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**OSTRACODES DO CRETÁCEO–PALEÓGENO INFERIOR DA BACIA DE  
PELOTAS**

**São Leopoldo  
2010**

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PELOTAS**

Dissertação apresentada ao Programa de Pós-Graduação em Geologia da Universidade do Vale do Rio dos Sinos, como requisito parcial para obtenção do título de Mestre em Geologia.

**Orientador: Prof. Dr. Gerson Fauth**

**São Leopoldo  
2010**

*“Eternamente aos meus pais,  
Dilmar e Enedite que me  
ensinaram a nunca desistir de um  
sonho.....”*

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## RESUMO

O presente trabalho consiste no estudo taxonômico dos ostracodes marinhos da bacia de Pelotas e os respectivos aspectos paleoecológicos da assembléia no intervalo Cretáceo e Cretáceo–Paleógeno Inferior. Foram analisadas 479 amostras de calha, provenientes dos cinco poços 1-RSS-2, 1-RSS-3, 2-RSS-1, 1-SCS-3B e 1-SCS-2. A fauna registrada totalizou 98 espécimes, distribuídos em nove famílias, 21 gêneros, 34 espécies. Dois gêneros e duas espécies foram mantidos como táxons indeterminados. As espécies identificadas foram: *Cytherella* cf. *C. araucana* Bertels, 1974; *Cytherelloidea spirocostata* Bertels, 1973; *Bairdoppilata triangulata* Edwards, 1944; *Actinocythereis indigena* Bertels, 1969; *Brachycythere* gr. *sapucariensis* Krömmelbein, 1964; *Wichmannella araucana* Bertels, 1969 e *Wichmannella meridionalis* Bertels, 1969. Os gêneros mais diversificados foram *Cytherella* e *Paracypris* com sete e quatro espécies, respectivamente. O intervalo Turoniano foi o mais abundante, com a significativa presença dos gêneros *Brachycythere* e *Cytherella*. A família mais abundante foi a Trachyleberididae, com oito gêneros e 12 espécies, seguida da família Cytherellidae com dois gêneros e oito espécies. A passagem do limite Cretáceo–Paleógeno Inferior (K–Pg) na bacia de Pelotas foi marcada por uma mudança faunística com o desaparecimento dos gêneros, *Cytherelloidea*, *Argilloecia*, *Cythereis*, *Brachycythere*, *Pondoina* e *Rostrocytheridea*, e o aparecimento de *Neonesidea*, *Bairdoppilata*, *Ambocythere*, *Buntonia*, *Langiella?*, *Trachyleberis* e *Krithe*. A associação dos ostracodes cretácicos na bacia de Pelotas sugere um ambiente marinho nerítico com águas quentes.

**Palavras-chave:** bacia de Pelotas, ostracodes, Cretáceo, Paleógeno.

## ABSTRACT

The taxonomic study of marine ostracods from Pelotas Basin and the respective paleoecological assemblages aspects in the Cretaceous and Cretaceous–Lower Paleogene interval were studied. 479 cutting samples from wells 1-RSS-2, 1-RSS-3, 2-RSS-1, 1-SCS-3B e 1-SCS-2 were analyzed. 98 specimens belonging to 9 families, 21 genera and 34 species. 2 genera and 2 species were supported as undetermined taxon. The species identified were: *Cytherella* cf. *C. araucana* Bertels, 1974; *Cytherelloidea spirocostata* Bertels, 1973; *Bairdoppilata triangulata* Edwards, 1944; *Actinocythereis indigena* Bertels, 1969; *Brachycythere* gr. *sapucariensis* Krömmelbein, 1964; *Wichmannella araucana* Bertels, 1969 and *Wichmannella meridionalis* Bertels, 1969. The most diversified genera were *Cytherella* and *Paracypris* with 7 and 4 species, respectively. The Turonian was the most ostracodes-rich interval with significant presence of the genera *Brachycythere* and *Cytherella*. The most abundant families were Trachyleberididae and Cytherellidae with 2 genera and 8 species. The K–Pg boundary in the Pelotas basin is marked by a faunal change which disappearance the genera *Cytherelloidea*, *Argilloecia*, *Cythereis*, *Brachycythere*, *Pondoina* and *Rostrocytheridea*, and the first occurrence of *Neonesidea*, *Bairdoppilata*, *Ambocythere* *Buntonia*, *Langiella?*, *Trachyleberis* and *Krithe*. The Cretaceous ostracods association in Pelotas Basin suggest a neritic marine environment with warm water temperatures.

**Keywords:** Pelotas Basin, ostracods, Cretaceous, Paleogene.

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## 1. INTRODUÇÃO

Os estudos micropaleontológicos nas bacias marginais brasileiras têm contribuído para o melhor entendimento da paleoecologia, paleobiogeografia e bioestratigrafia do Oceano Atlântico durante o Mesozóico e o Cenozóico. Estes estudos são importantes ferramentas para o entendimento e a reconstituição das condições ambientais que atuaram na época da formação e deposição das bacias sedimentares, principalmente pela rápida evolução biológica das espécies nos milhares de anos.

A bacia de Pelotas foi originada durante a separação das placas tectônicas da América do Sul e África, possuindo um espesso pacote sedimentar do período Cretáceo e Paleógeno.

Os ostracodes constituem um grupo de pequenos crustáceos artrópodes que são muito bem representados no registro fóssil, ocorrendo desde o Ordoviciano até o Recente. Isso deve-se à composição de sua carapaça quitino-calcária, que possui alto potencial de preservação. Os ostracodes, ao longo de seu processo evolutivo, adaptaram-se a praticamente todos os ambientes aquáticos, desde lagoas efêmeras de água doce a bacias marinhas profundas, sendo predominantemente bentônicos. Sua distribuição específica está condicionada a fatores químicos, físicos e biológicos como salinidade, temperatura, profundidade, granulometria do substrato e disponibilidade de alimento. Este grupo pode ser usado como marcadores paleoecológicos e bioestratigráficos, sendo em algumas bacias o principal grupo fóssil para fins bioestratigráficos. Os ostracodes marinhos possuem uma grande distribuição nos estratos cretácicos das bacias marginais brasileiras, entretanto, existe uma grande carência de estudos deste grupo fóssil nestas bacias.

O Cretáceo representa um período chave para a compreensão das mudanças em grande escala que culminaram com a separação dos continentes sul-americano e africano. Durante este período, o clima era quente e o mar registrou os maiores níveis já atingidos na história: de 100 a 300 m acima do nível atual (Chang e Kowsmann 1987).

No final deste período, ocorre um evento de grande extinção em massa, ocasionado por abruptos eventos geológicos que afetaram a vida em todo o planeta, principalmente das comunidades bentônicas, dentre elas, os ostracodes. Este evento, que ocorreu há cerca de 65 milhões de anos, apresenta suas causas ainda enigmáticas, sendo que seqüências completas que registrem este evento são raras.

O estudo dos ostracodes na bacia de Pelotas é justificado pela carência de estudos sobre esse grupo no Cretáceo marinho brasileiro, especialmente na região sul, bem como sobre o limite K–Pg.

Objetivou-se, a partir do estudo taxonômico e paleoecológico dos ostracodes da bacia de Pelotas, contribuir para o entendimento dos processos evolutivos na referida bacia e a influência do limite K–Pg na fauna de ostracodes da bacia de Pelotas.

## **2. OBJETIVOS**

- Realizar o estudo taxonômico dos ostracodes do Cretáceo–Paleógeno Inferior da bacia de Pelotas.
- Analisar as assembléias de ostracodes a fim de contribuir para o conhecimento paleoecológico das bacias marginais das regiões sul-sudeste do Brasil.

## **3. ESTUDOS COM OSTRACODES CRETÁDICOS MARINHOS NO ATLÂNTICO SUL**

Tendo em vista a posição dos continentes durante o Cretáceo e todo o contexto paleogeográfico e paleoceanográfico deste período, é indispensável a realização de correlações da bacia de Pelotas com outros estudos realizados em bacias sedimentares próximas, que originaram-se no mesmo evento de separação gonduânica (Fig. 1). Dentre estas, podemos destacar as bacias localizadas no sul do Atlântico, Argentina, Antártida, África e Austrália. Para essa correlação, destacam-se os estudos micropaleontológicos cretácicos, com enfoques taxonômicos e paleoecológicos realizados nas bacias sedimentares da Argentina por Bertels (1969a, 1969b, 1975a, 1975b, 1976, 1977, 1995), Rossi de Garcia e Proserpio (1980), Ballent (1998) e Ballent e Wathley (1996, 2007).

Além destes, é possível comparar o conteúdo faunístico da bacia de Pelotas com o material dos trabalhos do Sul e Oeste da África realizados por Dingle (1969a, 1969b, 1971, 1982, 1985, 1988, 1996, 1999) e Dingle e Lord (1990), também com abordagens taxonômicas, paleoecológicas e paleobiogeográficas. Na Austrália, os estudos mais relevantes foram realizados por Bate (1972) e Neale (1975). Além destes, Majoran (1996), Majoran e Widmark (1998), Majoran *et al.* (1997) e Majoran e Dingle (2000) fizeram significativas abordagens com ostracodes para o sul do Atlântico e próximo ao litoral oeste africano, sobre paleoecologia, paleoceanografia e paleobiogeografia. Fauth (2002) estudou a paleobiogeografia dos ostracodes do Oceano Atlântico e Fauth *et al.* (2003) realizaram estudo taxonômico dos ostracodes da Antártida.

### **3.1. Estudos com ostracodes cretácicos marinhos no Brasil**

Os estudos com ostracodes do Cretáceo nas bacias marginais brasileiras são relativamente recentes. Destacam-se os trabalhos realizados por Delício (1994), que estudou os ostracodes do Cretáceo–médio/superior da bacia Potiguar e Viviers *et al.* (2000) que pesquisaram as afinidades estratigráficas e biogeográficas dos ostracodes do Aptiano superior–Campaniano das bacias Potiguar e Sergipe.

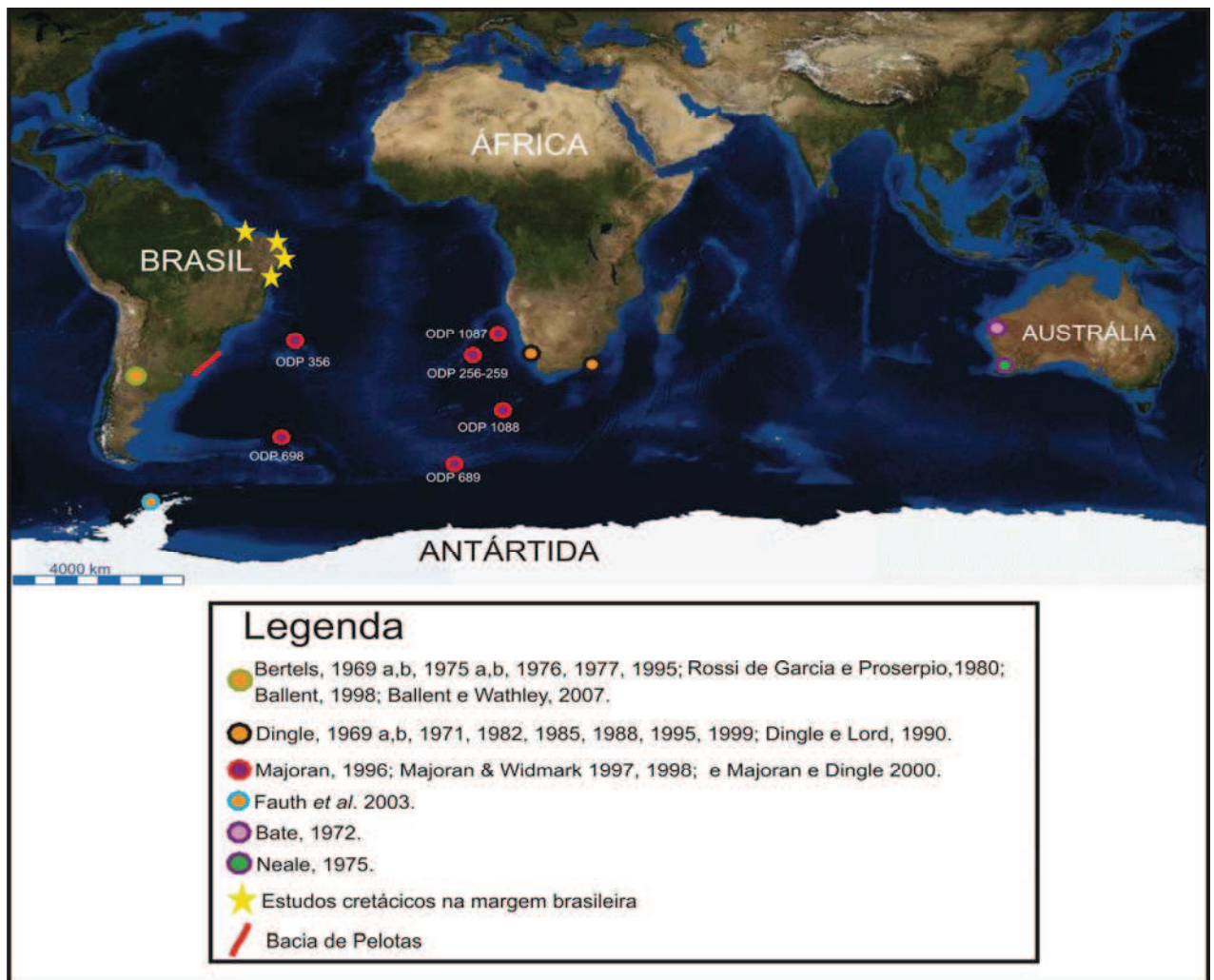


Figura 1- Estudos dos ostracodes cretácicos marinhos realizados no Atlântico sul (modificado de [www.onegeology.org](http://www.onegeology.org), 2010)

Outros estudos realizados nesta linha são: Fauth (2000) analisou a sistemática dos ostracodes da pedraira Poty da bacia Pernambuco-Paraíba com enfoque bioestratigráfico, paleoecológico e paleobiogeográfico. Fauth e Souza (2006) estudaram os ostracodes da bacia Pará-Maranhão, Fauth *et al.* (2005) estudaram o limite Cretáceo–Paleógeno em Poty (PE), e Fauth e Koutsoukos (2006) realizaram inferências paleoecológicas com ostracodes para a bacia Pernambuco-Paraíba. Piovesan (2008) realizou estudo taxonômico, paleoecológico e paleobiogeográfico para os ostracodes da bacia Pará-Maranhão do intervalo Turoniano–Maastrichtiano. (Fig. 2).

#### 4. O LIMITE K–Pg

Eventos de extinção em massa envolvem profundas mudanças na estrutura e diversidade do ecossistema. O limite Cretáceo–Paleógeno (K–Pg) marca um dos maiores eventos de extinção do Fanerozóico. Este evento registra o desaparecimento de 75% das espécies, tanto terrestres quanto marinhas, entre eles os dinossauros, ammonites, foraminíferos, nanofósseis, ostracodes e muitos outros grupos no final do Cretáceo (Skelton 2003, Ridley 2006). Neste período, houve mudanças ambientais

catastróficas na vida de todo planeta (ex., Skelton 2003, Keller 2003, Salgado-Labouriau 2008). Muitos estudos discutem que a possível causa deste evento catastrófico estaria relacionada a um grande impacto de um meteoro ocorrido em Yucatan, no México (Ward *et al.* 1995; Alegret *et al.* 2003; Hallam 2005; Keller 2003, 2008; Keller *et al.* 2007).

