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**OSTRACODA FROM THE QUIRICÓ FORMATION, LOWER
CRETACEOUS, SÃO FRANCISCO BASIN, MINAS GERAIS
STATE, BRAZIL: STRATIGRAPHY, TAXONOMY,
BIOSTRATIGRAPHY AND PALEOZOOGEOGRAPHY**

*OSTRACODA DA FORMAÇÃO QUIRICÓ, CRETÁCEO
INFERIOR, BACIA DO SÃO FRANCISCO, ESTADO DE MINAS
GERAIS, BRASIL: ESTRATIGRAFIA, TAXONOMIA,
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ABSTRACT

The Quiricó Formation yields a rich and diversified fossil record, and is the only Cretaceous formation from the São Francisco basin with ostracod occurrences. This formation was described from the banks of the Quiricó creek, tributary of the Prata river, hydrographic basin of the São Francisco river, which consists as the type locality. However, the stratotype section was never described. The present work presents the first description of the stratotype section of the Quiricó Formation and the first proposal of hypostratotype section, based on the lithological description and fossil record. Additionally, three other sections of this formation, rich in fossil content, are described. The studied sections are: stratotype section of the Quiricó Formation, by the banks of the Quiricó and São José creeks, hydrographic basin of the São Francisco river, Presidente Olegário County; hypostratotype section of the Tereza Farm, João Pinheiro County; São Bento Farm section, Carmo do Paranaíba County; Sono river section, João Pinheiro County; and São José Farm section, Presidente Olegário County. 21 species of ostracods occur in the Quiricó Formation: 1. *Harbinia* aff. *Harbinia angulata*; 2. *Harbinia symmetrica*; 3. *Harbinia* aff. *Harbinia salitrensis*; 4. *Harbinia alta*; 5. *Harbinia* aff. *Harbinia crepata*; 6. *Brasacypris ovum*; 7. *Brasacypris* aff. *Brasacypris morigerata*; 8. *Brasacypris fulfaro*; 9. *Cypridea hystrix*; 10. *Cypridea conjugata*; 11. *Cypridea* aff. *Cypridea infima*; 12. *Cypridea* aff. *Cypridea jequiensis*; 13. *Cypridea* sp.; 14. *Neuquenocypris* (*Protoneuquenocypris*) *antiqua*; 15. *Damonella* aff. *Damonella ultima*; 16. *Penthesilenula martinsi*; 17. *Penthesilenula pinto*; 18. *Alicenula longiformis*; 19. *Timiriasevia sanfranciscanensis*; 20. *Wolburgiopsis plastica*; 21. *Wolburgiopsis chinamuertensis*. The species recovered from the lower portion of the stratotype section, São Bento Farm section and Sono river section are herein presented for the first time. Also, the taxonomy of species of *Cypridea* is widely discussed. Based on the limnic ostracod taxonomy, biostratigraphic, paleozoogeographic and paleoenvironmental studies were connected. It is presented herein the first biostratigraphic zonation based on ostracods. For that, three sections were approached: stratotype section of the Quiricó Formation, hypostratotype section of the Tereza Farm and São Bento Farm section. Six biostratigraphic units are described, one superzone and five zones. The *Brasacypris ovum* Zone is defined by the lowest occurrences of *Brasacypris ovum* and of *Timiriasevia sanfranciscanensis*, and is attributed to the Berriasian. The *Penthesilenula pinto* Superzone is defined by the local range of *Penthesilenula pinto*, attributed to the Berriasian-Aptian/Albian? interval. Within this superzone, four zones are described: 1. Zone *Timiriasevia sanfranciscanensis*, defined by the first occurrence of *Timiriasevia sanfranciscanensis* and of *Cypridea hystrix*, attributed to the Berriasian; 2. Zone *Cypridea hystrix*, defined by the local range of *Cypridea hystrix*, attributed to the Valanginian-Hauterivian interval; 3. Zone *Alicenula longiformis*, defined by last occurrence of *Cypridea hystrix* and of *Alicenula longiformis*, attributed to the Barremian; and 4. Zone *Harbinia* spp., defined by the assemblage range of species of *Harbinia*, with the lower limit marked by the last occurrence of *Alicenula longiformis*, attributed to the Aptian. The paleozoogeographic analysis showed faunal similarities with several sedimentary basins in Brazil, Argentina and Africa with record from the Cretaceous of Gondwana.

