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EVOLUÇÃO DO TAMANHO CORPORAL DOS AMONOIDES (MOLLUSCA, CEPHALOPODA) DA BACIA SEDIMENTAR DE SERGIPE-ALAGOAS AO LONGO DO CRETÁCEO

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Orientador: Dr. Alexandre Liparini Campos

Coorientador: Dr. Pablo Ariel Martinez

DISSERTAÇÃO DE MESTRADO

Programa de Pós-Graduação em Geociências e Análise de Bacias

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Dissertação apresentada ao Programa de Pós-Graduação em Geociências e Análise de Bacias da Universidade Federal de Sergipe, como requisito para obtenção do título de Mestre em Geociências.

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por:

Franciely da Silva Santos
(Bióloga, Universidade Federal de Sergipe – 2016)

DISSERTAÇÃO DE MESTRADO

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“Revelando o passado, desenterrando o que há muito tempo não experimentava a luz, revivendo o não vivo, dando vida aos mortos, traduzindo ossos e rochas, trabalhando e dando sentido ao que, há milhares de anos, teve sentidos”

Hermínio Ismael de Araújo Júnior

RESUMO

Dentro dos estudos macroevolutivos, o tamanho corporal tem sido considerado um dos fenótipos mais diagnósticos na compreensão da interação dos organismos com o ambiente diante da influência dos princípios físicos, ecológicos e evolutivos. Para a determinação dos padrões evolutivos de tamanho corporal, os fósseis são as principais ferramentas que possibilitam visualizar as variações morfológicas ao longo do tempo geológico. Um dos padrões evolutivos mais expressivos, a Regra de Cope, corresponde a uma tendência ao aumento corporal dos organismos ao longo do tempo geológico, expresso como uma vantagem adaptativa. Alguns modelos evolutivos incluem o equilíbrio pontuado, estases e *Ornstein-Uhlenbeck*, que já foram documentados em diferentes grupos de organismos. A Bacia de Sergipe-Alagoas apresenta um rico e abundante conteúdo fossilífero de organismos marinhos, principalmente de moldes de conchas externas dos extintos amonoides, em um intervalo temporal de pelo menos 25 Ma (Aptiano superior ao Campaniano). Devido à abundância nos registros das rochas cretáceas da Bacia de Sergipe-Alagoas, os amonoides foram selecionados para serem investigados nesse trabalho. Portanto, o objetivo dessa pesquisa foi investigar se o tamanho das conchas de amonoides variaram ao longo do Cretáceo, a partir da técnica de morfometria geométrica, bem como, averiguar por qual modo ocorreu a evolução de seu tamanho corporal. Foram analisados 2045 fósseis, sendo adquiridas as fotografias de 506 amonoides selecionados. Os fósseis selecionados são de diferentes espécies, tombados no Laboratório de Paleontologia da Universidade Federal de Sergipe, compreendendo as idades, Aptiano tardio ao Turoniano/Coniaciano (entre ~115 Ma e 90 Ma). As imagens foram tratadas nos softwares TPSutil e TPSdig, inserindo sete marcadores anatômicos em cada foto, em vista lateral, obtendo assim um valor de centroide (Cs) para cada fóssil. A análise morfométrica e a investigação dos modelos evolutivos foram realizadas na plataforma R utilizando respectivamente os pacotes “geomorph” e “PaleoTS”. Os resultados mostraram um aumento no tamanho corporal dos amonoides ao longo do Cretáceo da Bacia de Sergipe-Alagoas e o modelo que melhor representa o padrão evolutivo do tamanho corporal dos amonoides foi o equilíbrio pontuado. Diante do cenário paleoambiental da Bacia de Sergipe-Alagoas durante o Cretáceo, as possíveis causas para o aumento do tamanho corporal estão relacionadas com eventos geológicos e/ou paleoambientais que ocorreram no momento da pontuação (94 Ma). Portanto, a ampliação dos mares ao longo do Cenomaniano e possíveis eventos de extinção ao final do mesmo poderia ter levado ao deslocamento do tamanho ótimo dos amonoides da Bacia de Sergipe-Alagoas.

Palavras-chave: Morfometria geométrica; Cretáceo de Sergipe; Amonitas; Aptiano-Coniaciano

ABSTRACT

Macroevolutionary studies consider body size one of the most diagnostic phenotypes to understanding the organisms -environment interaction in front of the influence of physical, ecological and evolutionary principles. To determine the evolutionary patterns of body size, fossils are the main tools that allow visualize the morphological variations over geological time. One of the most significant evolutionary patterns, Cope's Rule, corresponds to a tendency to increase organisms body size over geologic time, expressed as an adaptive general advantage. Some evolutionary models include punctuated balance, stasis and Ornstein-Uhlenbeck, which have already been documented in different groups of organisms. The Sergipe-Alagoas Basin presents a rich and abundant fossiliferous content of marine organisms, mainly of molds of external shells of the extinct amonoids, in a time interval of at least 25 Ma (Aptian superior to the Campanian). Due to the abundance in the records of the Cretaceous rocks of the Sergipe-Alagoas Basin, the ammonoids were selected to be investigated in this work. Therefore, the objective of this research was to investigate if the size of the ammonia shells varied along the Cretaceous, using the geometric morphometry technique, as well as to determine by what mode the evolution of their body size occurred. A total of 2045 fossils were analyzed, but after analyzing the degree of preservation, 506 ammonites were selected to be photographed. The selected fossils belongs to different species and they are registered in the Laboratory of Paleontology of the Federal University of Sergipe comprising the ages, Late Aptian to the Turonian / Coniacian (between ~ 115 Ma and 90 Ma). The images were treated in the software TPSutil and TPSdig, inserting seven landmarks in each photo, in lateral view, obtaining a centroid value (Cs) for each fossil. The morphometric analysis and the investigation of the evolutionary models were performed in the R platform using respectively the "geomorph" and "PaleoTS" packages. The results showed an increase in the body size of the ammonites along the Cretaceous of the Sergipe-Alagoas Basin and the model that best represents the evolutionary pattern of the ammonite body size was the punctuated equilibrium (~94 Ma). Considering the paleoenvironmental scenario of the Sergipe-Alagoas Basin during the Cretaceous, the possible causes for the increase in body size are related to geological and/or paleoenvironmental events that occurred at the punctuated moment. Therefore, the expansion of the seas along the Cenomanian and possible extinction events at the end of the Cenomanian could have led to the displacement of the ammonite optimal body size of the Sergipe-Alagoas Basin.

Keywords: Geometric morphometrics; Cretaceous of Sergipe; Ammonites; Aptian-Coniacian

Sumário

Capítulo 1- Introdução

1.1 Apresentação

Os amonoides cretáceos da Bacia de Sergipe-Alagoas tiveram papel fundamental no estabelecimento das principais biozonas da Bacia (ZUCON, 2005; BENGTSON; ZUCON; SOBRAL, 2017; SOBRAL, 2015) no entanto, sua diversidade nunca fora esmiuçada a ponto de se compreender a história evolutiva das formas aqui presentes. Considerando que os seres vivos estão intimamente ligados ao ambiente em que vivem e respondendo aos diferentes estímulos que recebem do ambiente ao longo do tempo geológico é possível averiguar e assim correlacionar os efeitos do ambiente na evolução da forma ou do tamanho dos organismos (NÜRNBERG; ABERHAN; KRAUSE, 2012).

Diante desse fato, essa pesquisa busca responder como os tamanhos dos amonoides evoluíram ao longo do Cretáceo. Assim, a relevância dessa pesquisa se dá por estudar um dos grupos fósseis mais abundantes na Bacia de Sergipe-Alagoas, os amonoides, a partir de um ponto de vista inédito para a mesma, que é a análise de seus tamanhos corporais, ao longo do Cretáceo. O tamanho corporal é uma das principais características de um organismo. Ele está diretamente ligado à compreensão da história evolutiva dos grupos. Por essa virtude, o tamanho corporal é amplamente analisado com o intuito de entender padrões e processos relacionados com a evolução de organismos.

Entre as diferentes tendências evolutivas relacionadas a tamanho corporal, a Regra de Cope é uma das mais citadas (eg. ALROY, 1998; HONE & BENTON 2005; HUNT & ROY 2006). Nesse padrão evolutivo observa-se um aumento direcionado do tamanho corporal de um grupo ao longo do tempo geológico. Segundo Souza (2014, p.9) “Tamanhos grandes geralmente conferem uma vantagem seletiva aos indivíduos dentro de uma população”. Hone & Benton (2005) relata que essas vantagens poderiam ser: uma maior retenção de calor, o aumento da sua capacidade predatória e de defesa contra predadores, sobrevivência às situações de estresse e resistência a variações climáticas.

À vista disso, se ter um aumento do tamanho corporal ao longo do tempo aparentemente confere diversas vantagens aos organismos, esperamos que os amonoides da Bacia de Sergipe-Alagoas apresentem essa tendência evolutiva.

O artigo 1 desse trabalho será submetido a revista *Evolution* e as normas de submissão encontram-se no Anexo 1.

1. 2 Objetivos

Geral

Investigar se o tamanho das conchas de amonoide da Bacia de Sergipe-Alagoas variaram ao longo do Cretáceo, a partir da técnica de morfometria geométrica.

Específicos

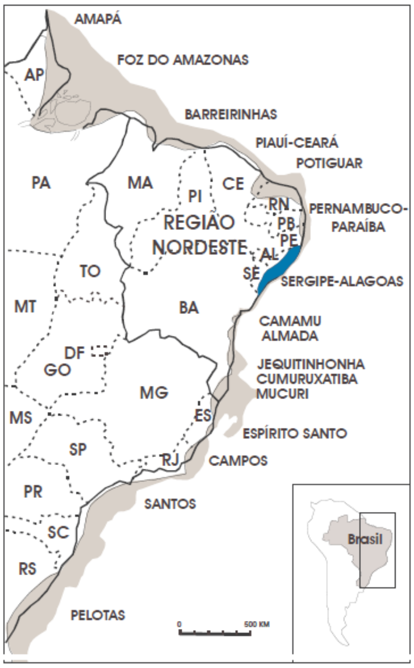
- Verificar se o tamanho das conchas aumentou ao longo do tempo geológico.
- Averiguar por qual modo ocorreu a evolução do tamanho corporal dos amonoides durante o Aptiano-superior até o limite Turoniano-Coniaciano.
- Correlacionar fatores paleoambientais, geológicos ou paleobiológicos que possam ter influenciado na evolução do tamanho corporal dos amonoides da Bacia de Sergipe-Alagoas.

1. 3 Localização da área

Área de estudo

Esse estudo foi realizado com material tombado no Laboratório de Paleontologia da UFS, proveniente do estado de Sergipe, de afloramentos das Formações Riachuelo e Cotinguiba, da Bacia de Sergipe- Alagoas (APÊNDICE 1). Essa Bacia limita-se ao norte com a Bacia de Pernambuco-Paraíba pelo alto de Maragogi e ao sul com a Bacia de Jacuípe (FIGURA 1). A área emersa desta Bacia possui 13.000 km^2 e a porção submersa alcança 20.000 km^2 até a profundidade de 2.000 metros (FEIJÓ, 1995).

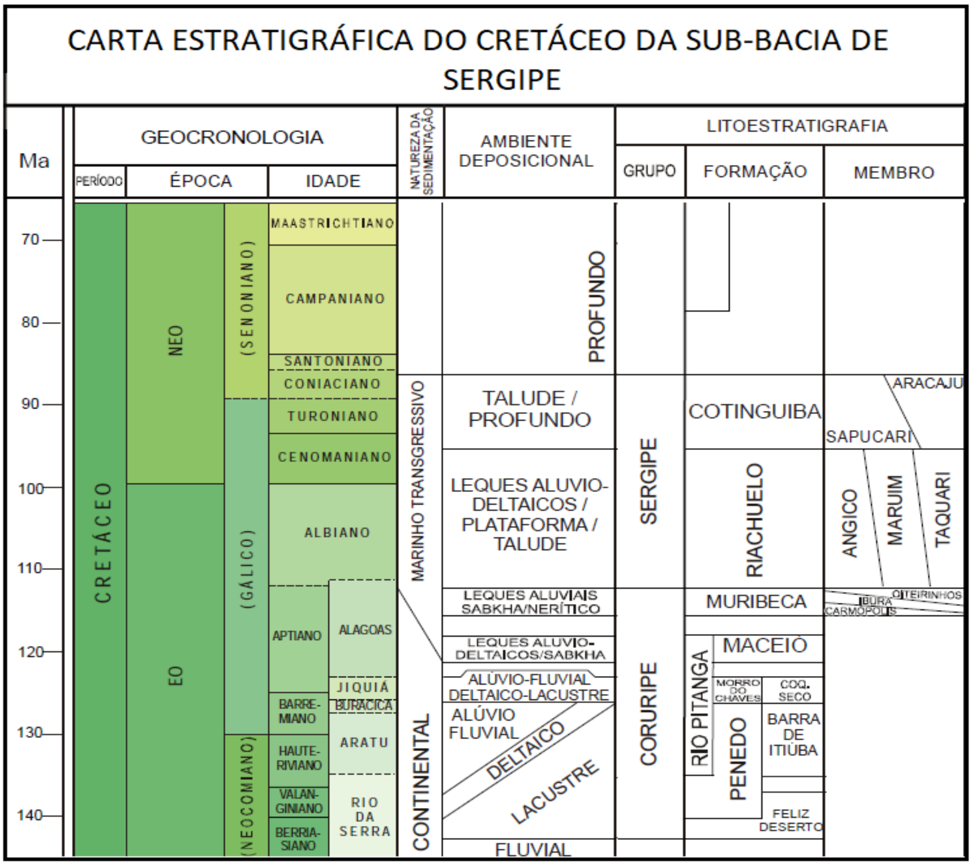
Figura 1- Localização da Bacia de Sergipe-Alagoas.



Fonte: Zucon, 2005.

De acordo com Zucon (2005), a sub-Bacia de Sergipe está localizada entre 9°S e 11°30'S e 35°30'W e 37°W, compreendendo uma área emersa de aproximadamente 6.000 km^2 e submersa de 5.000 km^2. Apresenta uma sequência Neomesozoica quase completa, com lacunas apenas nas áreas marginais (FIGURA 2).

Figura 2- Carta estratigráfica da sub-Bacia de Sergipe.



Fonte: Adaptado de CAMPOS- NETO *et al.*, 2007.

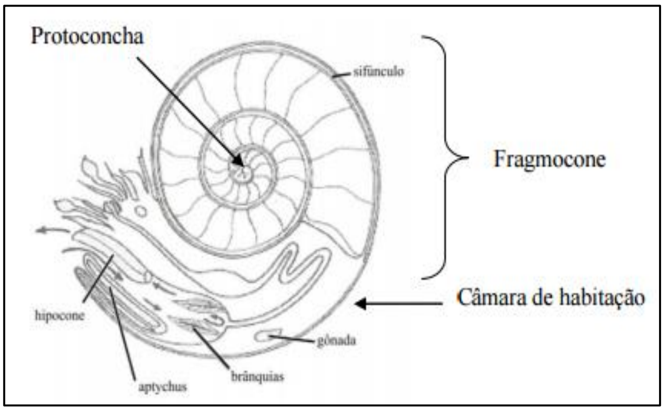
1. 4 Métodos de trabalho

Os fósseis dos amonoides que foram analisados nesse trabalho encontram-se depositados na coleção paleontológica do Laboratório de Paleontologia da Universidade Federal de Sergipe (LPUFS), compreendendo as idades, Aptiano tardio ao Turoniano/Coniaciano (~115 Ma a 90 Ma). No total, a coleção possui 2.329 fósseis tombados de amonoides agrupados em 7 superfamílias, destes, 1.784 estão classificados em nível de gênero, totalizando 43 gêneros.