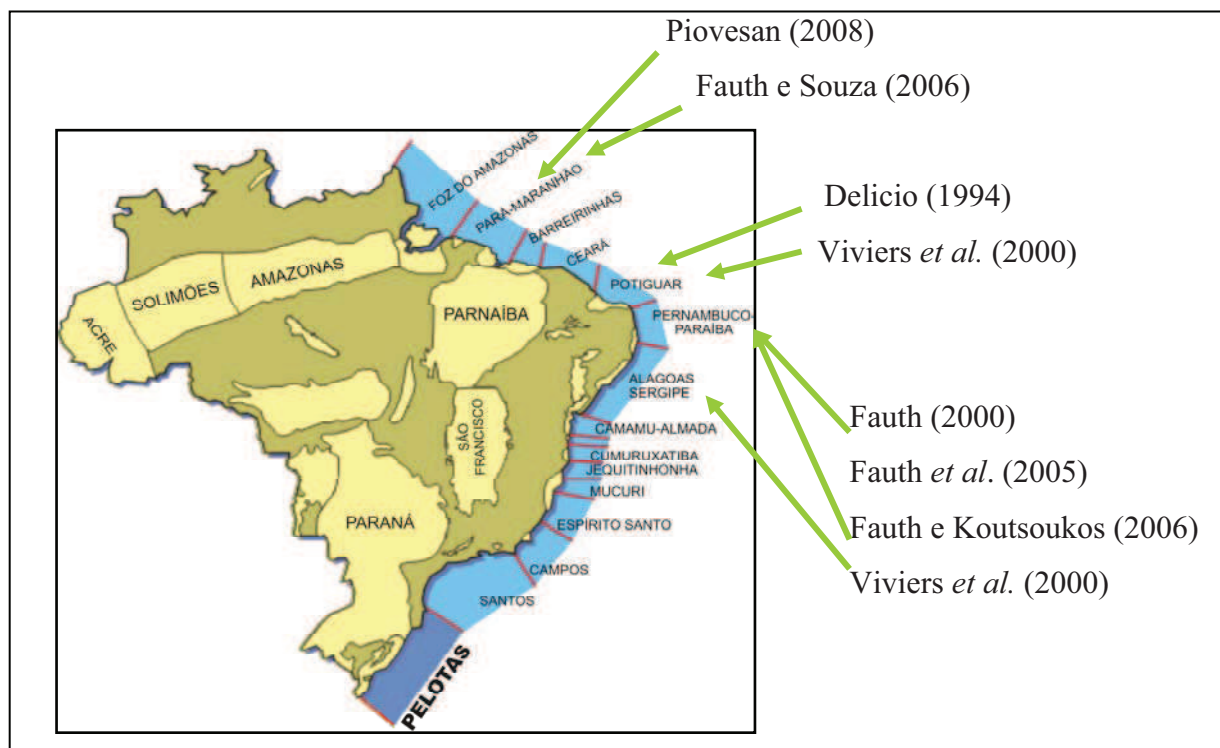


Figura 2- Estudos com ostracodes cretácicos marinhos nas bacias marginais brasileiras (modificado de Lima e Hamsi Junior 2003).

Nas últimas décadas o limite K–Pg tem sido estudado mundialmente em sedimentos marinhos por meio de diversos grupos de microfósseis (e.g., Donze *et al.* 1982, Bertels 1995, Keller e MacLeod 1995; Fauth *et al.* 2005, Keller 2005; Alegret e Thomas 2007; Aumond *et al.* 2009). Em El-Kef, na Tunísia, está localizada a seção-tipo do limite K–Pg. Outras seções conhecidas desse limite estão localizadas no Texas, Espanha, Itália, México, Argentina, Brasil e ODP 738.

Mundialmente, existem vários locais que apresentam bons registros da passagem K–Pg, entretanto, poucas destas seções contêm ostracodes.

A micropaleontologia e a estratigrafia do limite K–Pg da Argentina foram reportadas por Bertels (1969 a,b) com a determinação de três zonas estratigráficas locais, uma para o Daniano inferior e duas para o Maastrichtiano (médio e inferior). Em 1975, a mesma autora estudou os parâmetros ecológicos, através dos ostracodes, para o limite K–Pg na Argentina. Uma transgressão marinha foi observada durante o Cretáceo Superior e Paleógeno Inferior, com o aumento das temperaturas e salinidade normal. A fauna mostrou grande afinidade com o oeste africano.

Donze *et al.* (1982) realizaram um estudo detalhado da fauna de ostracodes do limite K–Pg de El-Kef, na Tunísia, identificando 50 espécies, sendo que 42 estavam presentes ao longo dos intervalos Maastrichtiano e Daniano.

Maddocks (1985) estudou os ostracodes marinhos do limite K–Pg nas três maiores seções deste contato presente no Texas: Litting Quarry, Walkers Creek e Brazos River. Na assembléia de Navarro e Midway, *Cytherella* foi o gênero dominante nas formações cretácicas e paleógenas. O início do Daniano (Paleógeno Inferior) foi marcado pelo primeiro registro, em Midway, de *Brachycythere plena* e *Bairdoppilata suborbicullata*.

Os ostracodes do Maastrichtiano e Paleoceno de Djebel Dry, na Argélia, foram estudados por Damotte e Fleury (1987), e compararam a fauna com os ostracodes de El-Kef. Dois sucessivos ambientes puderam ser identificados, um epibatial (Maastrichtiano) e um de plataforma externa (Daniano).

Browsers and De Deckker (1993) estudaram uma fauna bem preservada de ostracodes do Norte do Alaska correspondentes aos intervalos Maastrichtiano e Daniano. Foram definidas quatro assembléias de ostracodes na sequência não-marinha, marginal marinha e marinha rasa. A fauna de ostracodes indicou águas frias e forte endemismo, resultado de um possível isolamento do Oceano Ártico.

Em 1998, Said-Benzarti estudou os ostracodes do Campaniano superior ao Paleógeno da localidade de d'Ellès, na Tunísia. A fauna no limite K–Pg apresentou-se pobre e com registros pontuais dos ostracodes. Já a interpretação paleoecológica permitiu identificar um ambiente epibatial superior.

A fauna de ostracodes do K–Pg de Mali, oeste da África foi reportada por Colin *et al.* (1998). Foram analisados oito afloramentos e duas assembléias foram reconhecidas: uma endêmica no Maastrichtiano e outra no Paleoceno, com afinidades com Tethys e bacias atlânticas próximas.

Os ostracodes batiais do Cretáceo Superior ao Eoceno Médio foram estudados por Guernet e Danelian (2006) na Elevação de Demerara, no Suriname (Leg 207). Foi observado um menor registro de ostracodes no Paleógeno. As espécies consideradas detritívoras foram as mais afetadas do que as consideradas filtradoras. *Cytherella*, *Bairdia* e *Krithe* apresentaram registro tanto para o Cretáceo quanto para o Paleógeno.

#### **4.1. Limite K–Pg no Brasil**

Estudos que abordam o limite K–Pg, no Brasil, são escassos. Existe, até o momento, o registro de apenas quatro seções estudadas com a passagem K–Pg bem preservada e estão situadas nas bacias de Campos e Pernambuco (Fauth 2000).

Albertão *et al.* (1993) estudaram o limite K–Pg na pedreira Poty, na bacia Pernambuco-Paraíba, e consideraram uma das mais completas seqüências sedimentares do limite K–Pg por apresentar alta concentração de irídio, extinções bióticas e evidências de um possível impacto meteorítico e de um tsunami. Em 1994, Albertão *et al.* realizaram estudo micropaleontológico com base em foraminíferos e palinórfos no limite K–Pg ainda na bacia de Pernambuco-Paraíba,

observando o desaparecimento de quase todas as espécies de foraminíferos planctônicos, dinoflagelados, pólenes e esporos no final do Maastrichtiano.

Fauth *et al.* (2005) realizaram o estudo taxonômico e bioestratigráfico dos ostracodes do limite Cretáceo–Paleógeno na pedreira Poty, em Pernambuco, Nordeste do Brasil. Foi registrada uma significativa mudança faunística na passagem do Maastrichtiano para o Daniano na bacia. Depois de El-Kef, esta é a segunda seção com ostracodes que apresenta o registro mais completo da passagem K–Pg no mundo.

## 5. A EVOLUÇÃO DA BACIA DE PELOTAS

A evolução tectônica da bacia de Pelotas teve início no final do Jurássico e início do Cretáceo quando a costa leste brasileira e oeste africana foram atingidas por um intenso tectonismo: a “Reativação Wealdeniana”. A movimentação vertical ao longo de antigas zonas de fraqueza e o surgimento de novos falhamentos deram origem ao sistema “Rift Valleys” (Cesero & Ponte 1997) (Fig. 3).

Neste tempo, uma erosão atacou os blocos elevados e sobre esta superfície ocorreu a primeira invasão marinha. O nascente oceano caracterizava-se por ser fisiograficamente um estreito e alongado corpo d’água seccionado ao meio por uma cadeia vulcânica *Walvis Ridge-São Paulo Ridge* (Dias-Brito 1987).

O registro da sequência evaporítica na bacia de Pelotas é ausente, devido às condições de maior circulação oceânica já vigentes na porção sul (Bueno *et al.* 2007). Esta ausência atribui à bacia de Pelotas um aspecto monótono, pouco deformado, contrastando claramente com o restante da margem brasileira (Milani *et al.* 2000).

A ruptura efetiva entre os dois continentes teve início no Aptiano e durou entre 10 a 20 Ma (Fontana 1990), sendo que o estabelecimento das condições de oceano aberto de alta energia foi possível somente entre o final do Turoniano e Coniaciano (Cesero & Ponte 1997). Neste contexto, a bacia de Pelotas se insere como a precursora das demais bacias marginais da costa leste brasileira, devido a abertura da margem oceânica ter progredido de sul para norte, a partir do Platô das Ilhas Malvinas (Conceição *et al.* 1988).

Fontana (1990) caracteriza-a como uma bacia extensional e descreve o preenchimento sedimentar inicialmente por uma espessa sequência de sedimentos que inclui, predominantemente, folhelhos e arenitos subordinamente a carbonatos, conglomerados e rochas basálticas extrusivas.



Figura 3- Rift da América do Sul-África durante o Eo-Aptiano (modificado de Dias 2005).

Em estudo mais recente sobre a geologia da bacia de Pelotas, Bueno *et al.* (2007) propõem uma nova carta estratigráfica para a bacia e descrevem as sequências litoestratigráficas que representam os eventos de desenvolvimento da bacia. (Fig. 4). Entretanto, as denominações litoestratigráficas contidas em Dias *et al.* (1994) são mantidas (Fig. 5).



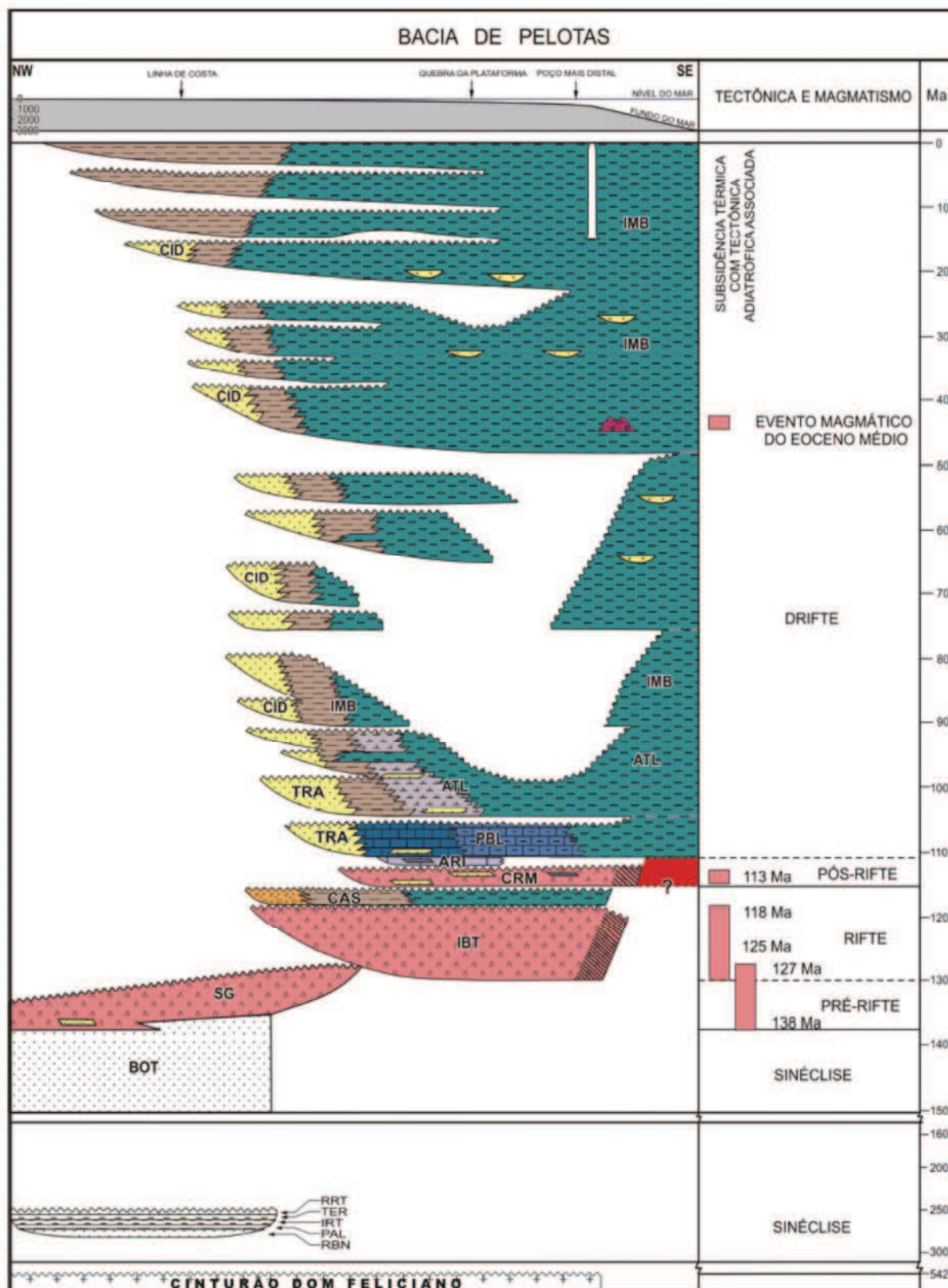


Figura 4- Carta Estratigráfica da bacia de Pelotas (modificado de Bueno et al. 2007).

Formação Imbituba	Compreende rochas basálticas na base da bacia de coloração cinza-escuro e castanho avermelhado, com textura porfirítica e subafanítica, com amígdalas preenchidas por quartzo, zeolitas, calcitas dentre outros minerais. É correlacionável com a Formação Camboriú da Bacia de Santos, e Cabiúnas da Bacia de Campos e é considerada síncrona a Formação Serra Geral da Bacia do Paraná.
Formação Cassino	Compreende rochas formadas por clásticos grossos e finos com conglomerados polimítico cinzento e castanho e siltito argiloso castanho-avermelhado, micáceo. Esta formação é correspondente com a Formação Guaratiba da Bacia de Santos e com a Formação Lagoa Feia da Bacia de Campos. É uma unidade afossilífera.
Formação Curumim	Designa rochas vulcânicas formadas por traquiandesitos cinza-esverdeado e apresenta discordância tanto pelos carbonatos Portobelo quanto pelos evaporitos Ariri. Existe possibilidade desta formação ser correlacionada com a Formação Curumim e a Formação Ipojuca, da Bacia de Pernambuco, porém não teve sua base atingida na perfuração do poço 1-SCS-1 no Alto de Florianópolis.
Formação Ariri	Apresenta os evaporitos neo-alagoas representativos da transição da sedimentação continental para marinha e foi definida e caracterizada na Bacia de Santos. Está presente na porção norte da Bacia de Pelotas.
Formação Portobelo	É formada pelos calcarenitos creme acastanhados e arenitos muito finos, sobrepostos concordantemente aos evaporitos Ariri. Possui espessas camadas calcárias, especialmente calcarenito bioclástico e oolítico e calcilito. Esta formação equivale às unidades carbonáticas Eoalbianas distribuídas pela costa brasileira como a Fm Guarujá na Bacia de Santos, Membro Quissamã na Bacia de Campos e Fm Regência na Bacia do Espírito Santo.
Formação Tramandai	Denomina os arenitos finos cinzentos, intercalados com folhelos, siltitos e calcários acinzentados, situados em discordância com a Fm Cidreira e interdigitados lateralmente com os carbonatos e pelitos das Fm Portobelo e Atlântida. Correlaciona-se com os sistemas clásticos albo-cenomânicos da Fm Florianópolis da Bacia de Santos, Membro Goitacás da Bacia de Campos, Fm São Mateus da Bacia do Espírito Santo.
Formação Atlântida	Nome proposto a espessa seção pelítica, composta por folhelho e siltito cinzentos, com camadas de arenito muito finos, argiloso e marga cinzenta. É considerado ambiente nerítico de plataforma externa e correlaciona-se com a Fm Itanhaém da Bacia de Santos, Membro Outeiro da Bacia de Campos, Fm Regência do Espírito Santo, dentre outras.
Formação Cidreira	Compreende arenitos muito finos até grosso, cinzento, e argila cinza escura. Os sistemas deposicionais presentes incluem leques costeiros progradando sobre plataforma, em ambiente nerítico. A correlação desta unidade se dá com as formações arenosas neocretáceas/terciárias presentes em toda costa brasileira.
Formação Imbé	É caracterizada por folhelho, argila e siltito cinza-esverdeado, com raras camadas de arenito turbidítico intercaladas. Correlaciona-se com todas as unidades pelíticas neocretáceas/terciárias de toda a costa brasileira. Os ambientes de deposição envolvidos são marinhos profundos, como plataforma externa, talude e bacia.

