007. Bacia de Pelotas. *Boletim de Geociências da Petrobras*, **15**(2):551-559.
- Burnett, J.A. 1998. Upper Cretaceous. In: P.R. Bown (ed.) *Calcareous Nannofossil Biostratigraphy*, Chapman-Hall, p. 132-199.
- Carreño, A.L.; Coimbra, J.C. & Carmo, D.A. 1997. Biostratigraphy of the Late Neogene and Quaternary ostracods in the Pelotas Basin, Southern Brazil. *Gaia*, **14**:33-43.
- Ceolin, D. & Fauth, G. 2009. Upper Cretaceous Ostracoda from the Pelotas Basin, Southern Brazilian continental margin. In: INTERNATIONAL SYMPOSIUM ON OSTRACODA, 16, 2009. *Abstracts*, Brasília, IRGO/UnB, p. 74.
- Closs, D. 1970. Estratigrafia da Bacia de Pelotas, Rio Grande do Sul. *Iheringia, Série Geologia*, **3**:3-37.
- Coimbra, J.C.; Carreño, A.L. & Anjos-Zerfass, G.S. 2009. Biostratigraphy and paleoceanographical significance of the Neogene planktonic foraminifera from the Pelotas Basin, southernmost Brazil. *Revue de Micropaléontologie*, **52**:1-14.
- Dias, J.L.; Sad, A.R.E.; Fontana, R.L. & Feijó, F. 1994. Bacia de Pelotas. *Boletim de Geociências da Petrobras*, Rio de Janeiro, **8**(1):235-245.
- Fontana, R.L. 1996. *Geotectônica e sismoestratigrafia da bacia de Pelotas e plataforma de Florianópolis*. Programa de Pós-graduação em Geociências, Universidade Federal do Rio Grande do Sul, Ph.D. thesis, 214 p.
- Gomide, J. 1989. Bacia de Pelotas - biocronoestratigrafia baseada em nanofósseis calcários. In: CONGRESSO BRASILEIRO DE PALEONTOLOGIA, 11, 1989. *Anais*, Curitiba, SBP, p. 338-351.
- Gonçalves, A.; Oliveira, M.A.M. & Motta, S.O. 1979. Geologia da bacia de Pelotas e da plataforma de Florianópolis. *Boletim Técnico da Petrobrás*, **22**(3):155-226.
- Koutsoukos, E.A.M. 1982. Geohistória e paleoecologia das bacias marginais de Florianópolis e Santos. In: CONGRESSO BRASILEIRO DE GEOLOGIA, 32, 1982. *Anais*, Salvador, SBG, p. 2369-2382.
- Madeira-Falcetta, M.; Thiesen, Z.V.; Bertels, A. & Kotzian, S.B. 1980. Foraminíferos e radiolários de testemunhos da plataforma continental e talude do Rio Grande do Sul, Brasil. In: CONGRESSO BRASILEIRO DE GEOLOGIA, 31, 1980. *Anais*, Balneário Camboriú, SBG, p. 3020-3100.
- Milani, E.J.; França, A.B. & Schneider, R.L. 1994. Bacia do Paraná. *Boletim de Geociências da Petrobras*, **8**(1):69-82.
- Ornellas, L.P. 1981. *Os ostracodes e seu significado na interpretação dos eventos cenozóicos na bacia de Pelotas, RS: transgressões, regressões, paleoecologia e bioestratigrafia*. Programa de Pós-graduação em Geociências, Universidade Federal do Rio Grande do Sul, Ph.D. thesis, 217 p.
- Perch-Nielsen, K. 1985. Mesozoic calcareous nannofossils. In: H.M. Bolli; J.B. Saunders & K. Perch-Nielsen (eds.) *Plankton Stratigraphy*, Cambridge University Press, v. 1, p. 329-426.
- Premaor, E.; Fischer, T.V.; Arai, M. & Souza, P.A. 2007. Palinologia da bacia de Pelotas: dados preliminares sobre a seção cretácea. In: CONGRESSO BRASILEIRO DE PALEONTOLOGIA, 20, 2007. *Anais*, Búzios, SBP, p. 231.
- Regali, M.S.P.; Uesugui, N. & Santos, A.S. 1974. Palinologia dos sedimentos meso-cenozóicos do Brasil (I). *Boletim Técnico da Petrobrás*, **17**(3):177-191.
- Roth, P.H. 1978. Cretaceous nannoplankton biostratigraphy and oceanography of the northwestern Atlantic Ocean. *Initial Reports of the DSDP*, **44**:731-760.
- Sanguinetti, Y.T. 1980. Bioestratigrafia (ostracodes) do Mioceno da bacia de Pelotas, Rio Grande do Sul. *Pesquisas*, **13**:7-34.
- Sissingh, W. 1977. Biostratigraphy of Cretaceous calcareous nannoplankton. *Geologie en Mijnbouw*, **56**(1):37-65.
- Thiesen, Z.V. 1977. Bolivinitidae e Caucasinidae (Foraminíferida) do Cenozóico superior da bacia de Pelotas, Rio Grande do Sul. *Acta Geológica Leopoldesina*, **2**(3):8-32.

Received in March, 2010; accepted in October, 2010.