Dos 2.329 fósseis de amonoides tombados no LPUFS, 2.045 espécimes, de diferentes gêneros, foram selecionados e o critério de seleção foi baseado nas informações de intervalo temporal disponíveis no livro tombo. Ou seja, os 284 espécimes excluídos nessa etapa não apresentavam informações sobre a idade geológica ou a localidade onde foram coletados, impossibilitando assim atribuir o intervalo temporal desses amonoides.

Posteriormente, os 2.045 amonoides foram avaliados em relação ao seu grau de preservação. Neste caso, foi estabelecido que os fósseis deveriam apresentar pelo menos a protoconcha (câmara inicial) e o fragmocone, possibilitando assim mensurar o tamanho mínimo de cada registro fóssil (FIGURA 3). Dessa forma, foram adquiridas fotografias de 506 fósseis que atenderam aos critérios acima descritos, necessários para a realização das análises morfométricas.

Figura 3: Estruturas morfológicas dos amonoides.



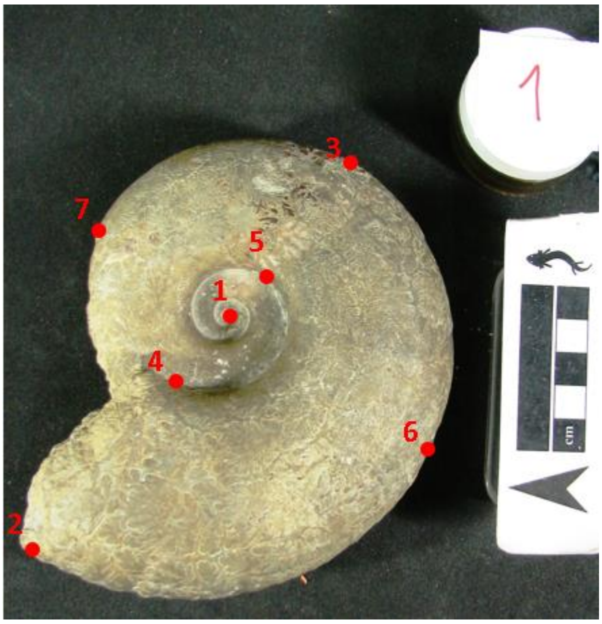
Fonte: Wrigth *et al*., 1996

A morfometria geométrica é uma ferramenta utilizada para estudar a forma e os tamanho dos organismos e como esses dois atributos se relacionam entre si. Além disso, diferentemente da morfometria linear, a morfometria geométrica permite não apenas estudar a forma e o tamanho, como também a visualização de forma gráfica e clara destas diferenças (Chaves, 2017).

Para a realização das análises morfométricas se faz necessário adquirir fotos da vista lateral de cada fóssil selecionado a partir de uma câmera fotográfica digital “Samsung” modelo “DV100 16.1MP”. Cada foto incluía um número de identificação e uma escala. As fotos foram adicionadas no *software* TPSutil para serem convertidas em um único arquivo com extensão “.tps”. Em seguida o arquivo “tps” foi importado no software TPSdig onde foram inseridas as coordenadas dos *landmarks* (marcos anatômicos).

Para os amonoides foram definidos 7 marcos anatômicos (Adaptado de Reyment, 2003): (1) Protoconcha; (2) e (3) diâmetro dorsoventral; (4) e (5) margem umbilical; (6) e (7) Diâmetro anteroposterior (FIGURA 4).

Figura 4: Amonoides fotografados, vista lateral, com escala, ID e os 7 marcos anatômicos dispostos.



Fonte: A autora, 2017.

Após a adição dos *landmarks* em cada foto, a análise morfométrica foi realizada na plataforma R versão 3.3.1 utilizando o pacote “geomorph" (ADAMS *et al.*, 2018). A partir da Análise de Procrustes, que faz a otimização via método de quadrados mínimos para os parâmetros de translação e rotação, foi possível obter o tamanho corporal mínimo de cada amonoide. O tamanho corporal obtido na análise será expresso em *Centroid Size* (Cs) ou Tamanho do Centroide. Essa medida é obtida a partir da distância entres os marcos anatômicos e o ponto central ou de gravidade resultante da disposição dos *landmarks*.

Todas as informações taxonômicas e temporais usadas nessas análises foram obtidas através do livro de tombo do LPUFS. As designações taxonômicas foram efetuadas, em sua maioria, pela paleontóloga Maria Helena Zucon e colaboradores do LPUFS, tendo-se por base o tratado de Wright *et al.* (1996).

A partir dos dados de tamanho corporal mínimo, as informações temporais e as taxonômicas foi possível investigar as hipóteses desse trabalho. Para isso foi avaliada a relação dos tamanhos corporais observado a nível de superfamília, bem como, averiguado se houve um aumento no tamanho corporal dos espécimes ao longo do tempo geológico.

Afim de atingir os objetivos, também foram analisados os modos de evolução dos tamanhos corporais dos amonoides da Bacia de Sergipe-Alagoas. Para isso foi utilizado a metodologia proposta por Hunt (2006) utilizando o pacote chamando "PaleoTS" (HUNT, 2015) no ambiente de trabalho R versão 3.3.1. Os modelos analisados foram: *Stasis* (~estase), *Strict Stasis* (~estase restrita), *Unbiased Randow Walk* - URW (~evolução neutra), *General Randow Walk* - *GRW* (~seleção direcional), Ornstein-Uhlenbeck – OU (~seleção estabilizadora) e *Punctuated change* (~equilíbrio pontuado).

Os modelos foram validados a partir do *Akaike Information Criterion*, com correção para amostras pequenas, (AICc), que parte do princípio da máxima verossimilhança. Para estimar qual modelo mais se aproximou da realidade foi observado o menor valor do AICc entre as propostas analisados.

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Capítulo 2- Artigo

Title Page

Title: Body size evolution of Ammonoids (Mollusca: Cephalopoda) in southern Atlantic Ocean

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Title: Body size evolution of Ammonoids (Mollusca: Cephalopoda) in southern Atlantic Ocean

Abstract

Body size is considered one of the most diagnostic phenotypes for understanding the interactions of organisms with their environment. If, on one hand, adaptive advantages favor increasing body size over time, environmental changes over geological time scales, on the other hand, can interrupt that evolutive tendency. We investigated here if the shell sizes of Ammonoids varied over a period of 25 million years (within the Cretaceous), as well as how that size evolution occurred. We analyzed 506 specimens of Ammonoids from the Sergipe-Alagoas Basin, in Brazil, using geometric morphometric techniques. Our findings demonstrated that there were two moments of body size stability as well as a punctuation of a marked increase in the sizes of subsequent lineages. In light of the paleo-environmental conditions during the Cretaceous, the possible causes of body size increases appeared to be related to geological/paleo-environmental events that occurred at a 94 Ma. The increase in ocean levels during the Cenomanian age, as well as possible extinction events at the end of that period, could have raised the optimal size for those Ammonoids. In spite of the fact that there are advantages to constantly increasing body size, we observed that geological or climatic events that occur over large temporal scales can have great relevance in determining macroevolutive patterns.

Key-words: Ammonites; Geometric Morphometrics; Model Evolution; Punctuated Equilibrium; Sergipe Cretaceous

Introduction

One of the central tenants of evolutionary studies is that ecological and historical processes lead to phenotypic differentiation (Adams & Collyer, 2009). Fossils are the principal tools used in attempts to understand phenotypic changes over long geological periods as, without those records, little or no information would be available concerning the evolutive history of life on earth (Hunt & Rabosky, 2014). Body size is one of the most obvious and important characteristics of all organisms, and from a paleo-ecological point of view, body size has been considered an extremely important diagnostic phenotype for understanding how living species interact with their environment and the principal physical, ecological, and evolutive factors that influence their survival (Novack-Gottshall, 2008). Observations of body size changes in a given lineage over time have been synthesized within Cope's rule (Cope, 1887; Knouft & Page, 2003) – which postulates that there is a tendency for endothermic animal lineages to evolve towards larger bodies over time (e.g., Alroy, 1998; Hone & Benton 2005; Hunt & Roy 2006). Not all lineages appear to follow that evolutive pattern, however, and different dynamics of body size changes over time have been observed. Some evolutive lineages, for example, demonstrate morphological stasis characterized by a constancy of a given phenotype over geological time. The individuals of those lineages demonstrate a basic phenotype, with only small fluctuations around a general mean (Hunt, 2007). Another evolutive mode, described by Stephen Jay Gould and Niles Eldredge (1972), is punctuated equilibrium, which advances the premise that evolution does not occur in a gradual manner, but is characterized by long periods of stasis punctuated by rapid phenotypic changes (Hunt 2008). Examples of punctuated equilibrium have been seen in organisms such as bryozoans (Jackson & Cheetham 1999) and trilobites (Eldrege & Gould 1972).

The analysis and documentation of body size evolutive tendencies in fossil lineages have largely been concentrated in the Mesozoic and Cenozoic periods (Macfadden, 1986;

Jablonski, 1997; Alroy, 1998; Dommergues, Montuire, & Neige, 2002; (Finkel, Katz, Wright, Schofield, & Falkowski, 2005). Some marine invertebrates that have been investigated during the Mesozoic in terms of their evolutive tendencies include mollusks and ostracods, principally because of their great abundance and ample temporal distribution in paleontological records (e.g., Jablonski, 1997, Hunt, Wicaksono, Brown, & Macleod, 2010, Heim, Knope, Schaal, Wang, & Payne, 2015). The use of locally restricted fossil records (which nonetheless demonstrate significant temporal continuity) in macroevolutive studies will reduce large-scale geographic effects that can interfere with the interpretation of evolutive processes. The Sergipe-Alagoas sedimentary basin contains an almost complete record of Neo mesozoic succession (Campos Neto, Souza-Lima, Cruz 2007). The Sergipe-Alagoas Basin preserves the geological record of the formation of the southern Atlantic Ocean from its very inception, especially within the Riachuelo and Cotinguiba geological formations. Those formations document the predominant influence of a boreal environment (Arai, 2014; Carvalho, Bengtson, & Lana, 2016), as well as global and regional climatic and geological events that occurred during the Neo cretaceous. Marine oxygen depletion events are attributed to the late Aptian and Albian periods (Koutsoukos, Mello, & Azambuja Filho, 1991; Carvalho, Bengtson, & Lana, 2016) and for the Cenomanian/Turonian transition (Mello, Koutsoukos, Hart, Brassell, & Maxwell, 1989, Valle et al., 2019). Sea level variations are also recorded in the geological layers, allowing the identification, for example, of Neo cretaceous oceanic transgressions (Bengtson, 1983; (Carvalho, Mendonça Filho, & Menezes, 2006).

Within the taxonomic groups identified within the Sergipe-Alagoas Basin are Ammonoids, mollusks of the Cephalopoda class that arose and diversified after the Devonian era until the end of the Cretaceous. That group is characterized by wide morphological variations, nektonic habits, rapid evolution, and their exclusiveness to marine environments; they are widely used for geological dating and stratigraphic correlations. Ammonoids were cosmopolitan in their distributions and are easy to identify, in spite of their generally poor states of preservation (Zucon, 2005). Due to their great abundance in Cretaceous rocks in the Sergipe-Alagoas Basin and their wide diversity and rapid phenotypic evolution, Ammonoids were selected for analysis in the present study. We analyzed here variations in the sizes of Ammonoid shells over a relatively long and continuous period of time in a restricted geographic area to determine the time and mode of their body size evolution in the southern Atlantic Ocean and identify possible related events in their environment.

Materials and Methods

Data collection

The Ammonoid fossils analyzed in the present work had been deposited in the paleontological collection of the Paleontology Laboratory, at the Federal University of Sergipe – LPUFS, Brazil. Those Ammonoids were collected in Sergipe State in outcrops of the Riachuelo and Cotinguiba formations in the Sergipe-Alagoas Basin (Supporting information) and correspond to ages from the late Aptian to the Turonian/Coniacian boundary (~115 Ma to 90 Ma) (Fig. 1) (Table S1).

The criteria utilized for selecting the samples examined were based on their degree of preservation in the fossil record. We analyzed 506 specimens of Ammonoids that demonstrated intact protoconches and phragmocones, therefore allowing the measurement of the minimum shell size of each individual (Table S1). A digital camera (Samsung model DV100 16.1MP) was used to geometric morphometrics analyzes from the lateral views of Ammonoid specimens. Each photograph included a specimen identification number and a metric scale. To geometrics morphometrics we used the *TPSdig* software to digitalize seven anatomical landmarks (adapted from Reyment, 2003) (Fig. S1).

Statistical Analyses

The body size of each Ammonoid was estimated from the Centroid Size (Cs), a measure of the dispersion of the anatomical markers around their centers of gravity, with “geomorph" package (Adams, Collyer, & Kaliontzopoulou, 2018) in R platform version 3.3.1.

We prepared a histogram to analyze the distribution frequencies of Ammonoid sizes, and used the ANOVA and Tukey test to identify difference in body size (log Cs) between genera (n=441 individuals) and superfamilies (n=454 individuals). The Tetragonitoidea superfamily were not considered in the statistical comparisons with the other superfamilies due to its low sampling number (n=1). Also, we used ANOVA and Tukey test for any difference between Ammonoid body size (506 individuals) and geological ages.

To analyze the evolutive modes of body size among Ammonoids in the Sergipe-Alagoas Basin (n=506 individuals) we used the methodology proposed by Hunt (2006). The models analyzed were: *Stasis*, *Strict Stasis* (~strict stasis), *Unbiased Randow Walk* - URW, *General Randow Walk - GRW*, Ornstein-Uhlenbeck – OU, and *Punctuated change*. The evolutionary stasis model is characterized by the constancy in the mean of the observed variable (=tetha) (Sheets & Mitchell 2001), while strict stasis models indicate no real evolutionary changes and actually mean sampling errors (Hunt, Hopkins, & Lidgard, 2015). GRW is equivalent to directed evolutionary changes to the minimum or maximum values (Hunt, 2006) (directional selection). In contrast to GRW, in URW evolution is by neutral evolution and in OU, evolutionary changes are drawn near the peak in the adaptive landscape and thus equivalent to a stabilizing selection (Hunt, Bell, & Travis, 2008). The Punctuated change model assumes that there are several optimum separated by periods of stasis which describes the evolution by punctuated equilibrium. The models were compared using *Akaike Information Criterion*, with corrections for small sample sizes (AICc), based on the principle of maximum likelihood probability. We use the smallest AICc value among the models analyzed to estimate which best explained body size variations along evolutive time (considering a difference of two points sufficient to select the best model) (Burnham, Anderson, & Huyvaert, 2011). That analysis was performed using the "PaleoTS" package (Hunt, 2015) of R platform version 3.3.1 software.