Figura 5- Denominações litoestratigráficas da bacia de Pelotas (adaptado de Dias et al.1994).

### 5.1. Caracterização Geológica

A bacia de Pelotas localiza-se entre os paralelos 28° e 34° sul (Milani *et al.* 2000), tendo como limites ao norte a bacia de Santos sobre o Alto de Florianópolis, e ao Sul o Alto de Polônio, junto ao limite territorial com o Uruguai (Bueno *et al.* 2007).

Em sua porção brasileira, a bacia de Pelotas apresenta uma extensão de 375.000 km<sup>2</sup> até lâmina d'água de 2.000 m, correspondendo a cerca de 40.000 km<sup>2</sup> emersos (Gonçalves 1979; Dias *et al.* 1994) (Fig. 6).

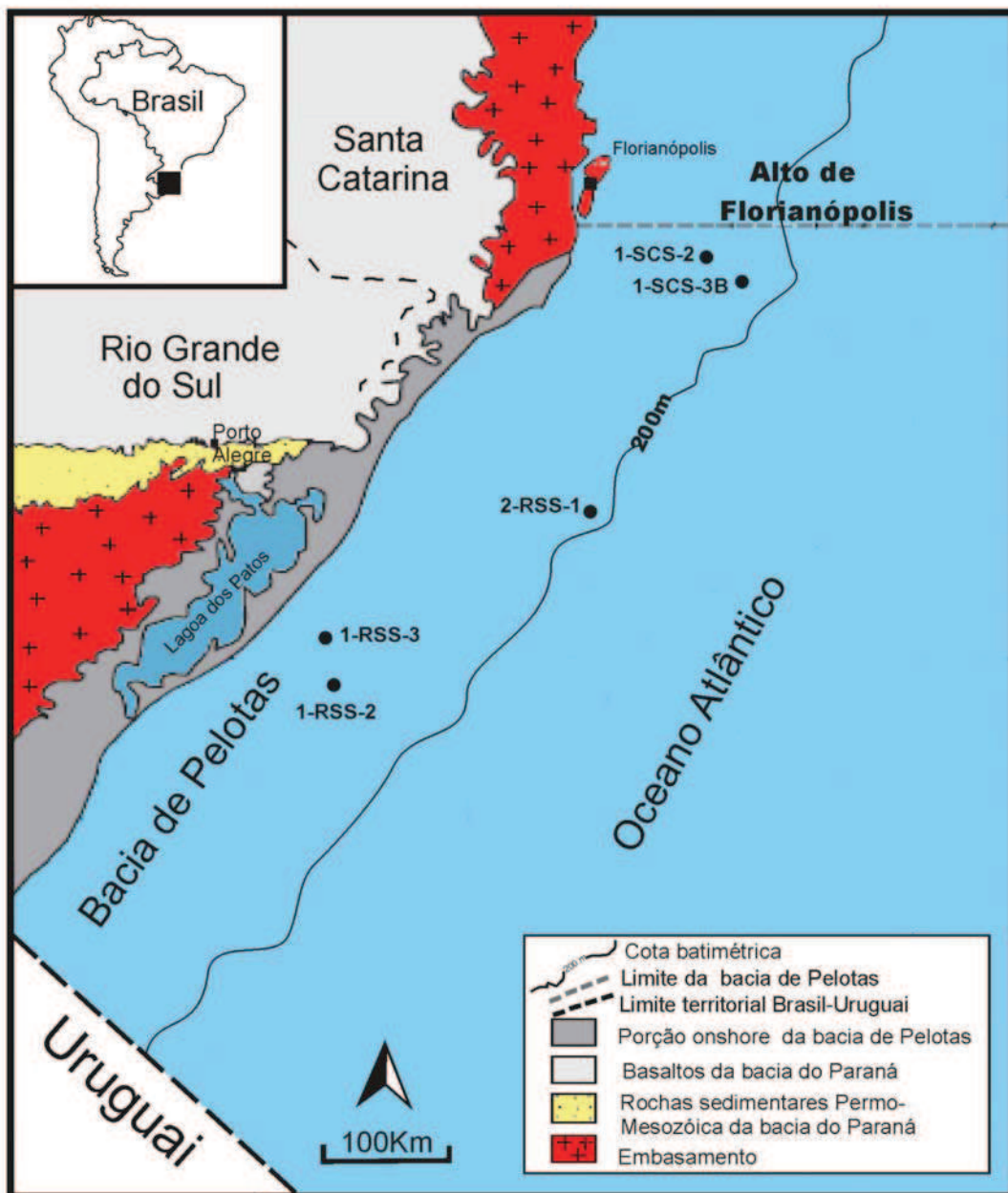


Figura 6- Mapa de Localização da bacia de Pelotas com os poços em estudo (modificado de Anjos e Carreño 2004).

O conhecimento geológico da bacia de Pelotas foi possível somente a partir da perfuração de poços realizados pela Petrobras entre as décadas de 1970 e 1980, tanto em sua porção emersa quanto submersa, além de dados sísmicos de excelente qualidade. Esta litologia foi inicialmente descrita por Closs (1970) e redefinida posteriormente por Gonçalves (1979) e Dias *et al.* (1994). As rochas que formam a bacia de Pelotas podem ser encontradas sobre o embasamento Pré-Cambriano ou localmente, sobre as rochas da bacia do Paraná. Algumas dessas sequências representam ciclos transgressivos-regressivos regidos pela variação e esforços intraplacas derivados das orogenias andinas (Rio Bonito, Palermo, Irati) (Zalán *et al.* 1990). Outras foram influenciadas pelo clima de aridez associadas a subsidência da bacia (Teresina e Rio do Rastro), extenso campo de dunas

(Botucatu) e manifestações magmáticas do estágio pré-ruptura do Gondwana (Serra Geral) (Milani *et al.* 1994).

Bueno *et al.* (2007) determinam as sequências deposicionais da bacia de Pelotas, representadas por rochas sedimentares e vulcânicas do Cretáceo Inferior, Paleógeno e Neógeno. Os depósitos relacionam-se a extensão crustal cretácea e caracterizam quatro estágios de desenvolvimento da bacia: pré-rifte, rifte, pós-rifte e drifte.

A fase rift da bacia de Pelotas é representada pelos espessos derrames basálticos da Formação Serra Geral, sotopostos a Formação Imbituba depositados 2 Ma mais tarde. Caracteriza-se como uma manifestação magmática do estágio pré-ruptura do Gondwana. São considerados como estratos pré-rifte na evolução da bacia de Pelotas, representados pela Formação Cassino. Esta é interpretada como leques aluviais progradantes da borda flexural em direção a depocentros lacustres (Bueno *et al.* 2007).

O estágio de subsidência térmica pós-rifte é representado pelos basaltos, andesitos e taquiandesitos da Formação Curumim (Dias *et al.* 1994). Sua presença fica restrita a porção norte da bacia e é possível identificar sedimentos interderrames constituídos por arenitos continentais na base que se alternam para arenitos marinhos e carbonatos no topo, sugerindo uma deposição inicial lacustre que grada para um ambiente marinho.

A supersequência drifte é uma fase evolutiva do preenchimento da bacia e pode ser considerada em três fases: a inicial, representada por depósitos de plataforma rasa no Albiano; a intermediária, sendo um período transgressivo que se estende do Albiano ao Oligoceno e, a final, constituindo-se de uma cunha clástica regressiva no Neógeno (Fig. 7).

A sequência plataformal é formada pelos depósitos carbonáticos e siliciclásticos da Formação Portobelo, caracterizando uma plataforma mista. O início do ciclo transgressivo fica bem marcado pela presença da espessa seção de pelitos da Formação Atlântida. Interpreta-se um ambiente marinho raso, que sofre a transgressão dos pelitos da plataforma externa da Formação Atlântida. A partir disso, observa-se uma alternância de transgressões e regressões de maior ordem, onde passam a ocorrer erosões mais acentuadas intercaladas a eventos transgressivos de ampla distribuição, como o ocorrido no Paleoceno. O ambiente costeiro passa a ser dominado pelos leques de clásticos grossos e finos da Formação Cidreira. A sequência regressiva é representada pelas rochas das Formações Cidreira e Imbé, onde os siltitos e arenitos finos da primeira, progradam sobre os pelitos da segunda, caracterizando uma cunha sedimentar regressiva (Bueno *et al.* 2007).

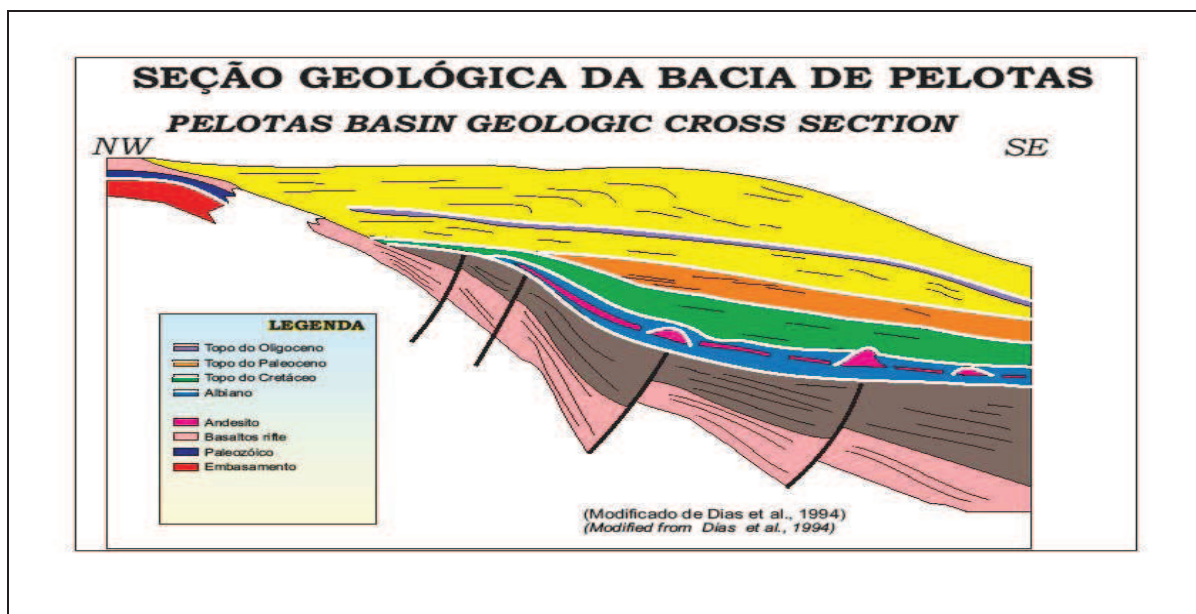


Figura 7- Seção geológica da bacia de Pelotas (modificado de Dias et al. 1994).

## 6. ESTUDOS MICROPALAEONTOLÓGICOS NA BACIA DE PELOTAS

Os ostracodes da bacia de Pelotas inicialmente foram abordados por Sanguinetti (1974) sobre a tafofaunula e bioestratigrafia datada para o Mioceno da bacia. Mais tarde, em 1979, a mesma autora realiza o estudo taxonômico dos ostracodes miocênicos em oito perfurações realizadas pela Petrobras no período de 1950 e 1964. O primeiro esboço bioestratigráfico para a bacia com este grupo de microfósseis foi realizado por Sanguinetti (1980).

Ornellas (1981) apresentou uma proposta de biozoneamento para o Cenozóico da bacia de Pelotas em sete poços de sondagens perfurados na porção onshore da bacia. Sanguinetti *et al.* (1991, 1992), realizaram o estudo taxonômico dos ostracodes para o Pós-Mioceno da bacia.

Mais tarde, Carreño *et al.* (1997) apresentaram um estudo bioestratigráfico, em cinco poços, para o Neógeno e Quaternário da bacia com o reconhecimento de quatro Zonas de Associação. Carreño *et al.* (1999) registraram as mudanças paleodeposicionais evidenciadas pelos ostracodes durante o Cenozóico, em especial o Neógeno e Quaternário.

Os estudos realizados na porção offshore da bacia de Pelotas, tiveram início com Koutsoukos (1982) na análise bioestratigráfica e paleoecológica utilizando foraminíferos no poço 1-SCS-3B. Gomide (1989), através do estudo com nanofósseis calcáreos, estabeleceu a biocronoestratigrafia para a bacia, sendo que a biozona mais antiga identifica idade Albiano–Cenomaniano, representando o mais completo estudo bioestratigráfico marinho para a bacia de Pelotas. Drozinski *et al.* (2003) estudaram os ostracodes Sub–Recentes da bacia, com amostras do programa Revizee, realizado pelo Ministério do Meio Ambiente. Os autores realizaram análise tafonômica e relacionaram os padrões de distribuição destes microcrustáceos às diferentes massas de água que ali se apresentaram. Anjos e Carreño (2004) realizaram estudo bioestratigráfico com foraminíferos planctônicos para o Neógeno da

bacia no poço 1-SCS-3B. Mais tarde, Coimbra *et al.* (2007) realizaram estudo paleoecológico e bioestratigráfico nos poços 1-SCS-3B e 1-SCS-2, também utilizando foraminíferos planctônicos, para o Neógeno da bacia.

Rodrigues e Fauth (2007) apresentaram o estudo preliminar dos ostracodes do intervalo Albiano–Cenomaniano da bacia utilizando amostras de calha, no poço 1-RSS-2. Premaor *et al.* (2007) e Fisher *et al.* (2007) apresentaram o estudo bioestratigráfico de palinomorfos, com resultados preliminares, para a seção cretácica e paleocênica, respectivamente, com amostras de testemunho do poço 2-RSS-1 da porção onshore e offshore da bacia.

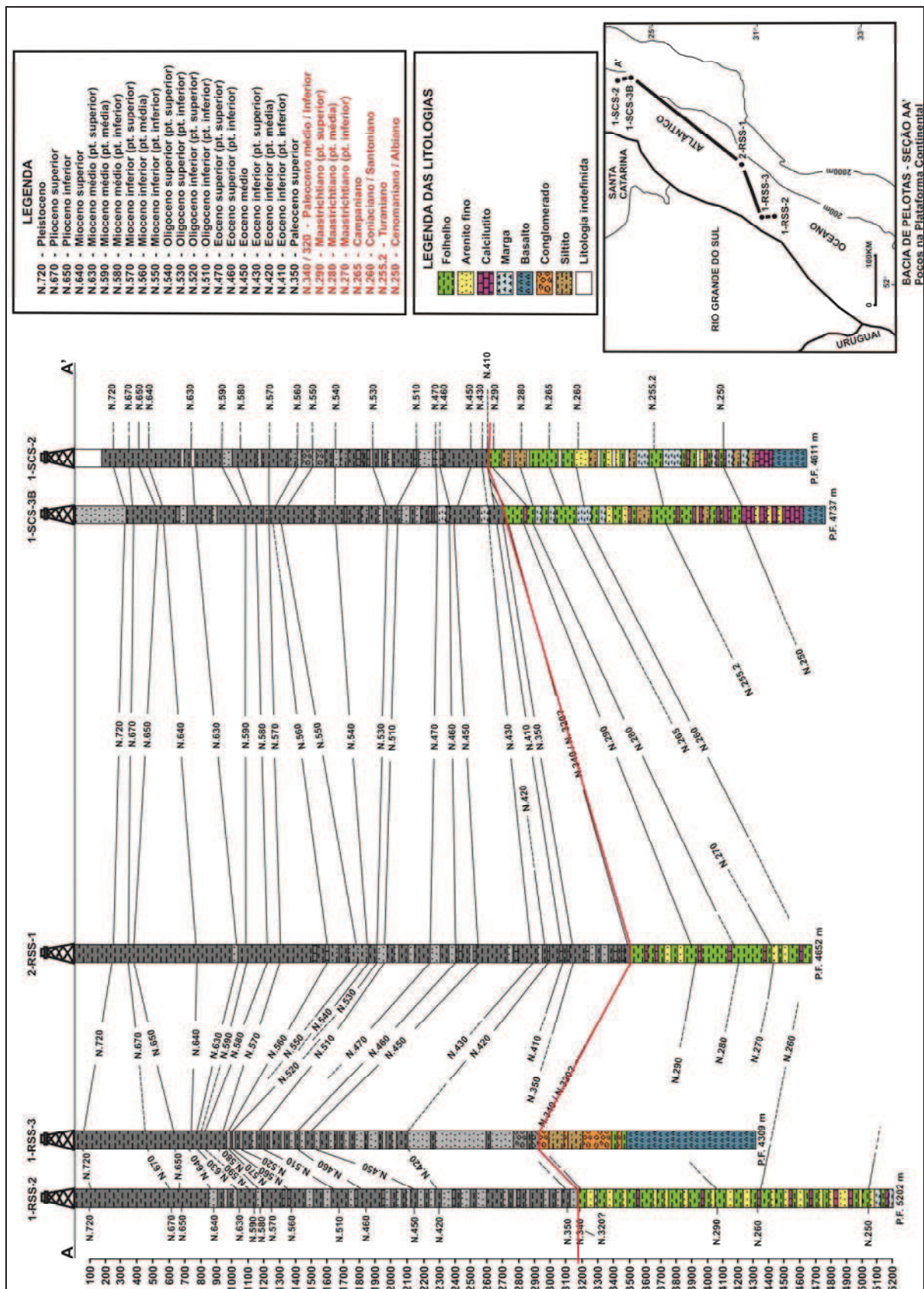
Guerra (2009) realizou biozoneamento estratigráfico na bacia com amostras de testemunho do poço 2-RSS-1, sugerindo que o intervalo Maastrichtiano inferior possa estar abaixo do determinado por Gomide (1989) na bacia.