Key-words: Quiricó Formation, stratotype section, hypostratotype section, ostracod, biostratigraphy, paleozoogeography.

RESUMO

A Formação Quiricó apresenta um registro fóssil abundante e diversificado, e é a única formação do Cretáceo da bacia do São Francisco com a ocorrência de ostracodes. Essa Formação foi descrita a partir das margens do ribeirão Quiricó, tributário do rio da Prata, bacia hidrográfica do rio São Francisco, que consiste da localidade tipo. No entanto, a seção-tipo não foi descrita. O presente trabalho apresenta a primeira descrição da seção-tipo da Formação Quiricó e a primeira proposta de uma seção-tipo suplementar, baseadas na descrição litológica e ocorrências fossilíferas. Adicionalmente, outras três seções desta formação, ricas em conteúdo fossilífero, são descritas. Os afloramentos da Formação Quiricó estudados são: seção-tipo da Formação Quiricó, margens dos ribeirões Quiricó e São José, bacia hidrográfica do rio São Francisco, Município de Presidente Olegário; seção-tipo suplementar da Fazenda Tereza, Município de João Pinheiro; seção da Fazenda São Bento, Município de Carmo do Paranaíba; seção do rio do Sono, Município de João Pinheiro; e seção da Fazenda São José, Município de Presidente Olegário. 21 espécies de ostracodes ocorrem na Formação Quiricó: 1. *Harbinia* aff. *Harbinia angulata*; 2. *Harbinia symmetrica*; 3. *Harbinia* aff. *Harbinia salitrensis*; 4. *Harbinia alta*; 5. *Harbinia* aff. *Harbinia crepata*; 6. *Brasacypris ovum*; 7. *Brasacypris* aff. *Brasacypris morigerata*; 8. *Brasacypris fulfaroi*; 9. *Cypridea hystrix*; 10. *Cypridea conjugata*; 11. *Cypridea* aff. *Cypridea infima*; 12. *Cypridea* aff. *Cypridea jequiensis*; 13. *Cypridea* sp.; 14. *Neuquenocypris* (*Protoneuquenocypris*) *antiqua*; 15. *Damonella* aff. *Damonella ultima*; 16. *Penthesilenula martinsi*; 17. *Penthesilenula pintoi*; 18. *Alicenula longiformis*; 19. *Timiriasevia sanfranciscanensis*; 20. *Wolburgiopsis plastica*; 21. *Wolburgiopsis chinamuertensis*. As espécies recuperadas a partir da porção inferior da seção-tipo da Formação Quiricó, da seção da Fazenda São Bento e do rio do Sono são apresentadas pela primeira vez. Além disso, a taxonomia de espécies de *Cypridea* é amplamente discutida. A partir da taxonomia de ostracodes límnicos, estudos bioestratigráficos, paleozoogeográfico a paleoambientais foram conduzidos. O presente trabalho consta como a primeira tentativa em estabelecer a bioestratigrafia baseada em ostracodes. Para isso, três seções são foram abordadas: seção-tipo da Formação Quiricó, seção-tipo suplementar da Fazenda Tereza e seção da Fazenda São Bento. Seis unidades bioestratigráficas são descritas, uma superzona e cinco zonas. A Zona *Brasacypris ovum* é definida pela primeira ocorrência de *Brasacypris ovum* e de *Timiriasevia sanfranciscanensis*, e é atribuída ao Barremiano. A Superzona *Penthesilenula pintoi* é definida pela amplitude de ocorrência de *Penthesilenula pintoi*, atribuída ao intervalo Berriasiano-Aptiano. Contidas nessa subzona, as quatro zonas são: 1. Zona *Timiriasevia sanfranciscanensis*, definida pela primeira ocorrência de *Timiriasevia sanfranciscanensis* e de *Cypridea hystrix*, atribuída ao Berriasiano; 2. Zona *Cypridea hystrix*, definida pela amplitude de ocorrência de *Cypridea hystrix*, atribuída ao intervalo Valanginiano-Hauteriviano; Zona *Alicenula longiformis*, definida pela última ocorrência de *Cypridea hystrix* e de *Alicenula longiformis*, atribuída ao Barremiano; Zona *Harbinia* spp., definida pela assemblagem de espécies de *Harbinia*, cujo limite inferior é marcado pela última ocorrência de *Alicenula longiformis*, atribuída ao Aptiano. A análise paleozoogeográfica indica similaridades entre faunas de bacias sedimentares do Brasil, da Argentina e da África com registro do Cretáceo do Gondwana.