Results

We observed high frequencies of small individual among the specimens analyzed, with high right skewness (Fig. S2). When we investigated the difference of the Cs between the genera, it could be seen that there were significant differences between the genera ($p < 0.001$). Among the genera analyzed, *Aioloceras* and *Cheloniceras* demonstrated the smallest body sizes, while *Hoplitoides* and *Solgerites* demonstrated the greatest centroid sizes. The genera *Hoplitoides*, *Pseudoaspidoceras*, and *Pseudotissotia* demonstrated greater body size variations, while *Cleoniceras*, *Neoptychites*, and *Leconteites* demonstrated the smallest amplitudes of variation (Fig. 2). The largest body sizes of the Ammonoids analyzed here were observed in the superfamilies Acanthoceratoidea and Deshayesitoidea, while Desmoceratoidea and Douvilleiceratoidea demonstrated the smallest centroid size values (Fig. S3), with significant correlations between the superfamilies analyzed ($p < 0.001$). The Tukey test (Table S2) indicated that the superfamilies Acanthoceratoidea and Deshayesitoidea were more similar to each other than to the other superfamilies. The body size showed significant difference between geological age (Fig. S4) ($p < 0.001$). Evaluations of size distributions over time indicated that the smallest specimens were the oldest individuals (from the late Aptian

[115 Ma]), and that the largest individuals were more recent (from the Turonian/Coniacian [90 Ma]).

Among the models analyzed, those that referred to punctuated equilibrium demonstrated the smallest ***AICc*** (196.4636), indicating them as providing the best explanations for body size variations over time (Table 1). That result is corroborated by the ***Akaike.wt*** (=1) value encountered here for the Punctuated equilibrium evolutive pattern (Fig. 3). The body size changes among Ammonoids that inhabited the Sergipe-Alagoas Basin occurred at approximately 94 Ma. The optimum attributed value (θ) to Cs during the first phase of stasis was $\theta = 9.82$, and $\theta = 24.01$ during the second phase of stasis. Many genera in the first phase of stasis were observed to fluctuate near that optimum value for body size (Fig. 3).

Discussion

Our results show two moments of evolutionary stasis with different optimum of the body size during the Cretaceous period in the southern Atlantic Ocean. Each of the large stasis periods represents a stability of both adaptive zones and ecological niche in the region (Voje, 2016). The punctuated equilibrium model best explained the observed variations in body size among Ammonoids in the Sergipe-Alagoas Basin during the Cretaceous. The timing of the change in optimum body size to larger individuals occurred at approximately 94 Ma, coinciding with diverse geological/paleo-environmental events such as oxygen depletion of the marine environment and elevated sea levels (with the consequent formation of new deep-sea niches) (Mello, Koutsoukos, Hart, Brassell, & Maxwell, 1989; Valle et al. 2019).

Although there have been many macroevolutionary studies of the body sizes of organisms (e.g., Newell, 1949; Alroy, 1998; Hone & Benton 2005; Hunt & Roy 2006; (Hone, Dyke, Haden, & Benton, 2008; Novack-Gottshall, 2008), few investigations have examined the sizes of extinct marine organisms. In spite of the great diversity, abundance, and wide geographic distributions of Ammonoids (the principal criteria for macroevolutionary studies), there have been few works focusing on the analysis the phenotype of body size (e.g., Dommergues, Montuire, & Neige, 2002). Most of the individuals analyzed in those studies have been members of the superfamily Acanthoceratoidea although, according to Mertz (2017), Ammonoids belonging to the superfamily Acanthoceratoidea demonstrated notable turnover of genera during the Cenomanian (100 Ma). Somewhat later, at the Cenomanian/Turonian boundary (94 Ma), numerous genera became extinct, although the genera of four families arose at that time: Vascoceratidae, Pseudotissotiidae, Collignoniceratidae, and Coilopoceratidae. The Ammonoids found in the Sergipe-Alagoas Basin at that time (Bengtson, 1983) include new occurrences of the genera of the same families mentioned by Mertz (2017).

Among the evolutive models analyzed (Hunt, 2006), the punctuated equilibrium model best expressed the true evolutive mode of body size among Ammonoids from the Sergipe-Alagoas Basin. Punctuated equilibrium is an evolutive process characterized by distinct moments of abrupt phenotypic alterations following periods of stasis. Those phenotypic alterations are marked by very rapid pulses, where morphological intermediates are often not preserved in the fossil assemblages (*Unsampled Punctuations*) or may appear only as rare and infrequent intermediate individuals (*Sampled Punctuations*) (Hunt, 2008). Other taxonomic groups corroborate the punctuated equilibrium model for body size, such as mammals (e.g., Mattila & Bokma 2008). Stanley (1973) noted that there appears to be an ideal body size for each species (*optimum body size*) for each niche that they can occupy. Changes in the physical or biotic environment within a given niche, however, can alter that ideal body size leading to evolution in the direction of a new body size (Stanley, 1973). When Ammonoid body sizes are examined in light of the punctuated equilibrium model, it can be seen that size changes occurred at approximately 94 Ma, at the Cenomanian/Turonian boundary. Interestingly, the largest genera in our study (*Solgerites*, *Hoplitoides* e *Pseudotissotia*) have their origin in the Cenomanian-Turonian boundary (94 Ma). Environmental conditions during Aptian to Albian (~125-100 Ma) were marked by a shallow sea being formed due to the fragmentation of the South American and African plates (Zucon, 2005). The ideal body size of Ammonoids living at that time was smaller (θ = 9.82) than after the punctuation in Cenomanian-Turonian boundary (94 Ma) (θ = 24.01), strongly suggesting that those altered paleo-environmental conditions influenced body size. However, patterns of the strong phenotypic changes on a region can be a result of non-evolutionary processes, for example the colonization of an area by animals from another (Van Bocxlaer, Damme, & Feibel, 2008). We cannot exclude the possibility that fauna from other regions have arrived at Sergipe-Alagoas Basin after 94 Ma. Thus, our study does not allow us to determine completely the process that drive the body size of Ammonoids in the region.

During the early Aptian until the Cenomanian (~115-100 Ma), the shallow sea was turbid due to high fluxes of siliciclastic sediments, limiting the growth of organisms living in more superficial sites (Cainelli, Babinski, & Santos, 1987). Additionally, Ammonoids (and other cephalopods) used their high resolution vision (Audino, Marian, & Lopes, 2015) to obtain food resources (Leonardo, 2010), so that the high water turbidity may well have hindered their ability to obtain food and consequently negatively influenced (Waller & Svensson 2017) body size. Another paleo- environmental factor that could have influenced Ammonoid size at that time was the depleted oxygen condition of the ocean (Carvalho, Bengtson, & Lana, 2016), as cephalopods require well- oxygenated waters (Batt, 1993). Although the sea was shallow at that time, it is possible that water circulation was still limited. After the late

Cenomanian (~100 - 94 Ma) marine transgressions altered the environment in the Sergipe-Alagoas Basin (Cainelli, Babinski, & Santos, 1987), precisely at the moment when larger body sizes abruptly appeared (~94 Ma). The ocean became deeper at that time, and included the continental slope into the bathyal, therefore opening new niches that could be occupied by the fauna already residing there or by species that migrated to the region following newly forming maritime routes. Additionally, that period was marked by extinctions provoked by an oceanic anoxic event (Mertz 2017), establishing a turnover period with high species substitutions. Mello, Koutsoukos, Hart, Brassell, & Maxwell (1989) identified hypoxic to anoxic conditions in the Sergipe-Alagoas Basin during the Cenomanian/Turonian period, but there is currently no evidence of large-scale extinctions or high faunal turnovers during that period.

The observed temporal occurrences of Ammonoids in the Sergipe-Alagoas Basin indicate that individuals of the superfamily Acanthoceratoidea (which had the largest body sizes after the punctuation event) appear there during the middle Albian (~107 Ma). It can therefore be suggested that body size evolution in that superfamily reinforced a larger local pattern (and not necessarily the entrance of new specimens from other regions, with populations of larger individuals). As such, among many possibilities presented above, it would seem that the amplification of the seas during the Cenomanian, together with extinction events associated with oxygen depletion during the Cenomanian/Turonian, resulted in the shifting of optimum body sizes among Ammonoid species. Due to the alteration of those factors, larger Ammonoid species became established after the Turonian, establishing a punctuation during the evolutive history of that group in the basin.

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Figures Legends

Figure 1: Outcrops of the Sergipe-Alagoas Basin, where the ammonoids used in this study were collected (A). Temporal distribution of the genera from Sergipe-Alagoas Basin (in solid rectangles) and their global temporal distribution (grooves). The colors indicate which superfamily each genus belongs to (B).

Figure 2: Box-plots of the Body sizes (Cs) of the Ammonoids classified at the genera level.

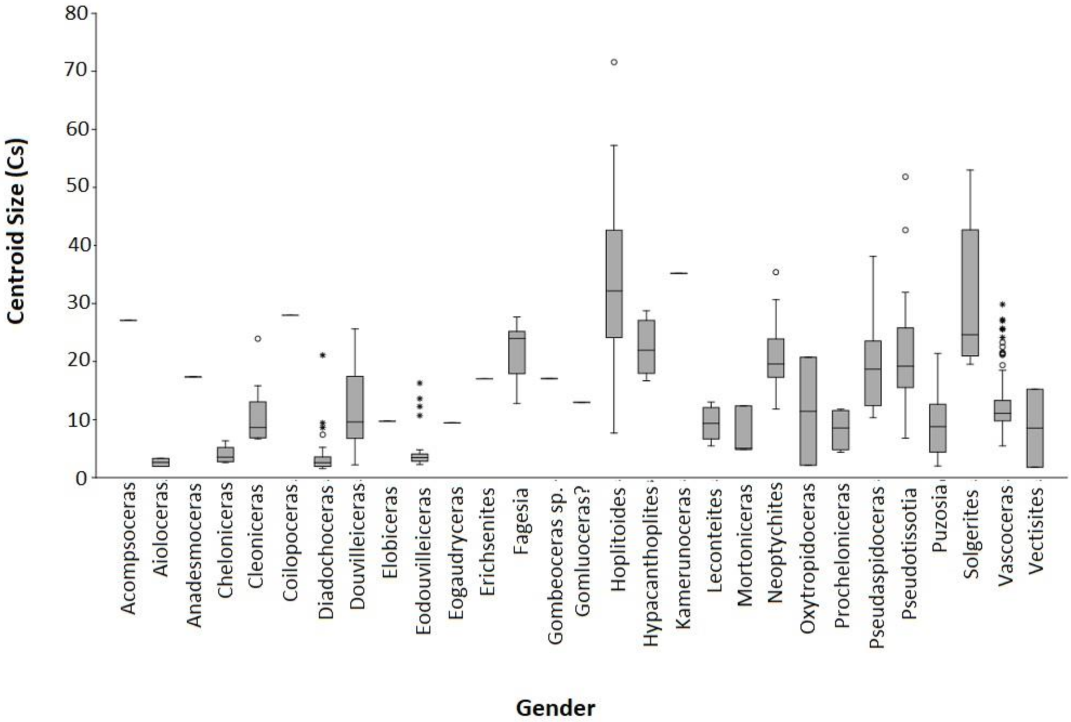
Figure 3: Evolutive pattern of Ammonoid body sizes in the Sergipe-Alagoas Basin, Brazil.

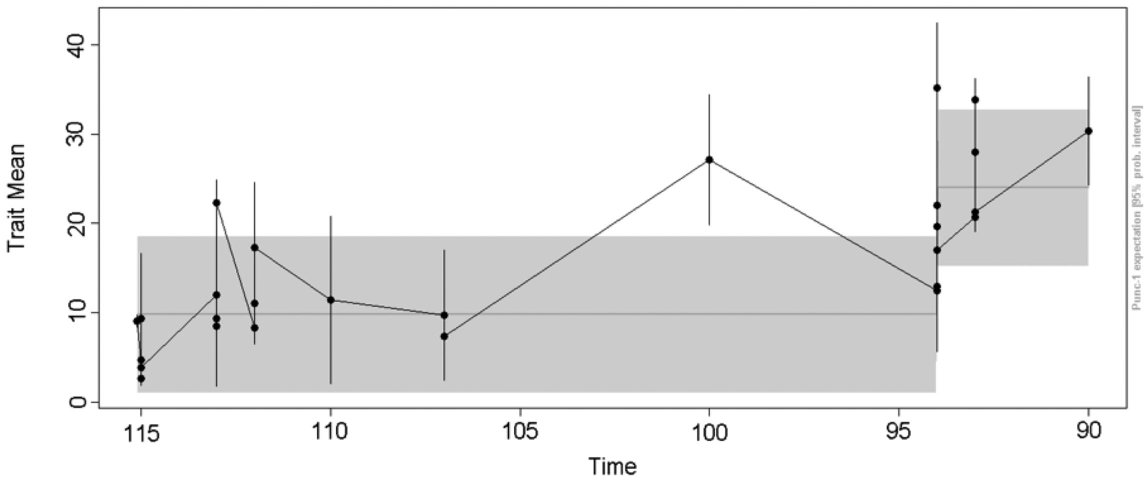
Tables

Table 1: Estimates from the evolutive models analyzed. *Stasis*, *Strict Stasis*, *Unbiased Random Walk - URW*, *General random Walk - GRW*, *Ornstein-Uhlenbeck – OU*, and *Punctuated change*, Log L (Log of likelihood probability), K (numbers of parameters), AICc (model value), and Akaike.wt (model weight).

	LogL	K	AICc	Akaike.wt
URW	-114.60587	2	293.6733	0
Stasis	-105.06231	2	214.5862	0
Strict stasis	-361.59932	1	725.3468	0
GRW	-143.76985	3	294.4997	0
OU	-142.13246	4	293.9316	0
Punc.	-93.39844	4	196.4636	1

Figures


Centroid Size (Cs)
80
70
60
50
40
30
20
10
0
Acompsoceras
Aioloceras
Anadesmoceras
Cheloniceras
Cleoniceras
Coilopoceras
Diadochoceras
Douvilleiceras
Elobiceras
Eodouvilleiceras
Eogaudryceras
Erichsenites
Fagesia
Gombeoceras sp.
Gomluoceras?
Hoplitoides
Hypacanthoplites
Kamerunoceras
Leconteites
Mortoniceras
Neoptychites
Oxytropidoceras
Procheloniceras
Pseudaspidoceras
Pseudotissotia
Puzosia
Solgerites
Vascoceras
Vectisites
Gender


Trait Mean
40
30
20
10
0
115
110
105
100
95
90
Time

Suporting Information

Figure S1. An Ammonoid specimen in lateral view, with a scale and identification number, indicating the seven anatomical landmarks utilized. 1. Protochonc, 2 and 3. Maximum dorsoventral curvature, 4-5. Umbilical margin and 6-7. Maximum anteroposterior curvature.