## 7. METODOLOGIA

Para o desenvolvimento deste estudo, foram utilizadas amostras de calha correspondentes ao pacote sedimentar do Cretáceo e do Paleógeno Inferior da bacia de Pelotas oriundas de cinco poços de sondagens realizadas pela Petrobras durante as décadas de 1970 e 1980. A datação da sequência cretácica dos poços estudados neste trabalho foi baseada no zoneamento bioestratigráfico com nanofósseis calcáreos, realizado por Gomide (1989) na bacia (Fig. 8). Estas amostras foram catalogadas e armazenadas pela Petrobras, e tombadas no Laboratório de Microfósseis Calcários do IG/UFRGS, coordenado pelo professor Dr. João Carlos Coimbra, de onde foram cedidas (Anexo). Foram utilizadas 479 amostras dos poços denominados 1-RSS-2, 1-RSS-3, 2-RSS-1, 1-SCS-3B e 1-SCS-2, correspondentes ao período Cretáceo e Paleógeno Inferior, as quais foram processadas no Laboratório de Micropaleontologia da Universidade do Vale do Rio dos Sinos – UNISINOS, utilizando a técnica convencional para o estudo de ostracodes fósseis (Fauth e Do Carmo, no prelo).

O processo consistiu na pesagem do material, desagregação com peróxido de hidrogênio (H<sub>2</sub>O<sub>2</sub>), lavagem em um conjunto de peneiras de fração granulométrica de 0,250 mm, 0,180 mm e 0,063 mm até ocorrer a separação completa das frações, e secagem em estufa a 60°C. Na sequência, procedeu-se à triagem em microscópio estereoscópico MOTIC SMZ – 168.

Os espécimes ilustrados passaram por um processo de limpeza em ultra-som devido as condições de preservação em que se encontravam, o que tornou possível a identificação taxonômica dos indivíduos. Para a realização deste procedimento, os espécimes foram acondicionados individualmente, em lâmina depósito, e levados ao ultra-som por um tempo médio de um a cinco minutos.



Das 479 amostras preparadas e triadas, 46 continham ostracodes (Quadro 1).

**Quadro 1: Amostras da bacia de Pelotas.**

Poços	Intervalo Amostrado (m)	Espaçamento entre amostras (m)	Total de amostras	Amostras com ostracodes	Total de espécimes
1-RSS-2	3.105-5.190	15	127	5	5
1-RSS-3	2.796-3.606	15	34	estéril	estéril
2-RSS-1	3.402-4.650	15	57	4	4
1-SCS-3B	2.490-4.725	15	139	21	57
1-SCS-2	2.490-4.605	15	122	16	30

Os espécimes melhor preservados e representativos de cada espécie foram fotografados em microscópio eletrônico de varredura do BPA/CENPES/PETROBRAS, no Rio de Janeiro e na Pontifícia Universidade Católica (PUC-RS), em Porto Alegre.

Para a classificação e identificação taxonômica foi utilizada bibliografia apresentada por Morkhoven (1963) e Benson (1961), além do catálogo on-line de Ellis e Messina e outras literaturas especializadas. Para a nomenclatura das superfamílias adotou-se a proposta revisada por Liebau (2005).

As estampas foram montadas no programa Adobe Photoshop CS3, versão 10. As figuras foram editadas no programa *Corel Draw*, versão 14.

O material tipo do presente estudo está depositado no Museu de Paleontologia da Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Brasil, na Sessão Ostracodes, sob os números MP-O 2109-2144.

Visando a divulgação científica dos resultados deste estudo, optou-se por escrever a dissertação em forma de artigo, levando em conta o incentivo do Programa de Pós-graduação em Geologia da Unisinos à produção bibliográfica do corpo discente. Desta forma, esse trabalho é composto de capítulos gerais introdutórios, um artigo completo (em processo de submissão) e lista de referências completa (artigo e capítulos introdutórios).



## **8. Cretaceous-Lower Paleogene Ostracods from the Pelotas Basin, Brazil.**

Ceolin, D & Fauth, G., 2010.

*Palaeobiodiversity and Palaeoenvironments*, em  
submissão

Este artigo apresenta o estudo taxonômico dos ostracodes e as considerações paleoecológicas para a bacia de Pelotas.

## Cretaceous–Lower Paleogene Ostracods from the Pelotas Basin, Brazil.

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### Abstract

A total of 479 samples from five drill-holes of the Pelotas Basin were analyzed. Ninety-eight specimens were recovered, belonging to nine families, twenty-one genera, thirty-four species. Four taxa could not be identified at generic level and are referred as “gen. *et sp. indet*”. The taxa identified or tentatively identified at specific level were: *Cytherella* cf. *C. araucana* Bertels, *Cytherelloidea spirocostata* Bertels, *Bairdoppilata triangulata* Edwards, *Actinocythereis indigena* Bertels, *Brachycythere* gr. *sapucariensis* Krömmelbein, *Wichmannella araucana* Bertels, and *Wichmannella meridionalis* Bertels. The most diversified genera were *Cytherella* and *Paracypris* with seven and four species, respectively. The most abundant families were Trachyleberididae and Cytherellidae. The K–Pg boundary in the Pelotas Basin is marked by a faunal change with the local disappearance of the genera *Cytherelloidea*, *Argilloecia*, *Cythereis*, *Brachycythere*, *Pondoina* and *Rostrocytheridea*, and the first local occurrence of *Neonesidea*, *Bairdoppilata*, *Ambocythere*, *Buntonia*, *Langiella*?, *Trachyleberis* and *Krithe*. The genera *Cytherella*, *Paracypris*, *Wichmannella* and *Actinocythereis* are recorded in the Cretaceous as well as the Paleogene. This faunal study suggests a neritic marine environment for the Pelotas Basin.

Keywords: Pelotas Basin, ostracods, Brazil, Cretaceous, Paleogene.

### Introduction

The Cretaceous represents a key period for understanding changes on a large scale, which culminated with the separation of the South American and the African continents originating the South Atlantic Ocean. The Cretaceous marine ostracods have been studied in some Brazilian coastal basins (Delicio 1994; Fauth 2000; Viviers et al. 2000; Fauth et al. 2005); however, there is a significant lack of studies on this fossil group in these basins. At the end of the Cretaceous the largest extinction events of the Phanerozoic is recorded. The K–Pg boundary records the disappearance of 75% of the terrestrial as well as the marine species (e.g., MacLeod et al. 1997; Alegret et al. 2003; Skelton 2003; Ridley 2006).

The abrupt environmental changes that occurred about 65 million years ago affected life on the planet, and its causes are still the subject of intensive discussions. Worldwide, there are many

places that show sections with the K–Pg boundary; however, few of these are well preserved and contain ostracods. Some of these studies were carried out in Argentina (Bertels 1969b), Tunisia, (Donze et al. 1982; Said-Benzarti 1998), Texas (Maddocks 1985), Algeria (Damotte and Fleury 1987), the north of Alaska (Browsers and De Deckker 1993), Mali (Colin et al. 1998), Brazil (Fauth et al. 2005), Suriname (Leg 207) (Guernet and Danelian 2006), and the Caribbean Sea, ODP Site 1001B (Leg 165) (Aumond et al. 2009). The GSSP stratotype section of the K–Pg boundary is located in El Kef, Tunisia. Therefore, the purpose of this paper is to present the taxonomic study on ostracods and the paleoecological considerations to Cretaceous and Cretaceous–Lower Paleogene in the Pelotas Basin.

### **Geological setting**

The Pelotas Basin is a coastal basin of southern Brazil, located between parallels 28°S and 34°S, and bordered to the north by the Santos Basin and to the south by Uruguay (Bueno et al. 2007) (Fig. 1). The origin of this basin is related to the fragmentation of Gondwana and the formation of the South Atlantic Ocean, with is considered the precursor of the remaining basins in the Brazilian coast.

The wells were drilled by Petrobras and represent the whole sedimentary Cretaceous package corresponding to the Imbituba, Cassino, Curumim, Ariri, Portobelo, Tramandaí, Atlântida, Cidreira and Imbé Formations (Dias et al. 1994).

### **Micropaleontological studies from the Pelotas Basin**

Up to now, the micropaleontological studies carried out in the Pelotas Basin were concentrated in the Cenozoic, mainly Miocene. There are no detailed studies for the Cretaceous period in this basin.

The first micropaleontological studies performed in this basin date back to the 1970s and concern geological characteristics (Closs 1970). Studies of ostracods in the Pelotas Basin include the interval of the Miocene to the Quaternary, carried out in wells located on the onshore portion of the basin. These studies have a taxonomic, paleontologic and biostratigraphic focus (Sanguinetti 1974, 1979, 1980; Sanguinetti et al. 1991; Sanguinetti et al. 1992; Carreño et al. 1997; Carreño et al. 1999). Micropaleontological studies on the offshore portion focused on foraminifera (Anjos and Carreño 2004; Coimbra et al. 2007) and calcareous nannofossils (Gomide 1989; Guerra 2009).

### **Material and Methods**

A total of 479 cutting samples were analyzed, including the Cretaceous–Lower Paleogene periods, corresponding to the drill-holes located on the offshore portion of the Pelotas Basin, 1-RSS-2, 1-RSS-3, 2-RSS1, 1-SCS-3B, and 1-SCS-2. The drill-hole 1-RSS-3 was barren to ostracodes. The ages of the sequences in the wells studied in this work are based on the study of calcareous nannofossils

(Gomide 1989) (Fig. 2). The samples were processed in the Micropaleontology Laboratory of the Universidade do Vale do Rio dos Sinos - UNISINOS, using the conventional technique for the study of fossil ostracods. The specimens illustrated in this study were cleaned by ultrasound to help in the taxonomic identification of the individuals. The specimens were photographed using a scanning electron microscope at BPA/CENPES/PETROBRAS, Rio de Janeiro and at the Pontifícia Universidade Católica (PUC-RS), Porto Alegre. The material is mainly preserved as carapaces. Therefore, internal details are not usually available to aid taxonomic determinations. Dimensions given in mm. The type material of the current study is deposited at the Museum of Paleontology, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Brazil, Ostracod Section, numbers MP-O 2109-2144.

### **Systematic paleontology**

For the taxonomic classification and identification adopted to a generic level, we followed both Benson (1961) and Morkhoven (1963). For nomenclature of suprageneric taxa, a new revised proposal was adopted (Liebau 2005).

Subclass Ostracoda Latreille, 1802  
Superorder Podocopomorpha Kozur, 1972  
Order Platycopida Sars, 1866  
Superfamily Cytherelloidea Sars, 1866  
Family Cytherellidae Sars, 1866  
Genus *Cytherella* Jones, 1849  
*Cytherella* cf. *C. araucana* Bertels, 1974  
Figure 3, figures 1-2

1974 cf. *Cytherella araucana* – Bertels, p. 388, pl.1, figs. 1 a-b, 2 a-b.

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 113.

**Age:** Campanian.

**Dimensions:** Figured specimen: MP-O-2109; length: 0.72 mm, height: 0.48 mm, width: 0.32 mm.

**Remarks:** The specimen of Bertels, from the Cretaceous of Argentina, showed a more elongated carapace and a smaller overlap in the posteroventral region. *Cytherella* cf. *C. araucana* in dorsal view is narrower in the anterior region compared to the species from Argentina. It is also similar to *C. terminopunctata* Holden, 1964 figured by Bertels (1975b), from the Upper Cretaceous of Fortín General Roca, Argentina. However, the Argentinean species has punctate only in the anterior and posterior regions.

*Cytherella* sp. 1

Figure 3, figures 3-4

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 54.

**Age:** Albian–Cenomanian.

**Dimensions:** Figured specimen: MP-O-2110; length: 0.83 mm, height: 0.48 mm, width: 0.40 mm.

**Description:** Carapace subrectangular in lateral view, with its maximum height in the anterior region. The right valve is larger than the left. The overlap is more pronounced in the anterior, ventral and dorsal margins. Anterior and posterior margins are symmetrically rounded. The dorsal margin is almost straight. Ventral margin appears slightly concave in middle. Surface smooth. In dorsal view, the carapace is ovoid and narrow. The maximum width occurs at the posterior region. In the midpoint of the carapace, occurs one shallow depression.

**Remarks:** *Cytherella* sp. 1 differs from *Cytherella* sp. 1 Fauth et al. 2003 from the Campanian of James Ross in Antarctica, by showing an overlap in the anterior and ventral margins. In dorsal view, it does not have a middle constriction in the carapace, and the anterior region is more rounded. *Cytherella* sp. 1 differs from *Cytherella* sp. 3 Dingle, 1981 from the Upper Cretaceous of Richards Bay, South Africa, by showing an overlap in the anterior and ventral margins. It differs from *Cytherella* cf. *C. araucana* Bertels, 1973, identified in this study, by being more elongated and smooth, and by having a middle constriction.

*Cytherella* sp. 2

Figure 3, figure 5

**Material:** Nine carapaces: one adult; eight juveniles.

**Occurrence:** Drill-hole 1-SCS-3B; samples 122, 123, 134, 136, 138; Drill-hole 2-RSS-1; sample 20.

**Age:** Maastrichtian–Paleogene.

**Dimensions:** Figured specimen: MP-O-2111 (sample 122, Drill-hole 1-SCS-3B); length: 1.3 mm, height: 0.93 mm, width: 0.65 mm.

**Description:** Carapace subovate in lateral view, with its maximum height in the middle of the carapace. The right valve overlaps the left one along the anterior, dorsal and ventral margins. The anterior and posterior margins are rounded. Dorsal and ventral margins are convex. The carapace is inflated in posterodorsal region. Surface smooth. Anterior region is significantly narrower than posterior region.

**Remarks:** It differs from *Cytherella* sp. 5, figured herein, by the larger dimensions and weaker overlap along the margins, which are also higher than that of *Cytherella* sp. 5. In dorsal view, it is inflated in the posterior region.

*Cytherella* sp. 3

Figure 3, figures 6-7

**Material:** Ten carapaces: one male; one female; eight juveniles.

**Occurrence:** Drill-hole 1-SCS-2; samples: 79, 104 e Drill-hole 1-SCS-3B; samples: 94, 99, 108.

**Age:** Turonian–Campanian.

**Dimensions:** Figured specimen: MP-O-2112; (sample 104, Drill-hole 1-SCS-2); length: 0.89 mm, height: 0.52 mm, width: 0.4 mm.