Palavras-chave: Formação Quiricó, seção-tipo, seção-tipo suplementar, ostracode, bioestratigrafia, paleozoogeografia.

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1. INTRODUCTION

The Quiricó Formation was originally named as Quiricó Member to designate a succession of sandstones intercalated with mudstones outcropping by the banks of the Quiricó creek, tributary of the Prata river, hydrographic basin of the São Francisco river, Minas Gerais State (Barbosa, 1965). Later on, this lithostratigraphic unit was elevated to Quiricó Formation, which is currently the accepted status (Campos and Dardenne, 1997a, 1997b). The type locality of the lithostratigraphic unit was defined, but wasn't formally described. From its proposition, there are few publications that approach the lithostratigraphy and fossiliferous content of the Quiricó Formation. The fossiliferous content is abundant and diversified, including carophytes, spinicaudatans, mollusks, fishes, other vertebrates and plant fragments, and it is the only formation from the Mesozoic of the São Francisco basin with the occurrence of ostracods (Do Carmo et al., 2004a; Campos and Do Carmo, 2005; Bittencourt et al., 2015; Leite et al., 2018).

Regarding the age of what is nowadays considered Quiricó Formation, its chronostratigraphic position was first cited by Scorza and Silva Santos (1955), with the identification of the fish *Dastilbe moraesi* Silva Santos in Scorza and Silva Santos, 1955 in layers of papyraceous shale from the Presidente Olegário region. The *Dastilbe* Genus occurs with an extraordinary preservation at the Araripe basin, in Aptian layers, which could indicate that the Quiricó Formation, on that location, was attributed to the Aptian as well (Scorza and Silva Santos, 1955). Ostracods, carophytes and bone fragments were recovered in outcrops of the Areado Group in the Minas Gerais State by Barbosa et al. (1970), and they determined that the ostracod fauna corresponded to that recovered in the Santana Formation, attributed to the Aptian/Albian. Posteriorly, Lima (1979) identified the Palynozone *Transitoripollis crisopolensis*, P-230, in the papyraceous shale from the Presidente Olegário region – the same layer where *Dastilbe moraesi* Silva Santos in Scorza and Silva Santos, 1955 was recovered –, attributing it to the Barremian to possibly lower Aptian, corroborated by Arai et al. (1995). However, several authors suggest that this palynozone is attributed to the Alagoas Local Stage, Aptian (Arai et al., 1989; Regali, 1989; Arai, 2001; Nascimento, 2013; Antunes et al., 2018). Therefore, the papyraceous shale remains attributed to the Aptian.