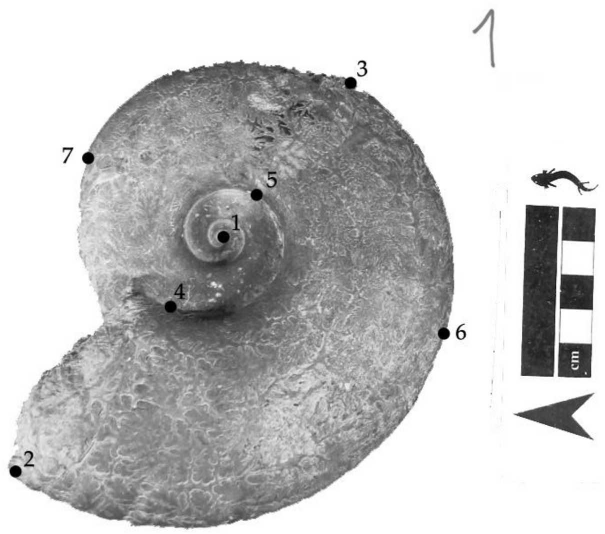


Figure S2: Frequency of centroid sizes of the Ammonoids genera fossils found in the Sergipe-Alagoas Basin, Brazil

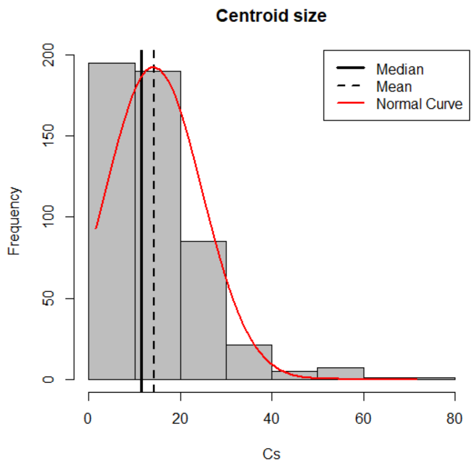


Figure S3: Box-plot of the Body sizes (Cs) of the Ammonoids classified at the superfamily level.

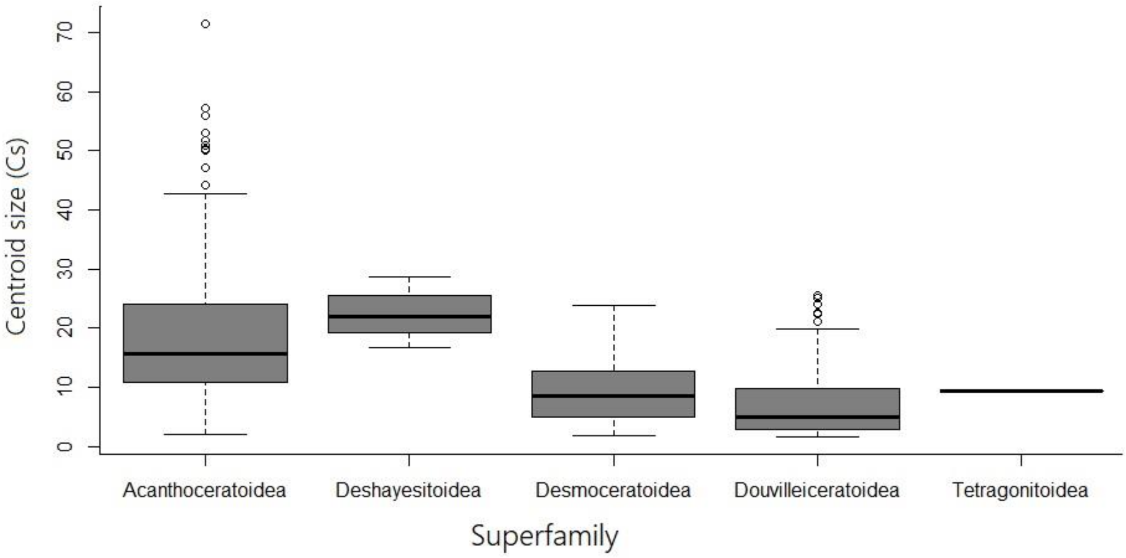


Figure S4: Ammonoids body sizes in relation to geological ages in the Cretaceous.

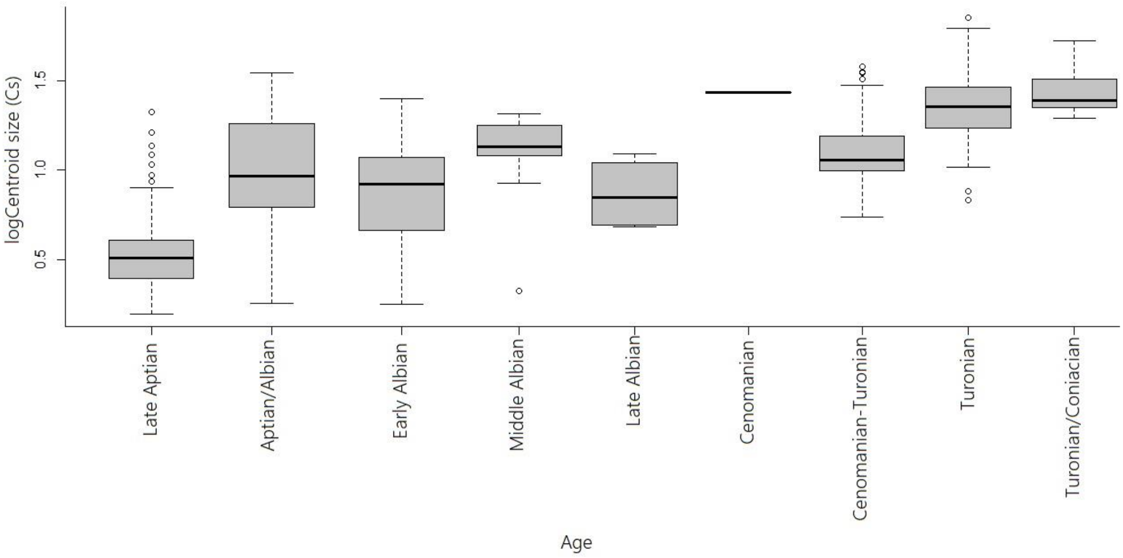


Table S1- Ammonoid individuals analyzed

COD	Age	Time	Superfamily	Gender	Centroid Size	Log Centroid Size	Outcrop	Formation
LPUFS-000462	Albian_lowest	112	Desmoceratoidea	Puzosia	14.57185123	2.67909167	São João da Mata 2	Riachuelo
LPUFS-000464	Albian_lowest	112	Desmoceratoidea	Puzosia	18.27418195	2.905489241	São João da Mata 2	Riachuelo
LPUFS-000465	Albian_lowest	112	Desmoceratoidea	Puzosia	20.42700079	3.016857594	São João da Mata 2	Riachuelo
LPUFS-000469	Albian_lowest	112	Desmoceratoidea	Puzosia	11.39519467	2.433191746	São João da Mata 2	Riachuelo
LPUFS-000662	Albian_lowest	112	Desmoceratoidea	Puzosia	11.17611532	2.41377894	São João da Mata 1	Riachuelo
LPUFS-000663	Albian_lowest	112	Desmoceratoidea	Puzosia	13.88005534	2.630452942	São João da Mata 1	Riachuelo
LPUFS-000664	Albian_lowest	112	Desmoceratoidea	Puzosia	11.53159069	2.445090285	São João da Mata 1	Riachuelo
LPUFS-000665	Albian_lowest	112	Desmoceratoidea	Puzosia	11.24646048	2.420053456	São João da Mata 1	Riachuelo
LPUFS-000666	Albian_lowest	112	Desmoceratoidea	Puzosia	11.16144936	2.41246582	São João da Mata 1	Riachuelo
LPUFS-000667	Albian_lowest	112	Desmoceratoidea	Puzosia	8.966145719	2.193455898	São João da Mata 1	Riachuelo
LPUFS-000668	Albian_lowest	112	Desmoceratoidea	Puzosia	10.34408071	2.336414444	São João da Mata 1	Riachuelo
LPUFS-000671	Albian_lowest	112	Desmoceratoidea	Puzosia	3.693922146	1.306688806	São João da Mata 1	Riachuelo
LPUFS-000679	Albian_lowest	112	Desmoceratoidea	Puzosia	3.098404705	1.130887368	São João da Mata 1	Riachuelo
LPUFS-000684	Albian_lowest	112	Desmoceratoidea	Puzosia	13.95749306	2.636016501	São João da Mata 1	Riachuelo
LPUFS-000935	Albian_lowest	112	Desmoceratoidea	Puzosia	4.674551951	1.542133319	São João da Mata 1	Riachuelo
LPUFS-000936	Albian_lowest	112	Desmoceratoidea	Puzosia	3.973807202	1.379724628	São João da Mata 1	Riachuelo
LPUFS-000937	Albian_lowest	112	Desmoceratoidea	Puzosia	3.518247432	1.257962977	São João da Mata 1	Riachuelo
LPUFS-000938	Albian_lowest	112	Desmoceratoidea	Puzosia	3.412572109	1.227466291	São João da Mata 1	Riachuelo
LPUFS-000939	Albian_lowest	112	Desmoceratoidea	Puzosia	2.753271959	1.012790008	São João da Mata 1	Riachuelo
LPUFS-000940	Albian_lowest	112	Desmoceratoidea	Puzosia	11.76865294	2.465439466	São João da Mata 1	Riachuelo
LPUFS-000941	Albian_lowest	112	Desmoceratoidea	Puzosia	14.34374871	2.663314217	São João da Mata 1	Riachuelo
LPUFS-000942	Albian_lowest	112	Desmoceratoidea	Puzosia	8.542316114	2.145032179	São João da Mata 1	Riachuelo
LPUFS-000973	Aptian_upper	115	Desmoceratoidea	Puzosia	10.70016256	2.370258934	Flor do Mucuri	Riachuelo
LPUFS-001068	Albian_lowest	112	Desmoceratoidea	Puzosia	10.30890549	2.333008132	São João da Mata 1	Riachuelo
LPUFS-001071	Albian_lowest	112	Desmoceratoidea	Puzosia	5.064943706	1.622343023	São João da Mata 1	Riachuelo
LPUFS-001075	Albian_lowest	112	Desmoceratoidea	Puzosia	6.230687077	1.829486612	São João da Mata 1	Riachuelo
LPUFS-001076	Albian_lowest	112	Desmoceratoidea	Puzosia	5.902684758	1.775407291	São João da Mata 1	Riachuelo

LPUFS-001077	Albian_lowest	112	Desmoceratoidea	Puzosia	6.443130896	1.863014586	São João da Mata 1	Riachuelo
LPUFS-001078	Albian_lowest	112	Desmoceratoidea	Puzosia	5.034922521	1.616398138	São João da Mata 1	Riachuelo
LPUFS-001081	Albian_lowest	112	Desmoceratoidea	Puzosia	2.876897076	1.056712309	São João da Mata 1	Riachuelo
LPUFS-001085	Albian_lowest	112	Desmoceratoidea	Puzosia	5.296968459	1.667134668	São João da Mata 1	Riachuelo
LPUFS-001088	Albian_lowest	112	Desmoceratoidea	Puzosia	4.512401398	1.506829472	São João da Mata 1	Riachuelo
LPUFS-001095	Albian_lowest	112	Desmoceratoidea	Puzosia	2.49894832	0.915869971	São João da Mata 1	Riachuelo
LPUFS-001097	Albian_lowest	112	Desmoceratoidea	Puzosia	2.708572518	0.99642175	São João da Mata 1	Riachuelo
LPUFS-001100	Albian_lowest	112	Desmoceratoidea	Puzosia	3.944635474	1.372356548	São João da Mata 1	Riachuelo
LPUFS-001103	Albian_lowest	112	Desmoceratoidea	Puzosia	2.82401786	1.038160644	São João da Mata 1	Riachuelo
LPUFS-001104	Albian_lowest	112	Desmoceratoidea	Puzosia	11.76755508	2.465346175	São João da Mata 1	Riachuelo
LPUFS-001106	Albian_lowest	112	Desmoceratoidea	Puzosia	2.947233498	1.080866933	São João da Mata 1	Riachuelo
LPUFS-001109	Albian_lowest	112	Desmoceratoidea	Puzosia	2.221566025	0.798212364	São João da Mata 1	Riachuelo
LPUFS-001110	Albian_lowest	112	Desmoceratoidea	Puzosia	1.98555932	0.685900648	São João da Mata 1	Riachuelo
LPUFS-001111	Albian_lowest	112	Desmoceratoidea	Puzosia	11.13475807	2.410071574	São João da Mata 1	Riachuelo
LPUFS-001112	Albian_lowest	112	Desmoceratoidea	Puzosia	2.258552298	0.814724032	São João da Mata 1	Riachuelo
LPUFS-001118	Albian_lowest	112	Desmoceratoidea	Puzosia	10.96133586	2.39437416	São João da Mata 1	Riachuelo
LPUFS-001123	Albian_lowest	112	Desmoceratoidea	Puzosia	8.604240545	2.152255168	São João da Mata 1	Riachuelo
LPUFS-001159	Albian_lowest	112	Desmoceratoidea	Puzosia	6.11913198	1.811420253	São Joaquim 4	Riachuelo
LPUFS-001172	Albian_lowest	112	Desmoceratoidea	Puzosia	5.954239528	1.784103492	São João da Mata 1	Riachuelo
LPUFS-001173	Albian_lowest	112	Desmoceratoidea	Puzosia	8.002387892	2.079739984	São João da Mata 1	Riachuelo
LPUFS-001174	Albian_lowest	112	Desmoceratoidea	Puzosia	4.991791244	1.607794812	São João da Mata 1	Riachuelo
LPUFS-001177	Albian_lowest	112	Desmoceratoidea	Puzosia	7.682168585	2.038901875	São João da Mata 1	Riachuelo
LPUFS-001178	Albian_lowest	112	Desmoceratoidea	Puzosia	15.53623211	2.743174852	São João da Mata 1	Riachuelo
LPUFS-001708	Cenomanian/Turonian	94	Desmoceratoidea	Puzosia	12.74413406	2.545071092	Santa Aninha	Cotinguiba
LPUFS-003283	Albian_mean	110	Desmoceratoidea	Puzosia	12.58099286	2.532187172	Estrada do Porto	Riachuelo
LPUFS-003284	Albian_mean	110	Desmoceratoidea	Puzosia	14.02770958	2.641034629	Estrada do Porto	Riachuelo
LPUFS-004525	Turonian	93	Desmoceratoidea	Puzosia	14.18816421	2.652408111	Pedreira Votorantin	Cotinguiba
LPUFS-004526	Turonian	93	Desmoceratoidea	Puzosia	21.39799453	3.063297204	Pedreira União	Cotinguiba
LPUFS-005240	Albian_mean	110	Desmoceratoidea	Puzosia	12.03889204	2.488142412	Est. de ferro Maruim - Rosário	Riachuelo
LPUFS-005243	Albian_lowest	112	Desmoceratoidea	Puzosia	11.68206102	2.458054419	Est. de ferro Maruim - Rosário	Riachuelo