**Diagnosis:** Carapace subovate and elongate in lateral view, with its maximum height just behind the middle of the carapace. The right valve overlaps entirely the left one. Anterior and posterior margins are symmetrically rounded. Dorsal and ventral margins are slightly convex. Surface ornamented by punctations in the anterior and posterior regions. Posterior region inflated in dorsal view.

**Remarks:** *Cytherella* sp. 3 differs from *Cytherella terminopunctata* Bertels, 1975b from the Middle Maastrichtian of the Jagüel Formation, Argentina, by the posterior margin symmetrically rounded and the dorsal region slightly convex. It differs from *Cytherella* sp. 1, figured herein, in the outline and absence of the middle constriction which is not observed in *Cytherella* sp. 3.

*Cytherella* sp. 4

Figure 3, figures 8-9

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 130.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2113; length: 0.77 mm, height: 0.52 mm, width: 0.44 mm.

**Description:** Carapace subovate in lateral view, with its maximum height in the posterior region. The right valve overlaps the left one around entire margin. The anterior and posterior margins are symmetrically rounded. Dorsal and ventral margins are slightly convex. Surface ornamented by punctations in the anterior and posterior region. In dorsal view, the carapace appears pear-shaped, with anterior region significantly narrower than posterior.

**Remarks:** *Cytherella* sp. 4 differs from *Cytherella* sp. 3, figured herein, being shorter and significantly higher. In dorsal view, it is more inflated in the posterior region. *Cytherella* sp. 3 has more prominent overlaps along the entire margin than does *Cytherella* sp. 4.

*Cytherella* sp. 5

Figure 3, figure 10

**Material:** four carapaces: one adult; three juveniles.

**Occurrence:** Drill-hole 1-SCS-3B; samples 134, 138.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2114; (sample 138); length: 0.89 mm, height: 0.65 mm, width: 0.47 mm.

**Description:** Carapace subovate in lateral view, with its maximum height in the middle region. Right valve overlaps the left valve along all the margins, and is weaker in the posteroventral region. The anterior and posterior margins are rounded. The anterior margin with carina. The dorsal margin is arched and convex in the middle portion and slightly concave towards the anterior part. The ventral margin is strongly convex. Surface smooth. In dorsal view, the posterior region is inflated.

**Remarks:** *Cytherella* sp. 5 differs from *Cytherella piacabucuensis* Neufville, 1973 from the Danian of Sergipe-Alagoas and Pernambuco-Paraíba in Brazil, figured by Fauth et al. (2005), in the outline of the overlap of the right valve and in the concavity of the anterodorsal margin. *Cytherella* sp. 5 is more oval, while *C. piacabucuensis* is more elongated with anterior and posterior symmetric margins.

*Cytherella* sp. 6

Figure 3, figures 11-12

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 79.

**Dimensions:** Figured specimen: MP-O-2115; length: 0.57 mm, height: 0.28 mm, width: 0.20 mm.

**Description:** Carapace subovate and elongate in lateral view, with its maximum height in the middle region. The right valve overlaps the left valve in the ventral and posterior margins. The anterior margin is rounded and posterior margin is obliquely rounded. The dorsal margin is almost straight. Surface ornamented by small punctations in the posterior region and slight reticulations near the margins. In dorsal view, the posterior region is inflated.

**Remarks:** Although *Cytherella* sp. 6 exhibits a pattern of ornamentation that is not very common for this genus, the possibility of this specimen belonging to the genus *Platella* (Coryell and Fields, 1977) is discarded, because the central groove is lacking, which is characteristic of the genus. Some authors consider *Platella* to be a junior synonym of *Cytherella* (e.g., Van Morkhoven 1963; Bate 1972). However, Dingle (2009) considers *Platella* to be a valid genus.

Genus *Cytherelloidea* Alexander, 1929

*Cytherelloidea spirocostata* Bertels, 1973

Figure 3, figures 13-14

1973 *Cytherelloidea spirocostata* Bertels, p. 313, pl. 1; figs. 5 a-c.

1995 *Cytherelloidea spirocostata* Bertels, p. 116, pl. 1; fig. 8.

**Material:** one carapace.

**Occurrence:** Drill-hole 2-RSS-1; sample 29.

**Age:** Upper Maastrichtian.

**Dimensions:** Figured specimen: MP-O-2116; length: 0.78 mm, height: 0.48 mm, width: 0.57 mm.

**Description:** Carapace elliptical in lateral view, anterior extremity broadly rounded. In dorsal view, carapace hexagonal elongate. The ornamentation consists of a single ridge disposed in a spire over each valve. The subcentral region possesses a slight dorsoventrally elongate depression.

**Remarks:** *Cytherelloidea spirocostata* differs from *Cytherelloidea megaspirocostata* Fauth et al. 2003 from the Santonian–Campanian of James Ross Island, Antarctica, by having more concentric ribs, a smaller size, and lack of convexity in the ventral margin. *C. spirocostata* also shows similarities with *C. westaustraliensis* Bate, 1972 from the Upper Cretaceous of the Carnarvon Basin in Australia, but differs because of the presence of more concentric ribs and because of the oval shape of the carapace.

**Stratigraphic distribution:** Lower Paleogene in Fortín General Rocca from Argentina and Upper Cretaceous in Pelotas Basin

Order Podocopida Sars, 1866

Suborder Bairdiocopina Gründel, 1967

Superfamily Bairdioidea Sars, 1888

Family Bairdiidae Sars, 1888

Genus *Neonesidea* Maddocks, 1969

*Neonesidea* sp.

Figure 3, figure 15

**Material:** eight carapaces: three adults; five juveniles.

**Occurrence:** Drill-hole 1-SCS-3B; samples 130, 132, 134, 136, 137, 138, 139. Drill-hole 1-SCS-2; sample 122.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2117 (Drill-hole 1-SCS-3B, sample 137); length: 1.02 mm, height: 0.65 mm, width: 0.52 mm.

**Description:** Carapace subtriangular in lateral view, with its maximum height in the anterior region. The overlap is weak and more pronounced in the anterodorsal and ventral margins. The posterior margin is narrower and more rounded than anterior. The dorsal margin is convex, sloping to posterodorsal region. The anterodorsal margin is slightly concave and the ventral margin is straight. In dorsal view, the carapace is subelliptical with greatest width in the anterior region. Surface smooth.

Genus *Bairdoppilata* Coryell, Sample and Jennings, 1935

*Bairdoppilata triangulata* Edwards, 1944

Figure 3, figure 16

1974 *Bairdoppilata triangulata* Sanguinetti, p.22, pl. 1, figs 1a-b.

**Material:** one carapace.



**Occurrence:** Drill-hole 1-SCS-3B; sample 122.

**Dimensions:** Figured specimen: MP-O-2118; length: 0.75 mm, height: 0.52 mm, width: 0.44 mm.

**Remarks:** *Bairdoppilata triangulata* Edwards, 1944 is the same species recorded by Sanguinetti (1974) from the Miocene of the Pelotas Basin. This specimen is considered caved material from the Miocene rocks and is not used for the paleoecological interpretation in the present study.

*Bairdoppilata* sp. 1

Figure 3, figure 17

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 121.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2119; length: 0.85 mm, height: 0.52 mm, width: 0.36 mm.

**Description:** Carapace subtrapezoidal in lateral view, with its maximum height in the middle region. The left valve overlaps the right valve on posterodorsal margin. The dorsal margin is arched and convex. The ventral margin is slightly concave in middle portion. Surface smooth.

**Remarks:** This specimen has the anterodorsal and posteroventral region broken and the posterodorsal region covered by sediment. This bars major refinement in the description.

Suborder Cypridocopina Jones, 1901

Superfamily Pontocypridoidea Liebau, 2005

Family Pontocyprididae Müller, 1894

Genus *Argilloecia* Sars, 1866

*Argilloecia* sp.

Figure 3, figure 18

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 118.

**Age:** Maastrichtian.

**Dimensions:** Figured specimen: length: 0.45 mm, height: 0.22 mm, width: 0.19 mm. (specimen lost).

**Description:** Carapace subtrapezoidal in lateral view, with its maximum height in the middle region. The right valve overlaps the left valve around entire margin. The posteroventral region is pointed. The ventral margin is almost straight. The dorsal margin is gently convex with a stronger slope in posterodorsal region. Surface smooth.

**Remarks:** *Argilloecia* sp. differs from *Argilloecia faba* Alexander, 1934, figured by Neufville (1973, 1979), from the Eocene of the Sergipe-Alagoas Basin, Brazil by showing a smaller angle in the posterior region and a more acute final portion. It differs from *Argilloecia?* sp. illustrated by Viviers et

al. (2000), from the Coniacian–Santonian of the Potiguar Basin, Northeast Brazil by having an almost straight ventral margin.

Superfamily Cypridoidea Baird, 1845

Family Candonidae Kaufmann, 1900

Subfamily Paracypridinae Sars, 1923

Genus *Paracypris* Sars, 1866

*Paracypris* sp. 1

Figure 4, figure 1

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 80.

**Age:** Turonian.

**Dimensions:** Figured specimen: MP-O-2120; length: 0.89 mm, height: 0.39 mm, width: 0.36 mm.

**Description:** Carapace subtrapezoidal and elongate in lateral view, with its maximum height in the middle region. The left valve overlaps the right valve around entire margin, except in the anterodorsal margin. The anterior margin is rounded and posterior margin is acute. The dorsal margin is convex and ventral margin is straight. Greatest length in ventral region. Surface smooth. In dorsal view, carapace is elliptic with greatest width in middle portion.

**Remarks:** *Paracypris* sp. 1 differs from *Paracypris* sp. Bertels, 1973 from the Danian of Argentina by a less arched dorsal margin and less acute posterior region. It differs from *Paracypris* sp. 2 Delicio, 1994 from the Upper Cretaceous of the Potiguar Basin, by the narrower anterior region and the less convex dorsal margin.

*Paracypris* sp. 2

Figure 4, figure 2

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 78.

**Age:** Turonian.

**Dimensions:** Figured specimen: MP-O-2121; length: 0.8 mm, height: 0.35 mm, width: 0.28 mm.

**Description:** Carapace subtrapezoidal and elongate in lateral view, with its maximum height in the anterior. The left valve overlaps the right valve in dorsal and ventral margins. The anterior margin is obliquely rounded. The dorsal margin is slightly convex, declining towards the posterodorsal region acutely. The anterodorsal margin with slight concavity more easily seen in right valve. The ventral margin is almost straight. Greatest length in ventral region. Surface ornamented with weak longitudinal stria better preserved near the ventral and posteroventral regions.

**Remarks:** More details on the posterior region of this specimen are not possible since this region is broken on the specimen.

*Paracypris* sp. 3

Figure 4, figure 3

**Material:** one valve.

**Occurrence:** Drill-hole 1SCS-3B; sample 134.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2122; length: 1.26 mm, height: 0.56 mm, width: 0.24 mm.

**Description:** Carapace subtrapezoidal in lateral view, with its anterior region rounded and posterior region acuminate. The maximum height is just anterior of middle region. The dorsal margin is gently convex sloping to the posterodorsal region. The ventral margin is straight. Greatest length in ventral region. Surface smooth. Internal features were not possible to visualize.

**Remarks:** *Paracypris* sp. 3 differs from *P. umzambaensis* Dingle, 1981 for the Senonian of Pondoland, South Africa, by having a less convex dorsal region. It differs from *Paracypris* sp. Fauth et al. 2003 from the Campanian of Antarctica, by the anterior region being symmetrically rounded and the posterior end less acute.

*Paracypris?* sp. 4

Figure 4, figure 4

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 138.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2123; length: 0.98 mm, height: 0.48 mm, width: 0.41 mm.

**Description:** Carapace subtrapezoidal in lateral view, with its maximum height in the middle region. The left valve overlaps the right valve around both the free and hinge margins. Greatest length in ventral region. Anterior margin rounded, posteroventral margin is slightly acuminate. The dorsal margin is convex, ventral margin with slight concavity in the middle. Surface smooth. In dorsal view presents elliptical outline with an acuminate extremity.

**Remarks:** *Paracypris?* sp. 4 differs from *Paracypris?* sp. Bertels, 1973 from the Lower Danian of Argentina by the less arched dorsal margin. It also differs from *Paracypris* sp. 2 Bertels, 1975b, from the same region, by the lower declivity in the posterodorsal region and more pronounced overlap in the ventral margin.

Suborder Cytherocopina Gründel, 1967

Infraorder Nomocytherininae Liebau, 1991

Superfamily Trachyleberidoidea Baird, 1850

Family Cytherettidae Triebel, 1952

Genus *Ambocythere* Bold, 1957

*Ambocythere* sp.

Figure 4, figure 5

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 138.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2124; length: 0.48 mm, height: 0.28 mm, width: 0.24 mm.

**Description:** Carapace subrectangular in lateral view, with maximum height in the middle region. The anterior margin is uniformly rounded. The posterior margin is truncated with three small spines. The ventral and dorsal margins are slightly convex. The carapace is ornamented with ribs, one on anterior margin one in the middle and two in ventral region. The left valve is slightly larger than right valve. In dorsal view, the greatest width is in the posterior region.

**Remarks:** This specimen differs from *Ambocythere elongata* Bold, 1958 from the Miocene of Cuba by different pattern of reticulation and lack of denticulate flange developed in the end of the posterior region.

Subfamily Buntoniinae Apostolescu, 1961

Genus *Buntonia* Howe, 1935

*Buntonia* sp.

Figure 4, figures 6-7

**Material:** Two carapaces: one adult; one juvenile.

**Occurrence:** Drill-hole 1-SCS-3B; sample 135; Drill-hole 1-SCS-2; sample 121.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2125; length: 0.81 mm, height: 0.52 mm, width: 0.36 mm.

**Description:** Carapace subtriangular in lateral view, with its maximum height at the anterior cardinal angle. The left valve overlaps the right valve at the anterior cardinal angle and posterior margin. The anterior margin is broadly rounded and posterior margin is narrow and slightly acuminate. Weak posterodorsal cardinal angle. The ventral margin is broadly and uniformly convex. Surface ornamented with punctations in central region. The ventral area is ornamented with four small longitudinal ribs parallel to ventral margin. Dorsal view is subelliptical with extremity compressed and middle region inflated.

**Remarks:** It differs from *Buntonia?* sp. Dingle, 1981 from the Campanian and Maastrichtian of the Igoda Formation in South Africa by being shorter and by lacking the small concavity in the posterodorsal region.

Family Trachyleberididae Sylvester-Bradley, 1948

Genus *Actinocythereis* Puri, 1953  
*Actinocythereis indigena* Bertels, 1969b

Figure 4, figure 8

1969b *Actinocythereis indigena* Bertels, p. 262, pl.5, figs 1a-c.

1975a *Actinocythereis indigena* Bertels, p. 347, pl.3, fig 6.

2001 *Actinocythereis* cf. *A. indigena* Bertels, 1969, Szczechura, 178, pl.4, figs 6a-b.

**Material:** Three carapaces: one adult; two juveniles.

**Occurrence:** Drill-hole 2-RSS-1; sample 30; Drill-hole 1-SCS-3B; sample 104; Drill-hole 1-SCS-2; sample 122.

**Age:** Campanian–Paleogene.

**Dimensions:** Figured specimen: MP-O-2126 (sample 30, drill-hole 2-RSS-1); length: 0.89 mm, height: 0.48 mm, width: 0.45 mm.

**Description:** Carapace subtrapezoidal in lateral view. Anterior margin broadly rounded, posterior margin acutely rounded. Dorsal outline straight and ventral slightly convex. In dorsal view, carapace subrectangular with compressed extremities. The ornamentation consists of three longitudinal rows of nodes, irregular in size. Anterior margin with two rows of tubercle. Eye tubercle present.

**Remarks:** The illustrated specimen here is broken on the anterodorsal margin, and the ornamentation is abraded.

**Stratigraphic distribution:** Lower Paleogene in Huantrai-co, Province del Neuquén in Argentina and Upper Cretaceous from Pelotas Basin.

*Actinocythereis* sp.1

Figure 4, figures 9-10

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 134.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2127; length: 1.18 mm, height: 0.65 mm, width: 0.61 mm.