The first detailed study on limnic ostracods from the Quiricó Formation was conducted by Do Carmo et al. (2004a), in the São Bento Farm (Carmo do Paranaíba County) and in the Sono river (João Pinheiro County). It was determined that the base of the Quiricó Formation on the studied locality would be attributed to the Barremian, encompassing, therefore, the Barremian-Aptian interval. However, the study of limnic ostracod taxonomy by Leite et al. (2018) determined that the base of the

formation could be attributed to the Rio da Serra Local Stage, and the Quiricó Formation would encompass the Valanginian-Aptian interval. A detailed review on worldwide distribution of species with records on Cretaceous of the São Francisco basin is approached on the chapter of the present thesis, entitled “ANALYSIS IN PALEOZOOGEOGRAPHIC DISTRIBUTION”.

The present work has five main objectives, they are: 1. description of stratotype, hypostratotype and other outcropping sections of the Quiricó Formation that are rich in fossiliferous content; 2. review and update of ostracod taxonomy; 3. proposal and analysis of biostratigraphic framework; 4. paleoenvironmental analysis; 5. and paleozoogeographic approach. With that, the present thesis aims to characterize the Quiricó Formation based on the description of the stratotype section, as well as the description and proposal of a hypostratotype section and three additional sections, focused on taxonomy, biostratigraphy, paleozoogeography and paleoecology of recovered ostracods. Additionally, it is presented herein a contribution to the expansion of knowledge on stratigraphy, biostratigraphy and paleozoogeography of the São Francisco basin, as well as implications for the central Gondwana during the Cretaceous.

So, this thesis includes new data on ostracod taxonomy and biostratigraphy, as well as three articles dealing with ostracod taxonomy, stratigraphy, biostratigraphy and paleozoogeography are presented herein. The three articles are:

1. “TAXONOMY OF LIMNIC OSTRACODA (CRUSTACEA) FROM THE QUIRICÓ FORMATION, LOWER CRETACEOUS, SÃO FRANCISCO BASIN, MINAS GERAIS STATE, SOUTHEAST BRAZIL” (Leite et al., 2018);
2. “DESCRIPTION OF THE STRATOTYPE SECTION AND PROPOSAL OF HYPOSTRATOTYPE SECTION OF THE LOWER CRETACEOUS QUIRICÓ FORMATION, SÃO FRANCISCO BASIN, BRAZIL” (Leite and Do Carmo, 2021);
3. “BIOSTRATIGRAPHY OF LIMNIC OSTRACODA (CRUSTACEA) FROM THE QUIRICÓ FORMATION, LOWER CRETACEOUS OF THE SÃO FRANCISCO BASIN, MINAS GERAIS STATE, BRAZIL: AN APPROACH ON PALEOZOOGEOGRAPHIC EVOLUTION OF GONDWANA” (Leite et al., to be submitted. Appendix 1).

1.1. Studied area

The approached sections of the Quiricó Formation, from the Minas Gerais State, are: 1. Stratotype section of the Quiricó Formation, from the banks of the Quiricó and São José creeks, Presidente Olegário County (38225.00 mE, 7972508.00 mN; 387776.00 mE, 7968917.00 mN) (Leite

and Do Carmo, 2021); 2. Hypostratotype section of the Tereza Farm, João Pinheiro County (403859.00 mE, 8050999.00 mN) (Leite and Do Carmo, 2021); 3. São Bento Farm section, Carmo do Paranaíba County (368571.00 mE, 7908266.00 mN); 4. Sono river section, João Pinheiro County (396080.00 mE, 8012948.00 mN); 5. São José Farm section, Presidente Olegário County (387673.00 mE, 7968100.00 mN) (Fig. 1). Both Quiricó and São José creeks are confluent and tributary of the Prata river and they are very close to each other; the São José creek begins near the BR-365 and flows into the Quiricó creek (Fig. 2).