LPUFS-005245	Albian_mean	110	Desmoceratoidea	Puzosia	14.40241043	2.667395584	Est. de ferro Maruim - Rosário	Riachuelo
LPUFS-005372	Albian_mean	110	Desmoceratoidea	Puzosia	8.490757593	2.13897823	0,5Km NW Rosário	Riachuelo
LPUFS-005379	Albian_mean	110	Desmoceratoidea	Puzosia	13.00682346	2.565474102	0,5Km NW Rosário	Riachuelo
LPUFS-005523	Albian_mean	110	Desmoceratoidea	Puzosia	19.19819336	2.954816179	Cruzamento na BR - 101	Riachuelo
LPUFS-005525	Albian_mean	110	Desmoceratoidea	Puzosia	17.89369427	2.884448375	± 0,8 Km NW Rosário do Catete	Riachuelo
LPUFS-000414	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	8.448990668	2.134046987	Riachuelo 1	Riachuelo
LPUFS-000415	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	8.038379901	2.084227558	Porto dos Barcos 2	Riachuelo
LPUFS-000416	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	6.221896328	1.828074736	Riachuelo 1	Riachuelo
LPUFS-000478	Aptian/Albian	113	Desmoceratoidea	Leconteites	5.471284568	1.699513428	Porto dos Barcos 2	Riachuelo
LPUFS-000479	Aptian/Albian	113	Desmoceratoidea	Leconteites	7.856978688	2.061402142	Porto dos Barcos 2	Riachuelo
LPUFS-000480	Aptian/Albian	113	Desmoceratoidea	Leconteites	9.32831041	2.233053906	Porto dos Barcos 2	Riachuelo
LPUFS-000481	Aptian/Albian	113	Desmoceratoidea	Leconteites	11.09602702	2.406587118	Porto dos Barcos 2	Riachuelo
LPUFS-000483	Aptian/Albian	113			9.253621753	2.225015016	Porto dos Barcos 2	Riachuelo
LPUFS-000499	Aptian/Albian	113			22.05092123	3.09335438	Porto dos Barcos 2	Riachuelo
LPUFS-000498	Aptian/Albian	113			14.97835915	2.706606436	Porto dos Barcos 2	Riachuelo
LPUFS-000500	Aptian/Albian	113			6.26331277	1.834709242	Porto dos Barcos 2	Riachuelo
LPUFS-000504	Aptian/Albian	113			4.433767806	1.489249743	Porto dos Barcos 2	Riachuelo
LPUFS-000510	Aptian/Albian	113			34.9515829	3.553963758	Porto dos Barcos 2	Riachuelo
LPUFS-000512	Aptian/Albian	113			2.264428041	0.817322207	Porto dos Barcos 2	Riachuelo
LPUFS-000515	Aptian/Albian	113			3.884631429	1.357028109	Porto dos Barcos 2	Riachuelo
LPUFS-000517	Aptian/Albian	113			5.259229278	1.659984491	Porto dos Barcos 2	Riachuelo
LPUFS-000521	Aptian/Albian	113			3.483268813	1.247971167	Porto dos Barcos 2	Riachuelo
LPUFS-000525	Aptian/Albian	113	Douvilleiceratoidea	Vectisites	1.792539153	0.583633136	Porto dos Barcos 2	Riachuelo
LPUFS-000532	Aptian/Albian	113	Douvilleiceratoidea	Vectisites	15.22057221	2.722647947	Porto dos Barcos 2	Riachuelo
LPUFS-000534	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.912667328	1.364219323	Porto dos Barcos 3	Riachuelo
LPUFS-000535	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	2.971082227	1.088926273	Porto dos Barcos 3	Riachuelo
LPUFS-000543	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	4.795860315	1.567753112	Porto dos Barcos 3	Riachuelo
LPUFS-000729	Aptian/Albian	113	Deshayesitoidea	Hypacanthoplites	16.68460786	2.814486609	Flor do Mucuri	Riachuelo
LPUFS-001611	Turonian	93	Acanthoceratoidea	Pseudotissotia	18.65358568	2.926038389	Santa Aninha	Cotinguiba
LPUFS-001345	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	21.41349377	3.064021273	C-663	Cotinguiba

LPUFS-001527	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	19.38862831	2.964686724	Santa Aninha	Cotinguiba
LPUFS-001375	Turonian/Coniaciano	90	Acanthoceratoidea	Solgerites	53.01417404	3.970559313	C-663	Cotinguiba
LPUFS-001358	Turonian	93	Acanthoceratoidea	Pseudotissotia	21.75541665	3.079862768	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001289	Albian_upper	107	Acanthoceratoidea	Elobiceras	9.719888382	2.274174135	Pedreira Carapeba	Riachuelo
LPUFS-000795	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	13.59283037	2.609542475	Taquari 3	Riachuelo
LPUFS-001462	Turonian	93	Acanthoceratoidea	Pseudotissotia	42.6733254	3.753574027	Santa Aninha	Cotinguiba
LPUFS-000536	Albian_lowest	112	Douvilleiceratoidea	Procheloniceras	11.76934966	2.465498665	Porto dos Barcos 3	Riachuelo
LPUFS-000537	Albian_lowest	112	Douvilleiceratoidea	Procheloniceras	10.95301744	2.393614984	Porto dos Barcos 3	Riachuelo
LPUFS-000538	Albian_lowest	112	Douvilleiceratoidea	Procheloniceras	4.362122027	1.472958642	Porto dos Barcos 3	Riachuelo
LPUFS-000540	Albian_lowest	112	Douvilleiceratoidea	Procheloniceras	6.119197371	1.811430939	Porto dos Barcos 3	Riachuelo
LPUFS-000545	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.857985874	1.350145253	Porto dos Barcos 3	Riachuelo
LPUFS-000547	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.564649511	1.271065735	Porto dos Barcos 3	Riachuelo
LPUFS-000548	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	16.29092695	2.790608324	Porto dos Barcos 3	Riachuelo
LPUFS-000544	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.443402993	1.236460224	Porto dos Barcos 3	Riachuelo
LPUFS-000546	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.604092593	1.282070031	Porto dos Barcos 3	Riachuelo
LPUFS-000549	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.23573473	1.174256021	Porto dos Barcos 3	Riachuelo
LPUFS-000550	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	13.60135108	2.610169132	Porto dos Barcos 3	Riachuelo
LPUFS-000552	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	2.886746122	1.060129958	Porto dos Barcos 3	Riachuelo
LPUFS-000553	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	2.390839802	0.871644686	Porto dos Barcos 3	Riachuelo
LPUFS-000554	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.42876947	1.232201442	Porto dos Barcos 3	Riachuelo
LPUFS-000557	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	4.115819728	1.414838019	Porto dos Barcos 3	Riachuelo
LPUFS-000556	Albian_lowest	112			4.858560658	1.580742233	Porto dos Barcos 3	Riachuelo
LPUFS-000558	Albian_lowest	112			13.48959244	2.601918458	Porto dos Barcos 3	Riachuelo
LPUFS-000559	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	12.25642952	2.506050658	Porto dos Barcos 3	Riachuelo
LPUFS-000560	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.128698377	1.140617064	Porto dos Barcos 3	Riachuelo
LPUFS-000561	Albian_lowest	112			2.938064828	1.077751143	Porto dos Barcos 3	Riachuelo
LPUFS-000562	Albian_lowest	112			9.906599154	2.293201116	Porto dos Barcos 3	Riachuelo
LPUFS-000563	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.23763653	1.174843598	Porto dos Barcos 3	Riachuelo
LPUFS-000564	Albian_lowest	112			2.893276289	1.062389524	Porto dos Barcos 3	Riachuelo
LPUFS-000565	Albian_lowest	112			9.205717056	2.21982471	Porto dos Barcos 3	Riachuelo

LPUFS-000566	Albian_lowest	112			9.825614273	2.284992677	Porto dos Barcos 3	Riachuelo
LPUFS-000551	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	2.265310896	0.817712011	Porto dos Barcos 3	Riachuelo
LPUFS-000569	Albian_lowest	112			1.7867151	0.580378794	Porto dos Barcos 3	Riachuelo
LPUFS-000570	Albian_lowest	112	Desmoceratoidea	Leconteites	13.02395946	2.566790697	Porto dos Barcos 3	Riachuelo
LPUFS-000571	Albian_lowest	112			3.453994372	1.23953135	Porto dos Barcos 3	Riachuelo
LPUFS-000572	Albian_lowest	112			4.01622484	1.390342367	Porto dos Barcos 3	Riachuelo
LPUFS-000573	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	2.523136008	0.925502575	Porto dos Barcos 3	Riachuelo
LPUFS-000575	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	6.378070399	1.852865606	Porto dos Barcos 3	Riachuelo
LPUFS-000580	Albian_lowest	112			9.233356577	2.222822642	Porto dos Barcos 3	Riachuelo
LPUFS-000581	Albian_lowest	112			11.38096603	2.431942314	Porto dos Barcos 3	Riachuelo
LPUFS-000583	Albian_lowest	112	Desmoceratoidea	Cleoniceras	10.04954606	2.307527465	Engenho Lyra 1	Riachuelo
LPUFS-000584	Albian_lowest	112	Desmoceratoidea	Cleoniceras	6.68130306	1.899313037	Engenho Lyra 1	Riachuelo
LPUFS-000585	Albian_lowest	112	Desmoceratoidea	Cleoniceras	6.720425482	1.905151468	Engenho Lyra 1	Riachuelo
LPUFS-000587	Albian_lowest	112	Desmoceratoidea	Cleoniceras	6.833598271	1.921851368	Engenho Lyra 1	Riachuelo
LPUFS-000593	Albian_lowest	112	Desmoceratoidea	Cleoniceras	15.8308628	2.761961377	Engenho Lyra 1	Riachuelo
LPUFS-000594	Albian_lowest	112	Desmoceratoidea	Cleoniceras	8.335060761	2.120470806	Engenho Lyra 1	Riachuelo
LPUFS-000595	Albian_lowest	112	Desmoceratoidea	Cleoniceras	12.67209447	2.53940229	Engenho Lyra 1	Riachuelo
LPUFS-000596	Albian_lowest	112	Desmoceratoidea	Cleoniceras	13.06056214	2.569597166	Engenho Lyra 1	Riachuelo
LPUFS-000598	Albian_lowest	112	Desmoceratoidea	Cleoniceras	8.634900997	2.155812246	Engenho Lyra 1	Riachuelo
LPUFS-000599	Albian_lowest	112	Desmoceratoidea	Cleoniceras	23.93012309	3.175138046	Engenho Lyra 1	Riachuelo
LPUFS-000582	Albian_lowest	112	Desmoceratoidea	Cleoniceras	8.509108257	2.141137149	Engenho Lyra 1	Riachuelo
LPUFS-000626	Aptian/Albian	113			19.80807089	2.986089475	S. Joaquim I - RO-04	Riachuelo
LPUFS-000647	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	10.49965413	2.351342316	S. Joaquim I - RO-04	Riachuelo
LPUFS-000656	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.576515396	0.946437864	Porto dos Barcos 3	Riachuelo
LPUFS-000670	Albian_lowest	112			13.42528935	2.597140193	São João da Mata 1	Riachuelo
LPUFS-000672	Albian_lowest	112			5.844238363	1.765456281	São João da Mata 1	Riachuelo
LPUFS-000673	Albian_lowest	112			6.826938741	1.920876365	São João da Mata 1	Riachuelo
LPUFS-000677	Albian_lowest	112			9.673459004	2.26938595	São João da Mata 1	Riachuelo
LPUFS-000678	Albian_lowest	112			3.086354228	1.126990533	São João da Mata 1	Riachuelo
LPUFS-000680	Albian_lowest	112			3.030503019	1.108728619	São João da Mata 1	Riachuelo

LPUFS-000681	Albian_lowest	112			2.709531371	0.996775694	São João da Mata 1	Riachuelo
LPUFS-000682	Albian_lowest	112			16.27989402	2.789930851	São João da Mata 1	Riachuelo
LPUFS-000683	Albian_lowest	112			10.00686353	2.30327121	São João da Mata 1	Riachuelo
LPUFS-000685	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	7.396486517	2.001005092	Santo Antonio 1	Riachuelo
LPUFS-000686	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	5.20645372	1.649898956	Santo Antonio 1	Riachuelo
LPUFS-000689	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	3.572177189	1.273175267	Santo Antonio 1	Riachuelo
LPUFS-000690	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	3.387308985	1.220035797	Santo Antonio 1	Riachuelo
LPUFS-000691	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	8.617469756	2.15379151	Santo Antonio 1	Riachuelo
LPUFS-000692	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	3.220714084	1.1696031	Santo Antonio 1	Riachuelo
LPUFS-000693	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.84845059	1.046775194	Santo Antonio 1	Riachuelo
LPUFS-000694	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.763671374	1.016560004	Santo Antonio 1	Riachuelo
LPUFS-000695	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.976007887	1.090582767	Santo Antonio 1	Riachuelo
LPUFS-000696	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.568867568	0.943465167	Santo Antonio 1	Riachuelo
LPUFS-000698	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.270048851	0.819801352	Santo Antonio 1	Riachuelo
LPUFS-000699	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.529043576	0.927841198	Santo Antonio 1	Riachuelo
LPUFS-000687	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	21.08691825	3.04865286	Santo Antonio 1	Riachuelo
LPUFS-000700	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.199050472	0.788025664	Santo Antonio 1	Riachuelo
LPUFS-000701	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.002990344	0.694641236	Santo Antonio 1	Riachuelo
LPUFS-000702	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	2.081507329	0.733092309	Santo Antonio 1	Riachuelo
LPUFS-000703	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	1.855482032	0.618144518	Santo Antonio 1	Riachuelo
LPUFS-000704	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	1.90164944	0.642721636	Santo Antonio 1	Riachuelo
LPUFS-000705	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	1.864561374	0.623025837	Santo Antonio 1	Riachuelo
LPUFS-000706	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	1.776870653	0.574853757	Santo Antonio 1	Riachuelo
LPUFS-000707	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	1.614421948	0.478976966	Santo Antonio 1	Riachuelo
LPUFS-000708	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	1.795817794	0.585460514	Santo Antonio 1	Riachuelo
LPUFS-000709	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	1.562155204	0.446066409	Santo Antonio 1	Riachuelo
LPUFS-000710	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	3.061986481	1.119063882	Santo Antonio 1	Riachuelo
LPUFS-000711	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	9.40963749	2.241734429	Santo Antonio 1	Riachuelo
LPUFS-000712	Aptian/Albian	113	Douvilleiceratoidea		12.01686448	2.486311036	São Joaquim 3	Riachuelo
LPUFS-000713	Aptian/Albian	113	Douvilleiceratoidea		5.568574348	1.717139069	Taquari 1	Riachuelo