**Description:** Carapace subtrapezoidal in lateral view, with its maximum height at the anterior cardinal angle. The left valve overlaps the right valve at the anterior cardinal angle, posterodorsal, ventral and anterior region. The anterior margin is broadly rounded. Posterior margin is acute at carapace mid-height, the dorsal margin is almost straight converging to posterior end. Posterodorsal margin with weak posterior cardinal angle. Ventral margin slightly sinuous. The anterior and posterior regions have a groove parallel to margins. Eye tubercle present. Surface ornamented with three longitudinal rows of nodes, irregular in size. One row begins near the ventral region and extends to anterior margin. Another longitudinal row is in the middle and finishes at the subcentral tubercle. The anteroventral

and posteroventral margins have spines. Dorsal view is subhexagonal with anterior and posterior regions compressed.

**Remarks:** *Actinocythereis* sp. 1 differs from *Actinocythereis indigena* Bertels, 1969b identified in this work, by showing the anterior region obliquely rounded, ventral margin with a slight sinuosity and posterior region acuminate in the central portion.

Genus *Apatihowella* Jellinek and Swanson, 2003

*Apatihowella* sp. 1

Figure 4, figure 11

**Material:** seven carapaces: three adults; four juveniles.

**Occurrence:** Drill-hole 1-SCS-3B; samples 73, 122, 132, 134, 138.

**Dimensions:** Figured specimen MP-O-2128 (sample 132); length: 0.77 mm, height: 0.48 mm, width: 0.48 mm.

**Description:** Carapace subtrapezoidal in lateral view, with its maximum height at the anterior cardinal angle. The anterior and posterior margins are obliquely rounded. The posterior margin is narrow and dorsal margin is straight, with weak posterodorsal cardinal angle. The ventral margin is slightly convex. Small eye tubercle. The carapace is reticulated with small spines. Small denticles in the anterior and posterior margins. In dorsal view it is subelliptical.

**Remarks:** This genus *Apatihowella* was proposed by Jellinek and Swanson (2003) for South Atlantic Quaternary material and has similarities with our material. This genus validity is still controversy. Yasuhara et al. (2009) consider *Apatihowella* as a junior synonym of *Henryhowella* stating that the differences between these two genera are subtle and that large morphological variation exists between *Henryhowella* species. However some authors (Bergue and Coimbra 2008) are adopting *Apatihowella* for specimens showing a heavy ornamentation pattern composed by small spines concentrically arranged. Furthermore, *Apatihowella* does not presents the three longitudinal folds in the posterior half of the carapace as in *Henryhowella*.

*Apatihowella?* sp. 2

Figure 4, figure 12

**Material:** one carapace.

**Occurrence:** Drill-hole 2-RSS-1; sample 30.

**Dimensions:** Figured specimen: MP-O-2129; length: 0.85 mm, height: 0.53 mm, width: 0.41 mm.

**Description:** Carapace subovate in lateral view, with its maximum height at the anterior margin. The anterior and posterior margins are obliquely rounded. The posterior region is narrow. The dorsal and ventral margins are slightly convex, and taper towards posterior. Surface reticulate and with small spines parallel to margins. In dorsal view it is subelliptical with narrow anterior and posterior regions.

Genus *Cythereis* Jones, 1849

*Cythereis* sp.1

Figure 4, figures 13-14

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 116.

**Age:** Middle Maastrichtian.

**Dimensions:** Figured specimen: MP-O-2130; length: 0.73 mm, height: 0.44 mm, width: 0.32 mm.

**Description:** Carapace trapezoid in lateral view, with maximum height at the anterior cardinal angle. The anterior region is broadly rounded. The posterior region is slightly acuminate near the posterior cardinal angle. The dorsal and ventral margins are straight and subparallel. Eye tubercle present. Surface reticulated with two longitudinal ridges: one in the middle region and other near the ventral margin. On posterior margin there are small denticles along the border. In dorsal view, the regions adjacent to both anterior and posterior margins are compressed. The posterior region is larger than anterior.

Genus *Henryhowella* Puri, 1957

*Henryhowella* sp.

Figure 4, figure 15

**Material:** one valve.

**Occurrence:** Drill-hole 1-SCS-2; sample 56.

**Dimensions:** Figured specimen: MP-O-2131; length: 0.69 mm, height: 0.40 mm.

**Description:** Valve subrectangular in lateral view, with its maximum height at the anterior cardinal angle. The anterior margin is rounded and symmetrical. The posterior margin is narrower and more obliquely rounded than anterior. The dorsal margin is straight, sloping to posterior region. The ventral margin is sinuous with a slight concavity in central region. Eye tubercle present. The valve is ornamented with two rows of spines in dorsal margin and randomly distributed spines over the valve. Subcentral tubercle is present. Anterior margin is depressed. The observation of internal features is not possible.

**Remarks:** It differs from the *Henryhowella kempfi* Sanguinetti et al. 1993 recorded for the Miocene of the Pelotas Basin and Oligocene–Miocene of Santos Basin by Miller et al. (2002), by having the posterior region narrower and a concavity in the ventral margin. This specimen was found in Turonian samples and is probably from the Miocene. It is not used for paleoecological purposes in this study.

Genus *Langiella* Fauth et al. 2005

*Langiella?* sp.

Figure 4, figure 16

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 136.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2132; length: 0.60 mm, height: 0.35 mm, width: 0.28 mm.

**Description:** Carapace subrectangular in lateral view, with its maximum height in the anterior region. The left valve overlaps the right valve in the anterior and posterodorsal regions. Anterior margin obliquely rounded. Posterior margin is rounded and narrow with small denticles in posteroventral region. The region near the anterior and posterior border is depressed. The ventral margin is slightly convex and dorsal margin is slightly sinuous. Surface reticulate, and reticulations are arranged concentrically. A weak anterior marginal rib is present. Eye tubercle not evident. In dorsal view it is subhexagonal with greatest width in middle portion.

**Remarks:** It differs from *Langiella reimenti* (Neufville 1973) described by Fauth et al. 2005, from the Cretaceous–Paleogene boundary of the Pernambuco Basin, in shape around the margins and absence of eye tubercle.

Genus *Trachyleberis* Brady, 1898

*Trachyleberis* sp.

Figure 4, figures 17-18

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 121.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2133; length: 0.89 mm, height: 0.41 mm, width: 0.38 mm.

**Description:** Carapace subrectangular in lateral view, with its maximum height in the anterior region. The left valve overlaps the right valve. The dorsal and ventral margins are almost straight, and converge to posterior region that is narrower than anterior. The anterior region is rounded. The posterior end is angled. Surface is ornamented with small tubercles and spines randomly distributed. The anterior margin has two lines of spines; one along the border and the other parallel to the anterior margin, making the margin denticulate. Posteromedian region with weak groove parallel to dorsal margin. Dorsal view subhexagonal, with posterior region acuminate.

**Remarks:** *Trachyleberis* sp. differs from *Trachyleberis schizospinosa* Dingle, 1971 from the Upper Cretaceous of South Africa, by the more acuminate posterior region and less ornamented carapace.

Genus *Wichmannella* Bertels, 1969

*Wichmannella araucana* Bertels, 1969b

Figure 5, figure 1



1969b *Wichmannella araucana* Bertels, p. 273, pl. 2; figs. 4a-b.

1974 *Wichmannella araucana* Bertels, p. 390, pl. 2; figs. 1a-b.

1975a *Wichmannella araucana* Bertels, p. 343, pl.2; figs. 1a-b, 2.

**Material:** Two carapaces: one adult; one juvenile.

**Occurrence:** Drill-hole 1-SCS-3B; sample 123; Drill-hole 1-SCS-2; sample 122.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2134 (Drill-hole 1-SCS-2, sample 122); length: 0.97 mm, height: 0.60 mm, width: 0.56 mm.

**Description:** Carapace subrectangular in lateral view. Dorsal margin almost straight, ventral margin almost straight to slightly concave. Anterior margin somewhat obliquely rounded and posterior margin subrounded. The surface is ornamented by primary reticulation which is approximately concentrically disposed around the subcentral node. Eye tubercle clearly developed.

**Remarks:** It differs from *W. meridionalis* Bertels, 1969a identified herein by showing the anterior region obliquely rounded and a more pronounced eye tubercle.

**Stratigraphic distribution:** Upper Cretaceous from Huantrai-co, Neuquén Province, Fortín General Rocca from Argentina and Lower Paleogene from Pelotas Basin.

*Wichmannella meridionalis* Bertels, 1969a

Figure 5, figure 2

1969a *Wichmannella meridionalis* Bertels, p. 164, pl. 2, figs 1a-e, 2a-c.

1969b *Wichmannella meridionalis* Bertels, p. 272, pl. 9, figs 1a-b, 2a-b.

1973 *Wichmannella meridionalis* Bertels, p. 325, pl. 5, figs 2a-b.

1975a *Wichmannella meridionalis* Bertels, p. 346, pl. 3, figs 10, 11.

1995 *Wichmannella meridionalis* Bertels, p. 168, pl. 2, fig 12.

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 112.

**Age:** Campanian.

**Dimensions:** Figured specimen: MP-O-2135; length: 1.09 mm, height: 0.61 mm, width: 0.53 mm.

**Description:** Carapace subrectangular in lateral view, with rounded extremities, ovate in dorsal view. The ornamentation consists of a reticulation disposed parallel to the periphery. Eye tubercle present. Subcentral node suggested only by a slight annular depression.

**Remarks:** It differs from *Wichmannella magna* Bertels, 1975b by showing less developed eye tubercle and reticulation.

**Stratigraphic distribution:** Lower Maastrichtian in Jagüel Formation, Lower Danian in Roca Formation and Lower Paleogene in Pelotas Basin.

Subfamily Brachyocytherinae Puri, 1954  
Genus *Brachycythere* Alexander, 1933  
*Brachycythere* gr. *sapucariensis* Krömmelbein, 1964

Figure 5, figures 3-4

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 73.

**Age:** Turonian.

**Dimensions:** Figured specimen: MP-O-2136; length: 0.81 mm, height: 0.44 mm, width: 0.4 mm.

**Remarks:** *Brachycythere* gr. *sapucariensis* Krömmelbein, 1964 identified herein, shows similarities with the specimen illustrated by Viviers et al. (2000) for the Campanian of the Potiguar Basin in northeastern Brazil.

*Brachycythere* sp. 1

Figure 5, figure 5

**Material:** 16 carapaces: one adult; 15 juveniles.

**Occurrence:** Drill-hole 1-SCS-3B; samples 80, 90, 94, 99, 100, 114; Drill-hole 1-SCS-2; samples 53, 57, 70, 73, 85, 95.

**Age:** Albian–Cenomanian–Campanian.

**Dimensions:** Figured specimen: MP-O-2137 (sample 114, Drill-hole 1-SCS-3B.); length: 1.09 mm, height: 0.61 mm, width: 0.53 mm.

**Description:** Carapace subtriangular in lateral view, with its maximum height at the anterior cardinal angle. The left valve is larger than right and overlaps the anterodorsal margin to posterodorsal region. Anterior margin is rounded and posterior is acuminate. Ventral margin is slightly convex and dorsal margin is straight, inclined obliquely towards a weak posterior cardinal angle. Slightly depressed region near the eye tubercle. Surface finely punctate. The valve is inflated in ventrolateral region with greatest length at ventral margin. In dorsal view, carapace is inflated.

**Remarks:** *Brachycythere* sp. 1 resembles *Brachycythere longicaudata* Dingle, 1969a from the Upper Santonian of Pondoland, South Africa. It differs by having a less developed caudal process and absence of spines in the posteroventral margin.

Superfamily Cytherideoidea Sars, 1925  
Family Progonocytheridae Sylvester-Bradley, 1948  
Genus *Majungaella* Grékoff, 1963

*Majungaella* sp.

Figure 5, figure 6

**Material:** one carapace.

**Occurrence:** Drill-hole 1-RSS-2; sample 73.

**Age:** Coniacian–Santonian.

**Dimensions:** Figured specimen: MP-O-2138; length: 0.89 mm, height: 0.5 mm, width: 0.55 mm.

**Description:** Carapace subtrapezoidal in lateral view, with its maximum height in the anterior region. The anterior region is rounded and posterior is obliquely rounded. Ventral margin is gently convex. Dorsal margin is convex towards posterior region. Surface ornamented with weak concentric ribs in ventral, anterior and posterior regions.

**Remarks:** Very poorly preserved specimen.

Family Cytherideidae Sars, 1925

Genus *Pondoina* Dingle, 1969a

*Pondoina* sp.

Figure 5, figures 7-8

**Material:** three carapaces: one adult; two juveniles.

**Occurrence:** Drill-hole 1-RSS-2; samples 21, 33, 46.

**Age:** Albian–Cenomanian.

**Dimensions:** Figured specimen: MP-O-2139; (sample 21); length: 0.77 mm, height: 0.44 mm, width: 0.45 mm.

**Description:** Carapace subovate and elongate in lateral view, with its maximum height in the middle region. The left valve overlaps the right valve around entire margin. The anterior and posterior regions are broadly rounded. The dorsal margin is convex. The ventral region is inflated centrally and gently convex. The carapace is ornamented with slight longitudinal ribs and fine punctations. In dorsal view it is oval.

**Remarks:** *Pondoina* sp. differs from *P. sulcata* Dingle, 1969a identified from the Senonian of Pondoland, South Africa, by showing a less developed vertical groove in the median region of the carapace and a more convex dorsal margin.

Genus *Rostrocytheridea* Dingle, 1969b

*Rostrocytheridea* sp.

Figure 5, figure 9

**Material:** one left valve, probably juvenile.

**Occurrence:** Drill-hole 1-RSS-2; sample 07.

**Age:** Albian.

**Dimensions:** Figured specimen: MP-O-2140; length: 0.48 mm, height: 0.32 mm, width: 0.16 mm.

**Description:** Carapace subtriangular in lateral view, with its maximum height in the middle of carapace. Anterior margin is obliquely rounded and posterior margin tapering. Dorsal margin is arched and convex. Ventral margin is gently convex with prominent sinuosity posteroventrally. Surface smooth. Internal features were not possible to visualize.

**Remarks:** This specimen is possibly a juvenile instar and has the characteristics of the genus *Rostrocytheridea*.

Family Krithidae Mandelstam, 1960

Genus *Krithe* Brady et al. 1874

*Krithe* sp.

Figure 5, figures 10-11

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3B; sample 137.

**Age:** Paleogene.

**Dimensions:** Figured specimen: MP-O-2141; length: 0.77 mm, height: 0.29 mm, width: 0.25 mm.

**Description:** Carapace subelliptical in lateral view, with its maximum height at mid-length. The left valve overlaps the right at the ventral region, anterodorsal and posterodorsal. The anterior margin is rounded and posterior margin is obliquely truncate. Dorsal margin is gently convex and ventral margin is almost straight in left valve, sinuous in right valve. Surface smooth. In dorsal view it is elliptical, anteriorly acuminate and truncate in the posterior extremity. Greatest width in middle region.

**Remarks:** *Krithe* sp. differs from *Krithe rocana* Bertels, 1973 from the Danian of Argentina by having a less convex dorsal margin. It differs from *Krithe echolsae* Esker, 1968 of the Middle Paleocene of Egypt, figured by Bassiouni and Luger (1990), by having a discontinuous overlap in the dorsal and posterodorsal margins.

#### **Indeterminate taxa**

Gen. *et* sp. indet. 1

Figure 5, figure 12

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 122.

**Age:** Paleogene

**Dimensions:** Figured specimen: MP-O-2142; length: 0.61 mm, height: 0.32 mm, width: 0.28 mm.

**Description:** Carapace subtrapezoidal in lateral view, with its maximum height at the anterior cardinal angle. The left valve overlaps the right valve at the anterior and posterior cardinal angles. The anterior margin is rounded and posterior margin is acuminate in the middle region. The ventral margin is convex and dorsal margin is almost straight, slight inclined towards posterior cardinal angle. Eye

tubercle is weakly developed. Surface ornamented with central tubercle and slight reticulation. Near the anterior margin small spines occur parallel to margin. In dorsal view, greatest width in the middle region.

Gen. *et* sp. indet. 2

Figure 5, figure 13

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-3-B; sample 94.

**Age:** Turonian.

**Dimensions:** Figured specimen: MP-O-2143; length: 0.69 mm, height: 0.36 mm, width: 0.32 mm.

**Description:** Carapace subtrapezoidal in lateral view, with its maximum height in the anterior region. The anterior and posterior margins are rounded. Posterior region is narrow. Ventral margin is convex and dorsal margin is almost straight. Eye tubercle is weakly developed. Surface ornamented with punctations. In dorsal view, the posterior region is inflated.