**Appendix 1.** List of taxa identified in this study.**Heterococcoliths**

Order Eiffellithales Rood, Hay &amp; Barnard, 1971

Family Chiastozygaceae Rood, Hay &amp; Barnard, 1973 emend. Varol &amp; Grgis, 1994

Genus *Ahmuellerella* Reinhardt, 1964    *Ahmuellerella octoradiata* (Górká, 1957) Reinhardt, 1966 (Figure 3A)Genus *Tranolithus* Stover, 1966    *Tranolithus orionatus* (Reinhardt, 1966) Reinhardt, 1966 (Figure 3B)Genus *Reinhardtites* Perch-Nielsen, 1968    *Reinhardtites levis* Prins & Sissingh in Sissingh, 1977 (Figure 3C)Genus *Zeugrhabdotus* Reinhardt, 1965    *Zeugrhabdotus bicrescenticus* (Stover, 1966) Burnett in Gale et al., 1996 (Figure 3D)    *Zeugrhabdotus diplogrammus* (Deflandre in Deflandre & Fert, 1954) Burnett in Gale et al., 1996 (Figure 3E)    *Zeugrhabdotus embergeri* (Noël, 1958) Perch-Nielsen, 1984 (Figure 3F)    *Zeugrhabdotus sigmoides* (Bramlette & Sullivan, 1961) Bown & Young, 1997 (Figure 3G)Genus *Chiastozygus* Gartner, 1968    *Chiastozygus* sp. (Figure 3H)

Family Eiffellithaceae Reinhardt, 1965

Genus *Eiffellithus* Reinhardt, 1965    *Eiffellithus gorkae* Reinhardt, 1965 (Figure 3I)    *Eiffellithus turriseiffelii* (Deflandre in Deflandre & Fert, 1954) Reinhardt, 1965 (Figure 3J)

Order Podorhabdites Rood, Hay &amp; Barnard, 1971 emend. Bown, 1987

Family Axopodorhabdaceae Bown &amp; Young, 1997

Genus *Cribrosphaerella* Deflandre in Piveteau, 1952    *Cribrosphaerella ehrenbergii* (Arkhangelsky, 1912) Deflandre in Piveteau, 1952 (Figure 3K)Genus *Tetrapodorhabdus* Black, 1971    *Tetrapodorhabdus decorus* (Deflandre in Deflandre & Fert, 1954) Wind & Wise in Wise & Wind, 1977 (Figure 3L)

Family Biscutaceae Black, 1971

Genus *Biscutum* Black in Black & Barnes, 1959    *Biscutum magnum* Wind & Wise in Wise & Wind, 1977 (Figure 3M)

Family Prediscosphaeraceae Rood, Hay &amp; Barnard, 1971

Genus *Prediscosphaera* Vekshina, 1959    *Prediscosphaera cretacea* (Arkhangelsky, 1912) Gartner, 1968 (Figure 3N)    *Prediscosphaera spinosa* (Bramlette & Martini, 1964) Gartner, 1968 (Figure 3O)

Family Cretarhabdaceae Thierstein, 1973

Genus *Cretarhabdus* Bramlette & Martini, 1964    *Cretarhabdus conicus* Bramlette & Martini, 1964 (Figure 3P)Genus *Retecapsa* Black, 1971    *Retecapsa crenulata* (Bramlette & Martini, 1964) Grün in Grün & Allemann, 1975 (Figure 3Q)

Order Watznaueriales Bown, 1987

Family Watznaueriaceae Rood, Hay &amp; Barnard, 1971

Genus *Watznaueria* Reinhardt, 1964    *Watznaueria barnesiae* (Black, 1959) Perch-Nielsen, 1968 (Figure 3R)    *Watznaueria fossacincta* (Black, 1971) Bown in Bown & Cooper, 1989 (Figure 3S)

Order Arkhangelskiales Bown &amp; Hapton in Bown &amp; Young, 1997

Family Arkhangelskiellaceae Bukry, 1969 emend. Bown &amp; Hapton in Bown &amp; Young, 1997

Genus *Arkhangelskiella* Vekshina, 1959    *Arkhangelskiella cymbiformis* Vekshina, 1959 (Figure 3T)Genus *Broinsonia* Bukry, 1969    *Broinsonia parca* (Stradner, 1963) Bukry, 1969 (Figure 4A)    *Broinsonia parca constricta* (Hattner et al., 1980) Perch-Nielsen, 1984 (Figure 4B)

Family Kamptneriaceae Bown &amp; Hapton in Bown &amp; Young, 1997

Genus *Gartnerago* Bukry, 1969    *Gartnerago segmentatum* (Stover, 1966) Thierstein, 1974 (Figure 4C)**Heterococcoliths of uncertain affinities**Genus *Markalius* Bramlette & Martini, 1964    *Markalius inversus* (Deflandre in Deflandre & Fert, 1954) Bramlette & Martini, 1964 (Figure 4D)**Holococcoliths**

Family Calyptrosphaeraceae Boudreux &amp; Hay, 1969

Genus *Calculites* Prins & Sissingh in Sissingh, 1977    *Calculites obscurus* (Deflandre, 1959) Prins & Sissingh in Sissingh, 1977 (Figure 4E)**Nannoliths**

Family Braarudosphaeraceae Deflandre, 1947

Genus *Braarudosphaera* Deflandre, 1947    *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre, 1947 (Figure 4F)

Family Microrhabdulaceae Deflandre, 1963

Genus *Microrhabdulus* Deflandre, 1959

*Microrhabdulus decoratus* Deflandre, 1959 (Figure 4G)

Family Polycyclithaceae Forchheimer, 1972 emend. Varol, 1992

Genus *Uniplanarius* Hattner & Wise, 1980

*Uniplanarius gothicus* (Deflandre, 1959) Hattner & Wise, 1980 (Figure 4H)

*Uniplanarius sissinghii* Perch-Nielsen, 1986b (Figure 4I)

*Uniplanarius trifidus* (Stradner in Stradner & Papp, 1961) Hattner & Wise, 1980 (Figure 4J)

Genus *Micula* Vekshina, 1959

*Micula decussata* Vekshina, 1959 (Figure 4K)

Genus *Hexalithus* Gardet, 1955

*Hexalithus gardetiae* Bukry, 1969 (Figure 4L)