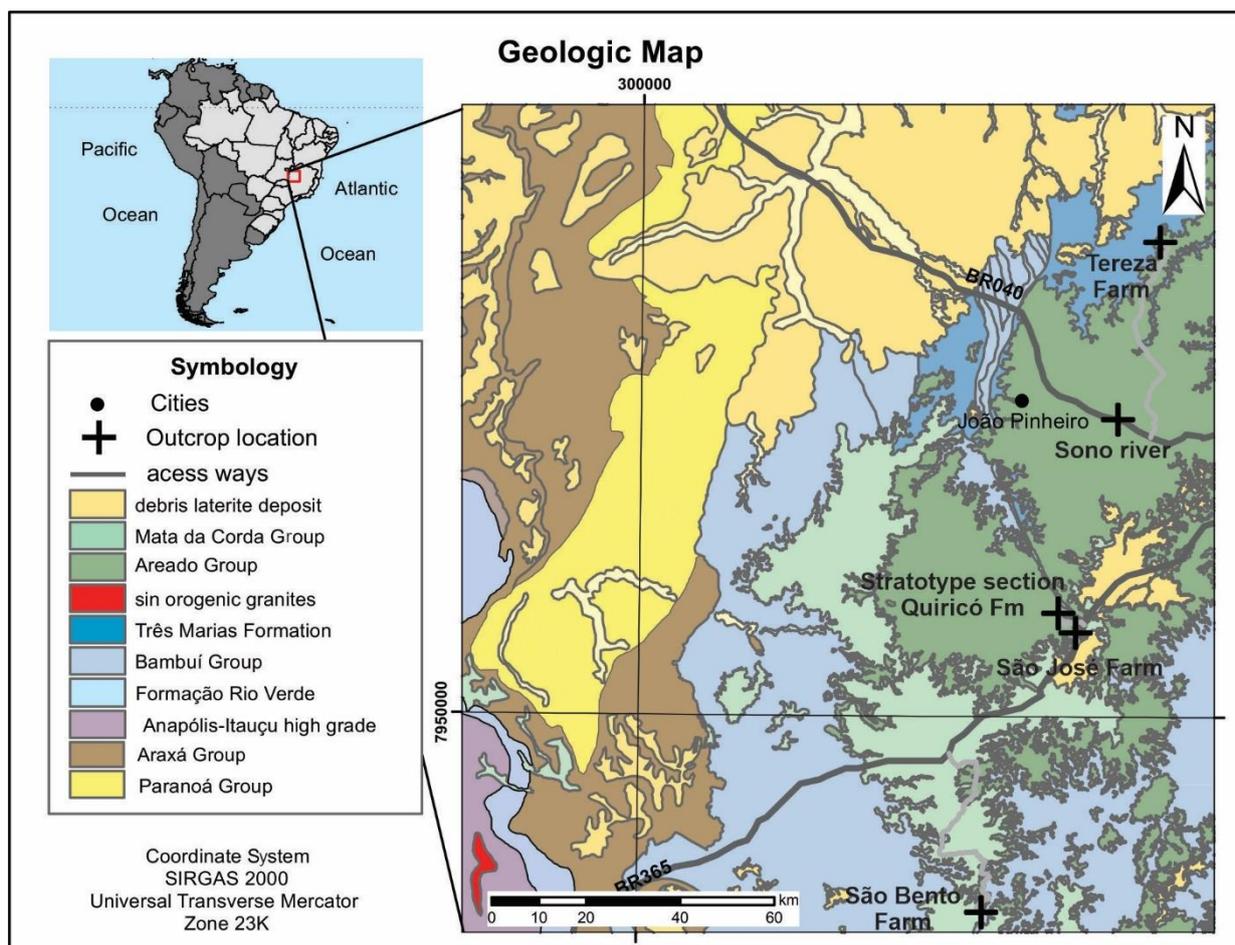


Figure 1. Geologic Map of the São Francisco basin, with the studied sections of the Quiricó Formation, Minas Gerais State, Brazil: stratotype section of the Quiricó Formation, Presidente Olegário County; hypostratotype section of the Tereza Farm, João Pinheiro County; São Bento Farm section, Carmo do Paranaíba County; Sono river section, João Pinheiro County; and São José Farm section, Presidente Olegário County (adapted from Leite and Do Carmo, 2021).