Gen. *et* sp. indet. 3

Figure 5, figure 14

**Material:** one carapace.

**Occurrence:** Drill-hole 1-SCS-2; sample 116.

**Age:** Maastrichtiano

**Dimensions:** Figured specimen: MP-O-2144; length: 0.56 mm, height: 0.24 mm, width: 0.2 mm.

**Description:** Carapace subrectangular in lateral view, with maximum height at the anterior margin. The posterior margin is slightly acuminate in the middle portion. Anterior margin is obliquely rounded. Ventral margin is almost straight. The dorsal margin is straight and gently inclined towards posterior region. Surface ornamented. In dorsal view, greatest width in the middle region.

**Remarks:** This specimen probably belongs to Leguminocythereididae based on outline of carapace and kind of ornamentation.

### **Faunal considerations**

The ostracod fauna of the Pelotas Basin, analyzed from the four wells, was found to be diversified but of low abundance in the intervals studied (Fig. 6). A total of 98 specimens were recovered, representing nine families, 21 genera, 34 species, and four undetermined taxa. *Cytherella* (7 species) and *Paracypris* (4 species) were the most diverse genera.

The fauna was most abundant in the drill-hole 1-SCS-3B, located in the north of the Basin, representing 58% of the total abundance of the drill-holes studied, followed by 1-SCS-2, with 33%.

The most abundant families in the Pelotas Basin are Trachyleberididae and Cytherellidae. This abundance is also recorded in the study of the K–Pg in Northeast Brazil, suggesting a neritic environment in that location (Fauth 2000).

The highest abundance and faunal richness for the basin is recorded for the Cretaceous, where 20 species are identified. The majority of them is ornamented and typical of warm and shallow waters, represented by the genera *Cytherella*, *Cytherelloidea*, *Paracypris*, *Argilloecia*, *Cythereis*, *Actinocythereis*, *Brachycythere*, *Wichmannella*, *Pondoina* and *Roastrocytheridea*.

In the Albian–Cenomanian interval of the basin, the ostracods are represented by *Cytherella* sp. 1, *Brachycythere* sp. 1, *Pondoina* sp. and *Roastrocytheridea* sp. *Pondoina* is a genus characteristic of shallow and brackish waters (Dingle 1969a). *Roastrocytheridea* is characteristic of coastal marine environments with warm water conditions (Ballent and Whatley 2007).

The interval with greatest ostracod abundance in the four wells analyzed in this study was the Turonian. The most abundant species were *Brachycythere* sp. 1 and *Cytherella* sp. 3. Associated with them were *Brachycythere* gr. *sapucariensis*, *Cytherella* sp. 6, *Paracypris* sp. 2, *Paracypris* sp. 3, and Gen. et. sp. indet. 3.

The Turonian interval was recorded in the wells 1-SCS-3B and 1-SCS-2, located at the northern portion of the basin. The biostratigraphic refinement of the Turonian of the Brazilian coastal basins has been difficult due to the poor and low diversity ostracod assemblages (Viviers et al. 2000). Various studies performed in the equatorial Atlantic record the occurrence of *Brachycythere* gr. *sapucariensis* (e.g., Neufville 1973; Grosdidier 1979; Viviers et al. 2000; Andreu 2002) for the Brazilian coast as well as the African coast. This record favors the presence of water just as warm in the Turonian of the Pelotas Basin, as the records for the remaining equatorial occurrences of this group. The highest occurrence of the genus *Brachycythere* between the Turonian–Santonian in the basin, can be related to the same period of transgression which occurred in the Upper Cretaceous in Africa (Dingle 1996) resulted from the progressive widening of the South Atlantic. This allows the warmer equatorial waters circulation around the southern tip (Puckett 2002). This genus is well represented in the equatorial Atlantic and in northern Africa. *Brachycythere sapucariensis* was primarily recorded in the Turonian of Northeast Brazil (Krömmelbein 1964), and the present record in Pelotas Basin of *Brachycythere* gr. *sapucariensis* is possibly the most meridional record of that species in the South Atlantic.

In the Coniacian–Santonian, a poor faunal association represented by Gen. et. sp. indet. 1 and *Brachycythere* sp. 1 is found. The Campanian studied in the wells 1-SCS-3B and 1-SCS-2 maintains the occurrence of *Brachycythere* sp.1 and *Cytherella* sp. 3 with *Cytherella* cf. *C. araucana*, *Actinocythereis indigena* and *Wichmannella meridionalis* appearing. The genus *Wichmannella* is found in the Upper Cretaceous–Paleogene of Argentina, while there are no records of this genus in the African and Brazilian basins. This is an endemic genus with the highest abundance in the south Gondwana province, which survived the passage of the K–Pg boundary (Bertels 1975a, Bertels-

Posotka 1995). *Wichmannella* is a genus characteristic of shallower waters and tolerant to the variations of salinity and pH (Bertels 1975a).

The Maastrichtian of the basin is marked by the occurrence of the genera *Cytherella*, *Cytherelloidea*, *Argilloecia*, *Cythereis*, *Actinocythereis*, and *Majungaella*, with the continuing presence of *Wichmannella*. The species *Cytherelloidea spirocostata*, with occurs in the Upper Maastrichtian in the basin, is recorded for the Danian of Argentina (Bertels 1973) and the Campanian of Antarctica (Fauth et al. 2003). *Cytherelloidea* is considered a thermophilic genus in shallow seas (minimum 10°C), where it is less tolerant than *Cytherella* to environmental change (Sohn 1962). Currently, this genus is related to environments of warm, marine, and shallow waters (Dingle 2009). *Cytherelloidea* is also recorded in southern Africa, possessing a considerable biostratigraphic potential in sediments of the Coniacian–Santonian (Dingle 1985).

The occurrence of *Actinocythereis* along with *Wichmannella* in the basin reinforces the model of neritic waters during the Cretaceous period in this area.

The Cretaceous–Paleogene boundary in the Pelotas Basin is marked by a faunal change, which follows the total or partial disappearance of some species and the reestablishment of a new fauna in the Paleogene. This same pattern was recorded not only in the fauna of Argentina (Bertels 1973), but also in other studies on the K–Pg boundary (e.g., Donze et al. 1982; Damotte and Fleury 1987; Fauth et al. 2005).

In Argentina, the genera *Wichmannella* and *Actinocythereis* survive the K–Pg boundary event. However these are replaced by new species of the same genera in the Lower Danian. In the Pelotas Basin, the genera *Wichmannella* and *Cytherella* show records for the Maastrichtian and Paleogene and could be considered as turnover from the Cretaceous. The Upper Maastrichtian and the Lower Danian of El Kef, Tunisia, show an interruption in the occurrence of ostracods near the K–Pg boundary, but also show that many taxa are reestablished subsequently (Donze et al. 1982) [‘Lazarus taxa’]. This has been interpreted as reflecting the expansion of a zone of minimum oxygen during the K–Pg boundary event (Peypouquet 1983). The greatest abundance of *Cytherella* recorded in the section of the Poty Quarry may suggest a dysoxic event in that location (Fauth 2000).

The ostracod association of the Lower Paleogene in the Pelotas Basin appeared to be less abundant than in the Cretaceous. The most abundant species in the Lower Paleogene is *Neonesidea* sp. The interval is characterized by the first local appearance of the genera *Neonesidea*, *Bairdoppilata*, *Trachyleberis*, *Buntonia*, *Ambocythere*, *Krithe*, *Langiella?*, Gen. et. sp. indet. 1, and the continuation of the genera *Cytherella*, *Actinocythereis*, *Wichmannella* and *Paracypris*, but the species being different from those recorded for the Cretaceous. A similar association is recorded at Poty Quarry (Fauth et al. 2005), but more diversified and abundant than in this study. In El Kef, the greatest abundance is recorded in the Danian, represented by the family Trachyleberididae (Donze et al. 1982). In the same way, the fauna of Argentina appears to be more abundant in the Paleogene (Bertels-Posotka 1995).

## Conclusions

The ostracod fauna recorded during the Cretaceous–Lower Paleogene in the Pelotas Basin showed an irregular distribution among the wells studied, and also showed a greater abundance and richness in the Cretaceous than in the Paleogene.

The K–Pg boundary is marked by a faunal change in the Pelotas Basin, recording the local disappearance of the genera *Cytherelloidea*, *Argilloecia*, *Cythereis*, *Brachycythere*, *Majungaella*, *Pondoina* and *Rostrocytheridea*, and local appearance of *Neonesidea*, *Bairdoppilata*, *Ambocythere*, *Buntonia*, *Langiella?*, *Trachyleberis* and *Krithe*. However, the genera *Wichmannella*, *Paracypris*, *Actinocythereis* and *Cytherella* are recorded in the Cretaceous as well as in the Paleogene of the Basin.

Based on faunal analyses, we believe that the Pelotas Basin records, for the Cretaceous and the Cretaceous–Lower Paleogene boundary, a neritic environment with normal conditions of salinity through the section studied. The presence of *Brachycythere* sp. 1, *Brachycythere* gr. *sapucariensis* Krömmelbein, 1964 and *Cytherelloidea spirocostata* Bertels, 1973 could be indicate an environment with warm temperatures, similar to the ones recorded for the modern equatorial region.

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## FIGURE CAPTIONS

**Fig. 1** Location map of the Pelotas Basin with drill-holes studied, modified from Anjos and Carreño (2004)

**Fig. 2** Drill-holes in Pelotas Basin with studied section A A', and nannofossil datum horizons modified from Gomide (1989)

**Fig. 3** All figures are SEM. Scale bars: 100  $\mu$ . (1-2) *Cytherella* cf. *C. araucana*, (1) carapace, left lateral view, MP-O-2109; (2) Dorsal view, MP-O-2109; (3-4) *Cytherella* sp. 1, (3) carapace, left lateral view, MP-O-2110; (4) Dorsal view, MP-O-2110; (5) *Cytherella* sp. 2, carapace, left lateral view, MP-O-2111; (6-7) *Cytherella* sp. 3, (6) carapace, left lateral view, MP-O-2112; (7) Dorsal view, MP-O-2112; (8-9) *Cytherella* sp. 4, (8) carapace, left lateral view, MP-O-2113; (9) Dorsal view, MP-O-2113; (10) *Cytherella* sp. 5, carapace, left lateral view, MP-O-2114; (11-12) *Cytherella* sp. 6, (11) carapace, right lateral view, MP-O-2115; (12) carapace, left lateral view, MP-O-2115; (13-14) *Cytherelloidea spirocostata*, (13) carapace, right lateral view, MP-O-2116; (14) Dorsal view, MP-O-2116; (15) *Neonesidea* sp., carapace, right lateral view, MP-O-2117; (16) *Bairdoppilata triangulata*, carapace, right lateral view, MP-O-2118; (17) *Bairdoppilata* sp. 1, carapace, right lateral view, MP-O-2119; (18) *Argilloecia* sp., carapace, left lateral view, specimen lost

**Fig. 4** All figures are SEM. Scale bars: 100  $\mu$ . (1) *Paracypris* sp. 1, carapace, right lateral view, MP-O-2120; (2) *Paracypris* sp. 2, carapace, right lateral view, MP-O-2121; (3) *Paracypris* sp. 3, valve, left lateral view, MP-O-2122; (4) *Paracypris?* sp. 4, carapace, right lateral view, MP-O-2123; (5) *Ambocythere* sp., carapace, left lateral view, MP-O-2124; (6-7) *Buntonia* sp., (6) carapace, left lateral view, MP-O-2125; (7) carapace, right lateral view, MP-O-2125; (8) *Actinocythereis indigena*, carapace, right lateral view, MP-O-2126; (9-10) *Actinocythereis* sp., (9) carapace, right lateral view, MP-O-2127; (10) Dorsal view, MP-O-2127; (11) *Apatihowella* sp. 1, carapace, left lateral view, MP-O-2128; (12) *Apatihowella?* sp. 2, carapace, left lateral view, MP-O-2129; (13-14) *Cythereis* sp., (13) carapace, left lateral view, MP-O-2130; (14) Dorsal view, MP-O-2130; (15) *Henryhowella* sp., valve, left lateral view, MP-O-2131; (16) *Langiella?* sp., carapace, left lateral view, MP-O-2132; (17-18) *Trachyleberis* sp., (17) carapace, left lateral view, MP-O-2133; (18) Dorsal view, MP-O-2133

**Fig. 5** All figures are SEM. Scale bars: 100  $\mu$ . (1) *Wichmannella araucana*, carapace, right lateral view, MP-O-2134; (2) *Wichmannella meridionalis*, carapace, left lateral view, MP-O-2135; (3-4) *Brachyocythere* gr. *sapucariensis*, (3) carapace, right lateral view, MP-O-2136; (4) Dorsal view, MP-O-2136; (5) *Brachyocythere* sp. 1, carapace, left lateral view, MP-O-2137; (6) *Majungaella* sp. carapace, right lateral view, MP-O-2138; (7-8) *Pondoina* sp., (7) carapace, right lateral view, MP-O-2139 (8) Dorsal view, MP-O-2139; (9) *Rostrocytheridea* sp., valve, left lateral view, MP-O-2140; (10-11)

*Krithe* sp., (10) carapace, right lateral view, MP-O-2141; (11) Dorsal view, MP-O-2141; (12) Gen *et* sp. indet. 1, carapace, left lateral view, MP-O-212142; (12) Gen *et* sp. indet. 2, carapace, right lateral view, MP-O-2143; (13) Gen *et* sp. indet. 4, carapace, right lateral view, MP-O-2144