LPUFS-000714	Albian_lowest	112	Douvilleiceratoidea		3.283072325	1.188779668	Coqueiro 1	Riachuelo
LPUFS-000715	Aptian_upper	115	Douvilleiceratoidea	Diadochoceras	3.549269788	1.266741889	Fortuna 1	Riachuelo
LPUFS-000717	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	9.269561464	2.226736071	Flor do Mucuri	Riachuelo
LPUFS-000719	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	8.465866794	2.136042408	Fortuna 1	Riachuelo
LPUFS-000722	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	6.842655742	1.923175923	Porto dos Barcos 2	Riachuelo
LPUFS-000723	Aptian_upper	115	Desmoceratoidea	Aioloceras	1.9103361	0.647279195	Coqueiro 9	Riachuelo
LPUFS-000724	Aptian_upper	115	Desmoceratoidea	Aioloceras	3.307939101	1.196325367	Coqueiro 9	Riachuelo
LPUFS-000733	Aptian/Albian	113	Deshayesitoidea	Hypacanthoplites	28.7603986	3.358999392	Flor do Mucuri	Riachuelo
LPUFS-000734	Aptian/Albian	113	Deshayesitoidea	Hypacanthoplites	21.76438678	3.080275	Flor do Mucuri	Riachuelo
LPUFS-000735	Aptian/Albian	113	Deshayesitoidea	Hypacanthoplites	22.13620776	3.097214628	Flor do Mucuri	Riachuelo
LPUFS-000740	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	7.813008428	2.055790092	Taquari 1	Riachuelo
LPUFS-000741	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	7.737151114	2.046033547	Taquari 1	Riachuelo
LPUFS-000749	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	18.75457777	2.93143787	Taquari 1	Riachuelo
LPUFS-000750	Aptian/Albian	113	Douvilleiceratoidea		6.311762666	1.842414982	Taquari 1	Riachuelo
LPUFS-000788	Aptian/Albian	113	Douvilleiceratoidea		5.001015805	1.609641053	Taquari 1	Riachuelo
LPUFS-000804	Aptian/Albian	113	Douvilleiceratoidea		24.01871751	3.178833423	Flor do Mucuri	Riachuelo
LPUFS-000815	Aptian/Albian	113	Douvilleiceratoidea		25.1592144	3.225224207	Flor do Mucuri	Riachuelo
LPUFS-000841	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	19.97822969	2.994643165	São Joaquim 3	Riachuelo
LPUFS-000851	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	25.62971208	3.243752307	Flor do Mucuri	Riachuelo
LPUFS-000853	Aptian/Albian	113	Douvilleiceratoidea		10.73417571	2.373432644	Flor do Mucuri	Riachuelo
LPUFS-000889	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	21.12371001	3.050396107	Coqueiro 7	Riachuelo
LPUFS-000891	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	9.891852161	2.291711404	São João da Mata 1	Riachuelo
LPUFS-000904	Aptian_upper	115	Douvilleiceratoidea		3.665170107	1.298874748	Limeira 6	Riachuelo
LPUFS-000905	Aptian/Albian	113	Douvilleiceratoidea		8.358301903	2.123255285	Porto dos Barcos 2	Riachuelo
LPUFS-000906	Aptian_upper	115	Douvilleiceratoidea		7.990102765	2.078203621	Mangueira 5	Riachuelo
LPUFS-000932	Aptian_upper	115	Tetragonitoidea	Eogaudryceras	9.40584421	2.241331221	São Joaquim 4	Riachuelo
LPUFS-000944	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	12.81923453	2.55094674	Estrada do Porto	Riachuelo
LPUFS-000947	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	4.905809653	1.590420146	Estrada do Porto	Riachuelo
LPUFS-000948	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	6.709512807	1.903526341	Estrada do Porto	Riachuelo
LPUFS-000951	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	12.33771241	2.512660621	Limeira 6	Riachuelo

LPUFS-000953	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	12.82085076	2.551072811	Porto dos Barcos 2	Riachuelo
LPUFS-000957	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	15.15220768	2.718146243	São João da Mata 2	Riachuelo
LPUFS-000959	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	6.205010622	1.825357131	Taquari 3	Riachuelo
LPUFS-000960	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	5.595819727	1.722019842	Taquari 3	Riachuelo
LPUFS-000967	Aptian/Albian	113	Douvilleiceratoidea		6.301446593	1.840779225	São Joaquim 3	Riachuelo
LPUFS-000969	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	6.614952553	1.889332625	Taquari 3	Riachuelo
LPUFS-000979	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.26444686	1.183090333	Coqueiro 8	Riachuelo
LPUFS-000985	Aptian/Albian	113	Douvilleiceratoidea		2.796095514	1.028223985	Riachuelo 1	Riachuelo
LPUFS-000986	Aptian/Albian	113	Douvilleiceratoidea		9.688465048	2.270936008	Porto dos Barcos 2	Riachuelo
LPUFS-000993	Aptian_upper	115			2.420643031	0.88403322	Espirito Santo 11	Riachuelo
LPUFS-001034	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	18.2208163	2.902564693	Taquari 1	Riachuelo
LPUFS-001038	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	2.18422576	0.781261422	Taquari 1	Riachuelo
LPUFS-001060	Aptian/Albian	113			14.1461665	2.649443669	Flor do Mucuri	Riachuelo
LPUFS-001063	Aptian/Albian	113			15.98711431	2.771783042	Flor do Mucuri	Riachuelo
LPUFS-001128	Albian_lowest	112	Desmoceratoidea	Anadesmoceras	17.34360359	2.853223769	Coqueiro 1	Riachuelo
LPUFS-001130	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	2.645643891	0.972914473	Limeira 1	Riachuelo
LPUFS-001132	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	10.68851759	2.369170043	Limeira 6	Riachuelo
LPUFS-001133	Aptian/Albian	113	Douvilleiceratoidea	Eodouvilleiceras	2.536662305	0.930849164	Porto dos Barcos 2	Riachuelo
LPUFS-001134	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	4.071116421	1.403917267	Coqueiro 8	Riachuelo
LPUFS-001160	Albian_lowest	112	Douvilleiceratoidea	Cheloniceras	3.504421334	1.25402541	Coqueiro 1	Riachuelo
LPUFS-001162	Aptian_upper	115	Douvilleiceratoidea	Cheloniceras	6.345243241	1.847705436	Coqueiro 8	Riachuelo
LPUFS-001163	Aptian_upper	115	Douvilleiceratoidea	Cheloniceras	2.592372045	0.952573304	Espirito Santo 11	Riachuelo
LPUFS-001164	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	3.439988038	1.235467994	Coqueiro 8	Riachuelo
LPUFS-001166	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	2.806643253	1.031989197	Coqueiro 8	Riachuelo
LPUFS-001167	Aptian_upper	115	Douvilleiceratoidea	Cheloniceras	4.023212324	1.392080669	Limeira 1	Riachuelo
LPUFS-001170	Aptian_upper	115	Douvilleiceratoidea	Cheloniceras	2.847814659	1.046551914	Coqueiro 8	Riachuelo
LPUFS-001168	Aptian_upper	115	Douvilleiceratoidea	Eodouvilleiceras	2.409524517	0.879429432	Coqueiro 8	Riachuelo
LPUFS-001216	Albian_mean	110	Acanthoceratoidea	Oxytropidoceras	2.105588204	0.74459486	Estrada do Porto	Riachuelo
LPUFS-000638	Aptian/Albian	113	Douvilleiceratoidea	Douvilleiceras	22.6860862	3.121751794	São Joaquim 1	Riachuelo
LPUFS-000794	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	22.44709157	3.111161055	Taquari 3	Riachuelo

LPUFS-1353	Turonian	93	Acanthoceratoidea	Pseudotissotia	19.31886951	2.961082313	Santa Aninha	Cotinguiba
LPUFS-1352	Turonian	93	Acanthoceratoidea	Pseudotissotia	22.40602618	3.109329949	Santa Aninha	Cotinguiba
LPUFS-1388	Turonian	93	Acanthoceratoidea	Hoplitoides	22.28788718	3.104043355	Pd. União	Cotinguiba
LPUFS-1361	Turonian	93	Acanthoceratoidea	Pseudotissotia	25.23851327	3.228371132	Santa Aninha	Cotinguiba
LPUFS-1560	Cenomanian/Turonian	94	Acanthoceratoidea	Fagesia	24.34715518	3.192415012	Santa Aninha	Cotinguiba
LPUFS-1351	Turonian	93	Acanthoceratoidea	Pseudotissotia	22.43821382	3.110765479	Santa Aninha	Cotinguiba
LPUFS-1331	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	25.68387157	3.24586323	Santa Aninha	Cotinguiba
LPUFS-1398	Cenomanian	100	Acanthoceratoidea	Acompsoceras	27.08024133	3.29880436	C-660	Cotinguiba
S/Nº	Turonian	93	Acanthoceratoidea	Pseudotissotia	26.69932078	3.284638126	Pd. União	Cotinguiba
CC-0003	Turonian	93	Acanthoceratoidea	Hoplitoides	50.3840102	3.919673867	Pd. União	Cotinguiba
CC-0012	Turonian	93			24.22567412	3.187412985	Pd. União	Cotinguiba
CC-0023	Turonian	93	Acanthoceratoidea	Hoplitoides	33.76203692	3.519337003	Pd. União	Cotinguiba
CC-0011	Turonian	93	Acanthoceratoidea	Hoplitoides	31.59858209	3.453112249	Pd. União	Cotinguiba
LPUFS-1438	Turonian	93	Acanthoceratoidea	Hoplitoides	44.12855947	3.78710718	Pd. Japaratuba	Cotinguiba
CC-0026	Turonian	93	Acanthoceratoidea	Hoplitoides	36.87808154	3.607617378	Pd. União	Cotinguiba
CC-0022	Turonian	93	Acanthoceratoidea	Hoplitoides	41.13640826	3.716893575	Pd. União	Cotinguiba
CC-0019	Turonian	93			31.10855701	3.437482926	Pd. União	Cotinguiba
CC-0020	Turonian	93	Acanthoceratoidea	Hoplitoides	33.38426858	3.508084788	Pd. União	Cotinguiba
CC-0021	Turonian	93	Acanthoceratoidea	Hoplitoides	35.80059191	3.577964427	Pd. União	Cotinguiba
CC-0006	Turonian	93	Acanthoceratoidea	Hoplitoides	34.30938053	3.535418802	Pd. União	Cotinguiba
S/Nº	Cenomanian/Turonian	94			32.18623506	3.471538878	Santa Aninha	Cotinguiba
LPUFS-1532	Turonian	93	Acanthoceratoidea	Pseudotissotia	29.03090384	3.368360912	Santa Aninha	Cotinguiba
LPUFS-1514	Turonian	93	Acanthoceratoidea	Pseudotissotia	18.4590748	2.915556109	Santa Aninha	Cotinguiba
LPUFS-1509	Turonian	93	Acanthoceratoidea	Pseudotissotia	22.29087006	3.10417718	Santa Aninha	Cotinguiba
LPUFS-1505	Turonian	93	Acanthoceratoidea	Pseudotissotia	21.68426904	3.076587069	Santa Aninha	Cotinguiba
LPUFS-1508	Turonian	93	Acanthoceratoidea	Pseudotissotia	21.88481618	3.085793071	Santa Aninha	Cotinguiba
LPUFS-1530	Turonian	93	Acanthoceratoidea	Pseudotissotia	25.64180464	3.244224013	Santa Aninha	Cotinguiba
LPUFS-1515	Turonian	93	Acanthoceratoidea	Pseudotissotia	23.48470189	3.156349226	Santa Aninha	Cotinguiba
LPUFS-1517	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	23.36460786	3.151222393	Santa Aninha	Cotinguiba
LPUFS-1513	Turonian	93	Acanthoceratoidea	Pseudotissotia	22.97249154	3.13429748	Santa Aninha	Cotinguiba

LPUFS-1538	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	24.0227506	3.179001323	Santa Aninha	Cotinguiba
LPUFS-1518	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	20.77028745	3.033523478	Santa Aninha	Cotinguiba
S/Nº	Turonian	93	Acanthoceratoidea	Pseudotissotia	31.81516244	3.459942982	Pd. União	Cotinguiba
CC-0016	Turonian	93	Acanthoceratoidea	Hoplitoides	50.9943697	3.931715229	Pd. União	Cotinguiba
CC-0010	Turonian	93	Acanthoceratoidea	Pseudotissotia	31.91506539	3.463078167	Pd. União	Cotinguiba
	Turonian	93			62.38662515	4.133350912	Pd. União	Cotinguiba
CC-0013	Turonian	93	Acanthoceratoidea	Hoplitoides	57.25946269	4.047592916	Pd. União	Cotinguiba
CC-0027	Turonian	93	Acanthoceratoidea	Hoplitoides	32.17948029	3.471328991	Pd. União	Cotinguiba
S/Nº	Turonian	93			41.78865867	3.732624979	Pd. União	Cotinguiba
S/Nº	Turonian	93	Acanthoceratoidea	Hoplitoides	27.46734862	3.312997976	Pd. União	Cotinguiba
CC-0035	Turonian	93	Acanthoceratoidea	Hoplitoides	26.52680182	3.278155611	Pd. União	Cotinguiba
CC-0034	Turonian	93	Acanthoceratoidea	Hoplitoides	23.10519786	3.140057608	Pd. União	Cotinguiba
CC-0017	Turonian	93	Acanthoceratoidea	Hoplitoides	24.60045432	3.202764911	Pd. União	Cotinguiba
S/Nº	Turonian	93	Acanthoceratoidea	Hoplitoides	23.69724265	3.165358697	Pd. União	Cotinguiba
CC-0032	Turonian	93	Acanthoceratoidea	Hoplitoides	22.85335279	3.129097837	Pd. União	Cotinguiba
CC-0025	Turonian	93	Acanthoceratoidea	Hoplitoides	27.7879785	3.324603499	Pd. União	Cotinguiba
CC-0658- Alunos - 96/1	Turonian	93			23.75878594	3.167952396	Pd. União	Cotinguiba
CC-0024	Turonian	93	Acanthoceratoidea	Hoplitoides	71.60336516	4.271142072	Pd. União	Cotinguiba
CC-0017	Turonian	93	Acanthoceratoidea	Hoplitoides	22.60039709	3.117967477	Pd. União	Cotinguiba
CC-0001	Turonian	93	Acanthoceratoidea	Coilopoceras	27.98306227	3.331599408	Pd. União	Cotinguiba
CC--0028	Turonian	93	Acanthoceratoidea	Hoplitoides	36.53351444	3.598230043	Pd. União	Cotinguiba
CC-0005	Turonian	93	Acanthoceratoidea	Hoplitoides	26.98441427	3.29525945	Pd. União	Cotinguiba
CC-0044	Turonian	93	Acanthoceratoidea	Neoptychites	35.40571287	3.566873188	Pd. União	Cotinguiba
S/Nº	Turonian	93	Acanthoceratoidea	Hoplitoides	50.11681616	3.914356604	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001348	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	29.85599568	3.39638568	Japaratuba	Cotinguiba
LPUFS-001362	Turonian	93	Acanthoceratoidea	Pseudotissotia	51.86046197	3.948556688	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001372	Turonian/Coniaciano	90	Acanthoceratoidea	Solgerites	22.37200698	3.107810489	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001359	Turonian	93	Acanthoceratoidea	Pseudotissotia	24.23265466	3.18770109	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001371	Turonian/Coniaciano	90	Acanthoceratoidea	Solgerites	24.63725404	3.204259689	Pedreira Faz. Aninha	Cotinguiba

LPUFS-001360	Turonian	93	Acanthoceratoidea	Pseudotissotia	27.22282143	3.304055645	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001374	Turonian/Coniaciano	90	Acanthoceratoidea	Solgerites	32.36762322	3.47715864	C-663	Cotinguiba
LPUFS-001471	Turonian	93	Acanthoceratoidea	Pseudotissotia	27.06007023	3.298059218	Santa Aninha	Cotinguiba
LPUFS-001422	Turonian	93	Acanthoceratoidea	Hoplitoides	47.07647928	3.851773498	Santa Aninha	Cotinguiba
LPUFS-001420	Turonian	93	Acanthoceratoidea	Hoplitoides	55.89550716	4.023484004	Santa Aninha	Cotinguiba
LPUFS-001419	Turonian	93	Acanthoceratoidea	Hoplitoides	35.36153751	3.565624718	Pedreira União	Cotinguiba
LPUFS-001428	Turonian	93	Acanthoceratoidea	Pseudotissotia	26.84996929	3.290264677	Pedreira Japaratuba	Cotinguiba
LPUFS-001427	Turonian	93	Acanthoceratoidea	Pseudotissotia	28.95749341	3.36582901	Pedreira Japaratuba	Cotinguiba
LPUFS-001478	Cenomanian/Turonian	94	Acanthoceratoidea	Kamerunoceras	35.18245385	3.560547488	Santa Aninha	Cotinguiba
LPUFS-001465	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	26.98436371	3.295257576	Santa Aninha	Cotinguiba
LPUFS-001475	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	35.24649366	3.562366054	Santa Aninha	Cotinguiba
LPUFS-001477	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	38.13530493	3.641140492	Santa Aninha	Cotinguiba
LPUFS-001545	Cenomanian/Turonian	94	Acanthoceratoidea	Fagesia	23.97915686	3.177184989	Santa Aninha	Cotinguiba
LPUFS-001564	Turonian	93	Acanthoceratoidea	Hoplitoides	26.20767699	3.266052383	Santa Aninha	Cotinguiba
LPUFS-001563	Turonian	93	Acanthoceratoidea	Hoplitoides	26.53138763	3.278328471	Santa Aninha	Cotinguiba
LPUFS-001546	Cenomanian/Turonian	94	Acanthoceratoidea	Fagesia	23.98697222	3.177510859	Santa Aninha	Cotinguiba
LPUFS-001565	Turonian	93	Acanthoceratoidea	Pseudotissotia	19.64783099	2.97796695	Santa Aninha	Cotinguiba
LPUFS-001542	Turonian	93	Acanthoceratoidea	Pseudotissotia	29.96834477	3.40014165	Santa Aninha	Cotinguiba
LPUFS-001508	Turonian	93	Acanthoceratoidea	Pseudotissotia	28.97138028	3.366308456	Santa Aninha	Cotinguiba
LPUFS-001556	Turonian	93	Acanthoceratoidea	Pseudotissotia	30.40175987	3.414500497	Santa Aninha	Cotinguiba
LPUFS-001327	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	15.61857654	2.74846101	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001329	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	12.91539083	2.558419687	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001328	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.907074935	2.293249142	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001326	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	8.540244179	2.1447896	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001368	Turonian	93	Acanthoceratoidea	Pseudotissotia	27.18823509	3.302784346	C-660	Cotinguiba
LPUFS-001347	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	21.15825365	3.052030073	Japaratuba 4	Cotinguiba
LPUFS-001370	Turonian/Coniaciano	90	Acanthoceratoidea	Solgerites	19.5146247	2.971164169	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001386	Turonian	93	Acanthoceratoidea	Hoplitoides	19.33571795	2.961954056	Pedreira União	Cotinguiba
LPUFS-001380	Turonian	93	Acanthoceratoidea	Neoptychites	18.80141263	2.933932007	Pedreira União	Cotinguiba
LPUFS-001383	Turonian	93	Acanthoceratoidea	Neoptychites	11.78882731	2.467152245	C-95- Machado	Cotinguiba

LPUFS-001330	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.39368836	2.433059549	Pedreira Faz. Aninha	Cotinguiba
LPUFS-001382	Turonian	93	Acanthoceratoidea	Neoptychites	17.32240642	2.852000832	Pedreira União	Cotinguiba
LPUFS-001381	Turonian	93	Acanthoceratoidea	Neoptychites	30.66418358	3.423095315	Rita Cacete	Cotinguiba
LPUFS-001441	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.24069293	2.326369286	Pedreira Japaratuba	Cotinguiba
LPUFS-001439	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.40135916	2.433732573	Pedreira Japaratuba	Cotinguiba
LPUFS-001437	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.8984378	2.476407114	Pedreira Japaratuba	Cotinguiba
LPUFS-001432	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	13.50745405	2.603241685	Pedreira Japaratuba	Cotinguiba
LPUFS-001409	Turonian	93	Acanthoceratoidea	Pseudotissotia	10.43915719	2.34556385	Pedreira União	Cotinguiba
LPUFS-001434	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.850384947	2.287510535	Pedreira Japaratuba	Cotinguiba
LPUFS-001408	Turonian	93	Acanthoceratoidea	Hoplitoides	10.9481225	2.393167981	Pedreira União	Cotinguiba
LPUFS-001404	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.660893854	2.268086175	Laranjeiras 28	Cotinguiba
LPUFS-001402	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	13.08066553	2.571135226	Santa Aninha	Cotinguiba
LPUFS-001457	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	11.98817467	2.48392072	Taquari 3	Riachuelo
LPUFS-001461	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	22.15375338	3.098006935	Santa Aninha	Cotinguiba
LPUFS-001467	Cenomanian/Turonian	94	Acanthoceratoidea	Fagesia	12.76147144	2.546430588	Santa Aninha	Cotinguiba
LPUFS-001511	Turonian	93	Acanthoceratoidea	Pseudotissotia	17.61559098	2.868784361	Santa Aninha	Cotinguiba
LPUFS-001507	Turonian	93	Acanthoceratoidea	Pseudotissotia	11.70770842	2.460247464	Santa Aninha	Cotinguiba
LPUFS-001510	Turonian	93	Acanthoceratoidea	Pseudotissotia	15.76847895	2.758012944	Santa Aninha	Cotinguiba
LPUFS-001504	Turonian	93	Acanthoceratoidea	Pseudotissotia	13.35072009	2.591570323	Santa Aninha	Cotinguiba
LPUFS-001529	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	16.11776914	2.779922337	Santa Aninha	Cotinguiba
LPUFS-001521	Turonian	93	Acanthoceratoidea	Pseudotissotia	10.58521427	2.359458147	Santa Aninha	Cotinguiba
LPUFS-001522	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	18.48270316	2.91683533	Santa Aninha	Cotinguiba
LPUFS-001544	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	17.37751854	2.855177333	Santa Aninha	Cotinguiba
LPUFS-001536	Turonian	93	Acanthoceratoidea	Pseudotissotia	19.2548433	2.957762629	Santa Aninha	Cotinguiba
LPUFS-001535	Cenomanian/Turonian	94	Acanthoceratoidea	Fagesia	19.6088461	2.975980796	Santa Aninha	Cotinguiba
LPUFS-001571	Turonian	93	Acanthoceratoidea	Hoplitoides	7.654080638	2.035238922	Santa Aninha C-663	Cotinguiba
LPUFS-001566	Turonian	93	Acanthoceratoidea	Pseudotissotia	17.52980147	2.863902374	Santa Aninha C-663	Cotinguiba
LPUFS-001558	Turonian	93	Acanthoceratoidea	Pseudotissotia	20.39551659	3.015315102	Santa Aninha	Cotinguiba
LPUFS-001590	Turonian	93	Acanthoceratoidea	Pseudotissotia	16.21605136	2.786001576	Santa Aninha	Cotinguiba
LPUFS-001589	Turonian	93	Acanthoceratoidea	Pseudotissotia	24.06178787	3.180625016	Santa Aninha	Cotinguiba

LPUFS-001577	Turonian	93	Acanthoceratoidea	Pseudotissotia	12.95577127	2.561541347	Santa Aninha	Cotinguiba
LPUFS-001592	Cenomanian/Turonian	94			8.955967739	2.192320097	Santa Aninha	Cotinguiba
LPUFS-001576	Cenomanian/Turonian	94	Acanthoceratoidea	Gombeoceras sp.	17.05443375	2.836410214	Santa Aninha	Cotinguiba
LPUFS-001599	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	13.37464769	2.593360952	Santa Aninha	Cotinguiba
LPUFS-001598	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	8.626167145	2.154800275	Santa Aninha	Cotinguiba
LPUFS-001625	Cenomanian/Turonian	94			7.734579023	2.045701058	Santa Aninha	Cotinguiba
LPUFS-001619	Turonian	93	Acanthoceratoidea	Pseudotissotia	13.45420214	2.599291484	Santa Aninha	Cotinguiba
LPUFS-001620	Turonian	93	Acanthoceratoidea	Pseudotissotia	14.15187948	2.649847441	Santa Aninha	Cotinguiba
LPUFS-001622	Turonian	93	Acanthoceratoidea	Pseudotissotia	19.16206284	2.952932431	Santa Aninha	Cotinguiba
LPUFS-001623	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	12.96056754	2.561911482	Santa Aninha	Cotinguiba
LPUFS-001610	Cenomanian/Turonian	94			7.871283697	2.063221162	Santa Aninha	Cotinguiba
LPUFS-001627	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	14.32639375	2.662103552	Pedra Branca 17	Cotinguiba
LPUFS-001672	Turonian	93	Acanthoceratoidea	Neoptychites	17.21734057	2.845917049	Santa Aninha	Cotinguiba
LPUFS-001694	Turonian	93	Acanthoceratoidea	Pseudotissotia	17.8000195	2.879199553	Santa Aninha	Cotinguiba
LPUFS-001691	Turonian	93	Acanthoceratoidea	Pseudotissotia	13.35468862	2.591867531	Santa Aninha	Cotinguiba
LPUFS-001695	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	10.33006049	2.335058139	Santa Aninha	Cotinguiba
LPUFS-001689	Turonian	93	Acanthoceratoidea	Pseudotissotia	12.85993012	2.554116285	Santa Aninha	Cotinguiba
LPUFS-001659	Turonian	93	Acanthoceratoidea	Pseudotissotia	15.26973287	2.725872626	Santa Aninha	Cotinguiba
LPUFS-001666	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	11.3825102	2.432077984	Santa Aninha	Cotinguiba
LPUFS-001673	Turonian	93	Acanthoceratoidea	Neoptychites	18.96947285	2.942830995	Santa Aninha	Cotinguiba
LPUFS-001670	Turonian	93	Acanthoceratoidea	Pseudotissotia	22.21662963	3.100841091	Santa Aninha	Cotinguiba
LPUFS-001613	Turonian	93	Acanthoceratoidea	Pseudotissotia	18.19911143	2.90137277	Santa Aninha	Cotinguiba
LPUFS-001710	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	14.32287541	2.661857938	Santa Aninha	Cotinguiba
LPUFS-001760	Cenomanian/Turonian	94		Gomluoceras ?	12.97989354	2.563401509	Santa Aninha	Cotinguiba
LPUFS-001758	Cenomanian/Turonian	94	Acanthoceratoidea	Erichsenites	16.99980712	2.833201998	Santa Aninha	Cotinguiba
LPUFS-001763	Turonian	93	Acanthoceratoidea	Pseudotissotia	16.0397301	2.775068776	Santa Aninha	Cotinguiba
LPUFS-001762	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	19.27474643	2.958795764	Santa Aninha	Cotinguiba
LPUFS-001768	Cenomanian/Turonian	94			11.43095984	2.436325449	Santa Aninha	Cotinguiba
LPUFS-001777	Turonian	93	Acanthoceratoidea	Pseudotissotia	16.42531063	2.798823476	Santa Aninha	Cotinguiba
LPUFS-001792	Turonian	93	Acanthoceratoidea	Pseudotissotia	13.96837823	2.636796077	Santa Aninha	Cotinguiba

LPUFS-001803	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	15.48440444	2.739833352	Santa Aninha	Cotinguiba
LPUFS-001782	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	18.09014821	2.895367492	Santa Aninha	Cotinguiba
LPUFS-001810	Cenomanian/Turonian	94	Acanthoceratoidea	Pseudaspidoceras	13.69091085	2.616732171	Bom Jesus	Cotinguiba
LPUFS-001802	Cenomanian/Turonian	94	Acanthoceratoidea	Fagesia	27.6570175	3.319879493	Santa Aninha	Cotinguiba
LPUFS-002636	Turonian	93			23.962432	3.176487271	Pedreira União	Cotinguiba
LPUFS-002672	Turonian	93	Acanthoceratoidea	Neoptychites	20.73583682	3.031863451	Pedreira União	Cotinguiba
LPUFS-002637	Turonian	93			23.09062336	3.13942662	Pedreira União	Cotinguiba
LPUFS-001784	Turonian	93	Acanthoceratoidea	Pseudotissotia	27.08479189	3.298972385	Santa Aninha	Cotinguiba
LPUFS-001794	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.16911045	2.319354738	Santa Aninha	Cotinguiba
LPUFS-001718	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.16314891	2.318768326	Santa Aninha	Cotinguiba
LPUFS-001713	Cenomanian/Turonian	94			7.576899507	2.02510408	Santa Aninha	Cotinguiba
LPUFS-002673	Turonian	93			23.4698771	3.155717773	Pedreira União	Cotinguiba
LPUFS-002901	Turonian	93	Acanthoceratoidea	Pseudotissotia	26.23451679	3.267075979	Japaratuba 16	Cotinguiba
LPUFS-002912	Turonian	93	Acanthoceratoidea	Pseudotissotia	18.98995643	2.94391023	Japaratuba 16	Cotinguiba
LPUFS-002905	Turonian	93	Acanthoceratoidea	Pseudotissotia	13.35530921	2.591914	Japaratuba 16	Cotinguiba
LPUFS-002913	Turonian	93	Acanthoceratoidea	Pseudotissotia	15.77340463	2.758325271	Japaratuba 16	Cotinguiba
LPUFS-002907	Turonian	93	Acanthoceratoidea	Pseudotissotia	12.42192941	2.519463412	Japaratuba 16	Cotinguiba
LPUFS-002910	Turonian	93	Acanthoceratoidea	Pseudotissotia	16.54019637	2.805793562	Japaratuba 16	Cotinguiba
LPUFS-002914	Turonian	93	Acanthoceratoidea	Pseudotissotia	16.87363595	2.825752401	Japaratuba 16	Cotinguiba
LPUFS-002915	Turonian	93	Acanthoceratoidea	Pseudotissotia	15.3847988	2.733379931	Japaratuba 16	Cotinguiba
LPUFS-002916	Turonian	93	Acanthoceratoidea	Pseudotissotia	17.19172167	2.84442797	Japaratuba 16	Cotinguiba
LPUFS-002917	Turonian	93	Acanthoceratoidea	Pseudotissotia	15.58163803	2.746093172	Japaratuba 16	Cotinguiba
LPUFS-002923	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.718182537	2.273998619	Japaratuba 16	Cotinguiba
LPUFS-002925	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.551856056	2.256735487	Japaratuba 16	Cotinguiba
LPUFS-002932	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.349210875	2.235291941	Japaratuba 16	Cotinguiba
LPUFS-002931	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.17926951	2.414061127	Japaratuba 16	Cotinguiba
LPUFS-002936	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	14.52863393	2.676121456	Japaratuba 16	Cotinguiba
LPUFS-002933	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.86293765	2.385356779	Japaratuba 16	Cotinguiba
LPUFS-002940	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.83965288	2.383210973	Japaratuba 16	Cotinguiba
LPUFS-002935	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	7.525902374	2.01835072	Japaratuba 16	Cotinguiba