**Fig. 6** Distribution of ostracods in four drill-holes studied, with K–Pg boundary. The drill-hole 1-RSS-3 is barren



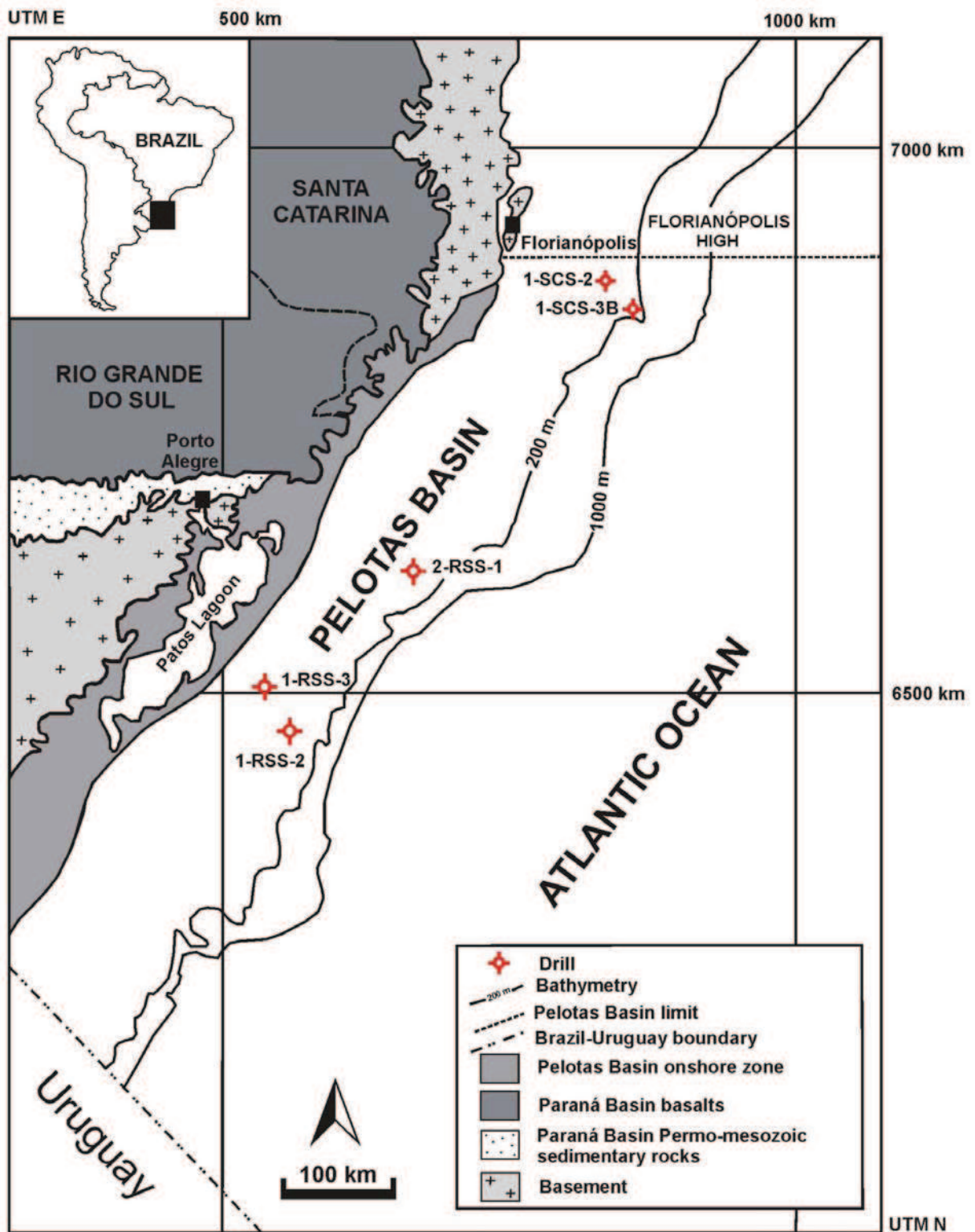


Figure 1



Figure 2

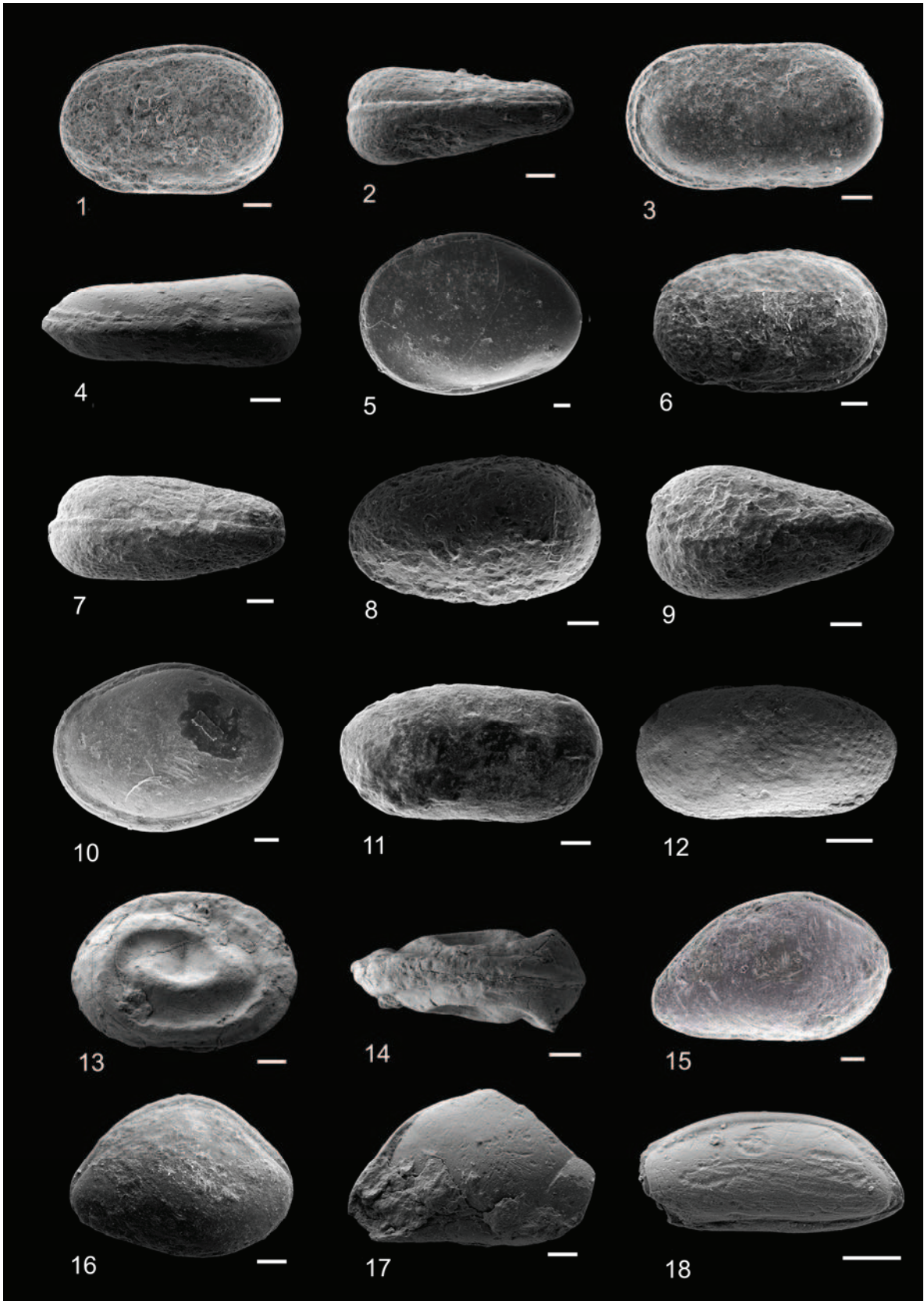


Figure 3

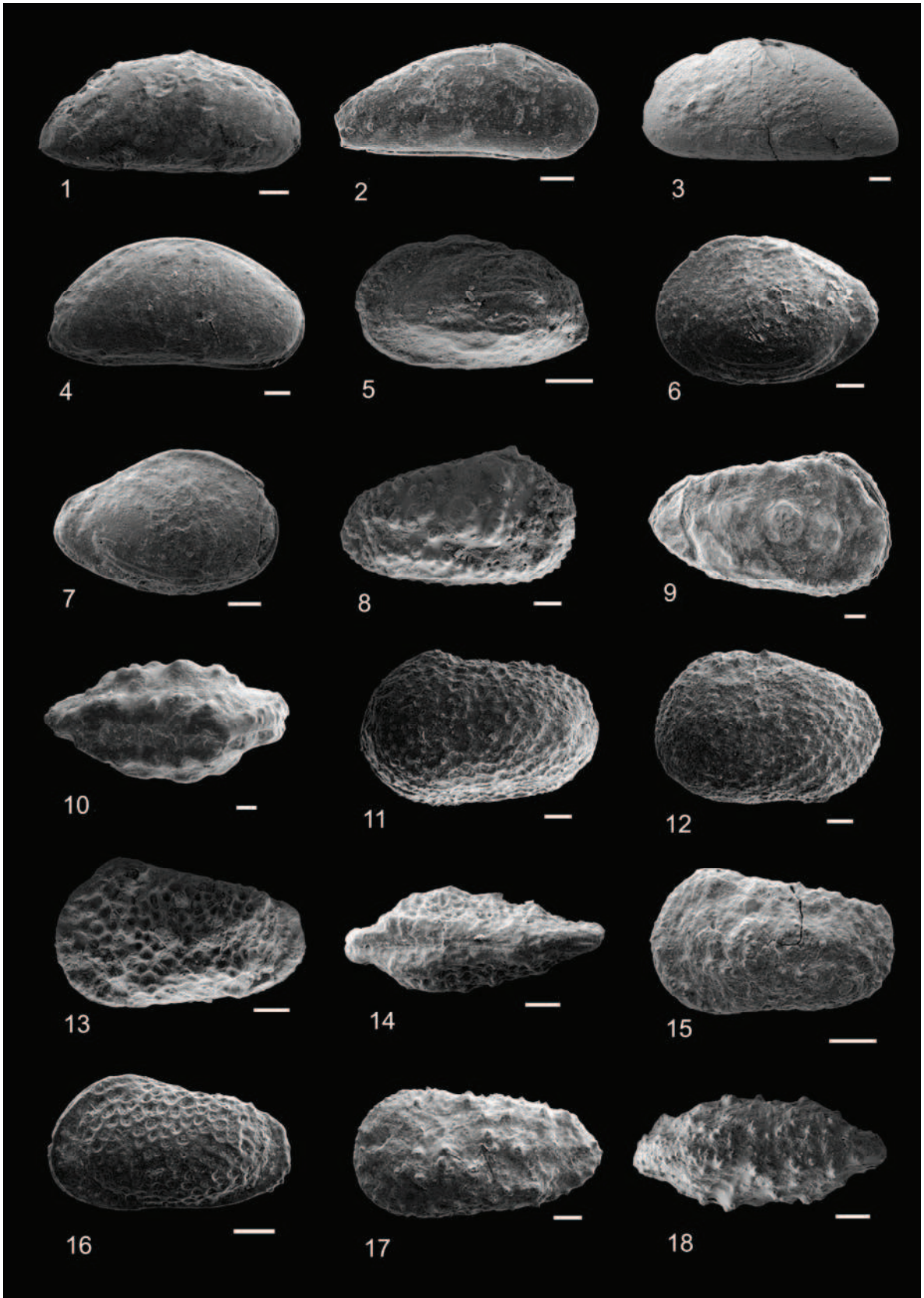


Figure 4

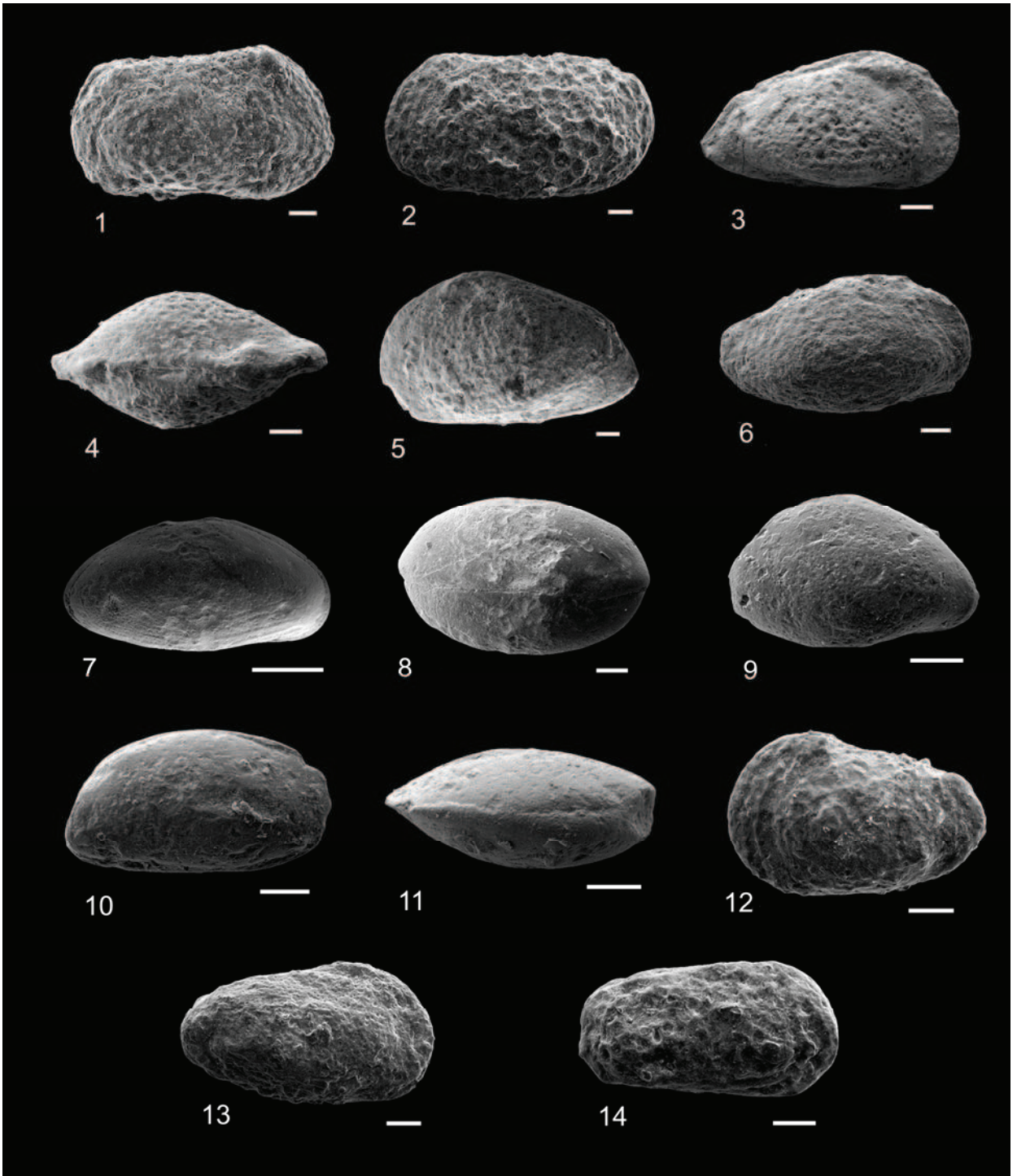


Figure 5

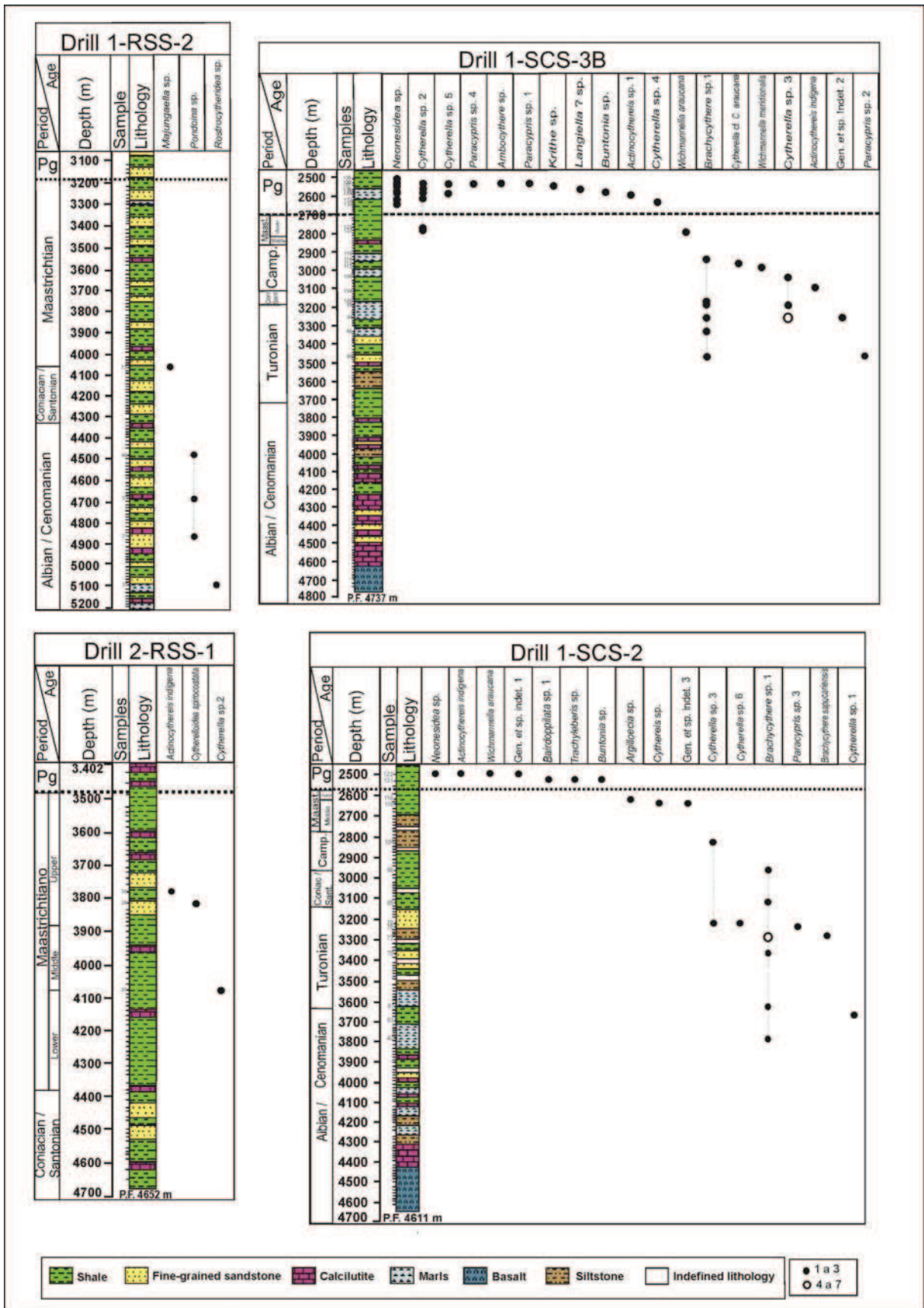


Figure 6

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## **10. ANEXOS**