LPUFS-003004	Turonian	93	Acanthoceratoidea	Pseudotissotia	6.762957801	1.911460339	Japaratuba 16	Cotinguiba
LPUFS-003190	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	8.202284679	2.104412735	Taquari 3	Riachuelo
LPUFS-003317	Turonian	93	Acanthoceratoidea	Pseudotissotia	12.08237469	2.491747753	Santa Aninha	Cotinguiba
LPUFS-003351	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	18.231308	2.903140336	Japaratuba C660	Cotinguiba
LPUFS-003509	Turonian	93	Acanthoceratoidea	Neoptychites	20.18631606	3.005004952	General Maynard	Cotinguiba
LPUFS-003650	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.30577848	2.425313965	Japaratuba 16	Cotinguiba
LPUFS-003651	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.21734852	2.324087111	Japaratuba 16	Cotinguiba
LPUFS-003652	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.20265705	2.416150987	Japaratuba 16	Cotinguiba
LPUFS-003653	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.629653	2.363647548	Japaratuba 16	Cotinguiba
LPUFS-003654	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	14.4484099	2.670584367	Japaratuba 16	Cotinguiba
LPUFS-003655	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.11612826	2.314131007	Japaratuba 16	Cotinguiba
LPUFS-003656	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.21056378	2.416856528	Japaratuba 16	Cotinguiba
LPUFS-003657	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	23.28954802	3.148004677	Japaratuba 16	Cotinguiba
LPUFS-003658	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	7.938023871	2.071664362	Japaratuba 16	Cotinguiba
LPUFS-003659	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	8.121148677	2.094471607	Japaratuba 16	Cotinguiba
LPUFS-003660	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	8.273800825	2.113093995	Japaratuba 16	Cotinguiba
LPUFS-003661	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.00587398	2.398429128	Japaratuba 16	Cotinguiba
LPUFS-003662	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.41756929	2.343493736	Japaratuba 16	Cotinguiba
LPUFS-003664	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.64533364	2.36512164	Japaratuba 16	Cotinguiba
LPUFS-003665	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.94467514	2.480285584	Japaratuba 16	Cotinguiba
LPUFS-003668	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	8.395307775	2.127672952	Japaratuba 16	Cotinguiba
LPUFS-003670	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	12.24157736	2.504838138	Japaratuba 16	Cotinguiba
LPUFS-003672	Cenomanian/Turonian	94			9.798475451	2.282226807	Japaratuba 16	Cotinguiba
LPUFS-003673	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	6.546665924	1.878955901	Japaratuba 16	Cotinguiba
LPUFS-003674	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	7.536167276	2.019713734	Japaratuba 16	Cotinguiba
LPUFS-003675	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	21.56249265	3.070955354	Japaratuba 16	Cotinguiba
LPUFS-003676	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.71986034	2.461284867	Japaratuba 16	Cotinguiba
LPUFS-002752	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.512391611	2.252595329	Japaratuba	Cotinguiba
LPUFS-002753	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.33716463	2.335745618	Japaratuba	Cotinguiba
LPUFS-002758	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	13.75147686	2.621146226	Japaratuba	Cotinguiba

LPUFS-002759	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	13.79262255	2.624133851	Japaratuba	Cotinguiba
LPUFS-002760	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	12.18049743	2.499836101	Japaratuba	Cotinguiba
LPUFS-002762	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	13.97775927	2.637467443	Japaratuba	Cotinguiba
LPUFS-002763	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	12.4406383	2.520968396	Japaratuba	Cotinguiba
LPUFS-002764	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	25.52084297	3.23949549	Japaratuba	Cotinguiba
LPUFS-002765	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.99556456	2.302141451	Japaratuba	Cotinguiba
LPUFS-002766	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.82793062	2.470463736	Japaratuba	Cotinguiba
LPUFS-002769	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.27122111	2.422252672	Japaratuba	Cotinguiba
LPUFS-002770	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.18246798	2.414347193	Japaratuba	Cotinguiba
LPUFS-002787	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.037701996	2.201404938	Japaratuba	Cotinguiba
LPUFS-002788	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.08405301	2.310955266	Japaratuba	Cotinguiba
LPUFS-002789	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.95111572	2.393441344	Japaratuba	Cotinguiba
LPUFS-002790	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	7.916957293	2.069006952	Japaratuba	Cotinguiba
LPUFS-002797	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	8.029033442	2.083064152	Japaratuba	Cotinguiba
LPUFS-002799	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	24.15139797	3.184342265	Japaratuba	Cotinguiba
LPUFS-002800	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.89112656	2.387948381	Japaratuba	Cotinguiba
LPUFS-002802	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.851975403	2.287671984	Japaratuba	Cotinguiba
LPUFS-002803	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.65708393	2.455914058	Japaratuba	Cotinguiba
LPUFS-002804	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	7.943972019	2.072413404	Japaratuba	Cotinguiba
LPUFS-002807	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.14452232	2.316933886	Japaratuba	Cotinguiba
LPUFS-002817	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	12.65956086	2.538412729	Japaratuba	Cotinguiba
LPUFS-002779	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.54926823	2.356056496	Japaratuba	Cotinguiba
LPUFS-002780	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	21.32483679	3.05987244	Japaratuba	Cotinguiba
LPUFS-002782	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.22337316	2.324676585	Japaratuba	Cotinguiba
LPUFS-002783	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.575117526	2.259167809	Japaratuba	Cotinguiba
LPUFS-002784	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.353609262	2.235762286	Japaratuba	Cotinguiba
LPUFS-002785	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.43022466	2.436261133	Japaratuba	Cotinguiba
LPUFS-002786	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.33166816	2.335213757	Japaratuba	Cotinguiba
LPUFS-002820	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	12.40495256	2.518095793	Japaratuba	Cotinguiba
LPUFS-002823	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.99562979	2.484542399	Japaratuba 16	Cotinguiba

LPUFS-002827	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.53040989	2.354267251	Japaratuba 16	Cotinguiba
LPUFS-002829	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.294540753	2.229427212	Japaratuba	Cotinguiba
LPUFS-002832	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.49330524	2.350737458	Japaratuba	Cotinguiba
LPUFS-002835	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	27.22862691	3.30426888	Japaratuba	Cotinguiba
LPUFS-002836	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	13.67517719	2.615582305	Japaratuba	Cotinguiba
LPUFS-002838	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	22.52876627	3.114792994	Japaratuba	Cotinguiba
LPUFS-002839	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.18316849	2.414409835	Japaratuba	Cotinguiba
LPUFS-002843	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	5.870442012	1.769929931	Japaratuba	Cotinguiba
LPUFS-002844	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.303471115	2.230387569	Japaratuba	Cotinguiba
LPUFS-002846	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	5.467454771	1.698813201	Japaratuba	Cotinguiba
LPUFS-002847	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	12.40512734	2.518109883	Japaratuba	Cotinguiba
LPUFS-004950	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.68349955	2.368700453	Japaratuba	Cotinguiba
LPUFS-004956	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.61865924	2.362612759	Japaratuba	Cotinguiba
LPUFS-004953	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	6.764838906	1.911738448	Japaratuba	Cotinguiba
LPUFS-004958	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	8.549043326	2.145819385	Japaratuba	Cotinguiba
LPUFS-004949	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	10.52134885	2.353406417	Japaratuba	Cotinguiba
LPUFS-004952	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	8.44422112	2.133482316	Japaratuba	Cotinguiba
LPUFS-004960	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.88869081	2.475587596	Japaratuba	Cotinguiba
LPUFS-004962	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.76995812	2.465550363	Japaratuba	Cotinguiba
LPUFS-004963	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	9.754881344	2.27776781	Japaratuba	Cotinguiba
LPUFS-004964	Cenomanian/Turonian	94	Acanthoceratoidea	Vascoceras	11.1381088	2.410372454	Japaratuba	Cotinguiba
LPUFS-005221	Albian_upper	107	Acanthoceratoidea	Mortoniceras	12.36335105	2.514736536	Usina Varginha	Riachuelo
LPUFS-005223	Albian_upper	107	Acanthoceratoidea	Mortoniceras	5.053920895	1.620164357	Usina Varginha	Riachuelo
LPUFS-005354	Albian_lowest	112	Douvilleiceratoidea	Douvilleiceras	25.14565073	3.224684948		Riachuelo
LPUFS-005361	Turonian	93	Acanthoceratoidea	Pseudaspidoceras	12.62591778	2.535751668	Est. Japaratuba - Pirambu	Cotinguiba
LPUFS-005362	Turonian	93	Acanthoceratoidea	Pseudaspidoceras	11.73391093	2.46248302	Est. Japaratuba - Pirambu	Cotinguiba
LPUFS-005373	Albian_mean	110	Acanthoceratoidea	Oxytropidoceras	20.74927233	3.032511178	0,5Km NW Rosário	Riachuelo
LPUFS-005366	Turonian	93	Acanthoceratoidea	Neoptychites	21.63948	3.074519424	2,5Km SW de	Cotinguiba
LPUFS-005574	Albian_upper	107	Acanthoceratoidea	Mortoniceras	4.829600225	1.574763695	Usina Varginha	Riachuelo

Table S2- P-values from Tukey test between the differences of body size (Cs). Shaded areas represent the existence of significant differences (p<0.001) between superfamilies.

	Acanthoceratoidea	Desmoceratoidea	Douvilleiceratoidea	Deshayesitoidea
Acanthoceratoidea				
Desmoceratoidea	0.0000000			
Douvilleiceratoidea	0.0000000	0.0006491		
Deshayesitoidea	0.8776325	0.0089258	0.0000907	

Capítulo 3- Conclusão

Os resultados mostraram que houve um aumento no tamanho corporal dos amonoides ao longo do Cretáceo da Bacia de Sergipe-Alagoas, onde os indivíduos de maior tamanho encontram-se agrupados, principalmente, na superfamília Acanthoceratoidea.

Quando comparada as outras superfamílias Acanthoceratoidea apresentou uma variação significativa com as superfamílias Douvilleiceratoidea e Desmoceratoidea, porém não há diferença significativa nos tamanhos quando comparada à Deshayesitoidea.

O modelo do equilíbrio pontuado foi o modo evolutivo que melhor explica a variação no tamanho corporal dos amonoides da Bacia de Sergipe-Alagoas ao longo do Cretáceo. O momento da mudança do *optimun body size*, para tamanhos corporais maiores, ocorreu há aproximadamente 94 Ma, coincidindo com diversos eventos geológicos/paleoambientais, como depleção do oxigênio no ambiente marinho, elevação do nível do mar e consequentemente a formação de novos ambientes (mares profundos).

Anexo

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Body size evolution of Ammonoids (Mollusca: Cephalopoda) in southern Atlantic Ocean

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Apêndice

Apêndice 1

Lista dos afloramentos de proveniência dos Amonoides analisados

Afloramento	Formação
± 0,8 Km NW Rosário do Catete	Riachuelo
0,5Km NW Rosário	Riachuelo
Coqueiro 1	Riachuelo
Coqueiro 7	Riachuelo
Coqueiro 8	Riachuelo
Coqueiro 9	Riachuelo
Cruzamento na BR - 101	Riachuelo
Engenho Lyra 1	Riachuelo
Espirito Santo 11	Riachuelo
Est. de ferro Maruim - Rosário	Riachuelo
Estrada do Porto	Riachuelo
Flor do Mucuri	Riachuelo
Fortuna 1	Riachuelo
Limeira 1	Riachuelo
Limeira 6	Riachuelo
Mangueira 5	Riachuelo
Pedreira Carapeba	Riachuelo
Porto dos Barcos 2	Riachuelo
Porto dos Barcos 3	Riachuelo
Riachuelo 1	Riachuelo
S. Joaquim I - RO-04	Riachuelo
Santo Antonio 1	Riachuelo
São João da Mata 1	Riachuelo
São João da Mata 2	Riachuelo
São Joaquim 1	Riachuelo
São Joaquim 3	Riachuelo
São Joaquim 4	Riachuelo
Taquari 1	Riachuelo
Taquari 3	Riachuelo
Usina Varginha	Riachuelo
2,5Km SW de	Cotinguiba
Bom Jesus	Cotinguiba
C-660	Cotinguiba
C-663	Cotinguiba
C-95- Machado	Cotinguiba
Est. Japaratuba - Pirambu	Cotinguiba
General Maynard	Cotinguiba
Japaratuba 4	Cotinguiba
Japaratuba 16	Cotinguiba
Laranjeiras 28	Cotinguiba
Pd. União	Cotinguiba
Pedra Branca 17	Cotinguiba
Pedreira Faz. Aninha	Cotinguiba
Pedreira Japaratuba	Cotinguiba
Pedreira União	Cotinguiba
Pedreira Votorantin	Cotinguiba
Rita Cacete	Cotinguiba
Santa Aninha	Cotinguiba

Aracaju, January 21st, 2020

Dear Blanckenhorn,

Editor-in-chief of Journal of Evolutionary Biology

We are pleased to submit our manuscript '*Body size evolution of Ammonoids (Mollusca: Cephalopoda) in southern Atlantic Ocean'*, by Franciely Santos, Alexandre Liparini and Pablo Ariel Martinez.

In this work, we investigated how evolved the size of the shells of ammonoids present in the Sergipe-Alagoas Sedimentary Basin. The Sergipe-Alagoas Basin contains an almost complete record of Neo Mesozoic marine succession from the Southern Atlantic Ocean. In addition, it is one of the richest and most abundant mollusc sites in the Brazilian Cretaceous. We use geometric morphometry to obtain the sizes of the ammonoids and maximum likelihood analysis to investigate the evolutionary models. Our findings showed that the punctuated equilibrium model was the best to represent the Ammonoids body size evolution in the Sergipe-Alagoas basin. We believe that geological and climatic factors found in this location during the Cretaceous may explain the pattern found.

We believe this study should be of interest to the readership of Journal of Evolutionary Biology, primarily as a critical reference for the issue of body size evolutionary models. For these reasons, we also believe that our study has the potential to render high citation rates. We confirm that this manuscript has not been published elsewhere and that it is not under consideration by another journal. The authors declare that they do not present any conflict of interest.

Msc. Franciely Santos