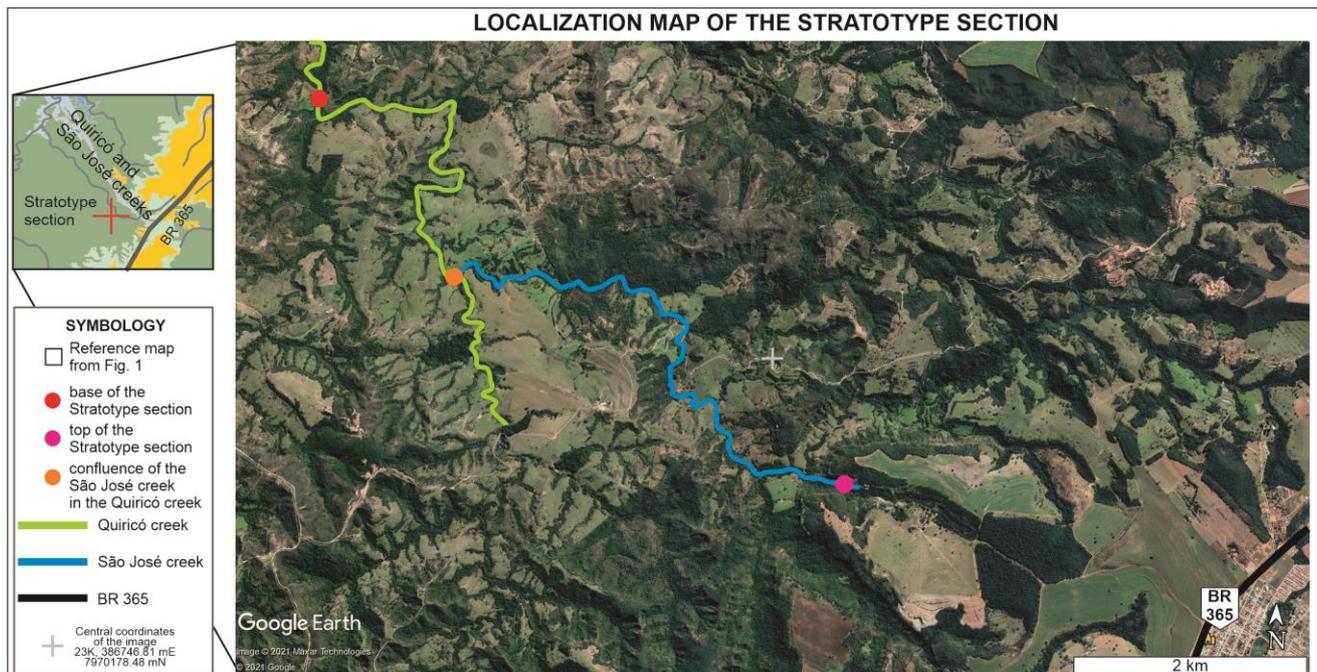


Figure 2. Localization map of the stratotype section of the Quiricó Formation. The base of the section is located in the banks of the Quiricó creek and the top of the section in the banks of the São José creek. Central coordinates of the image: 23K, 386746.81 mE, 7970178.48 mN (Leite and Do Carmo, 2021).

2. GEOLOGIC CONTEXT OF THE QUIRICÓ FORMATION

The São Francisco basin is intracratonic, little deformed in the central portion and deformed at the edges, due to two compressional mobile belts: to the west the Brasília Belt, and to the east the Araçuaí Belt. The base of the basin is composed by Proterozoic sedimentary rocks, overlapped by Phanerozoic sedimentary rocks (Zalán and Silva, 2007). The Phanerozoic portion is distributed over the Distrito Federal, Minas Gerais, Bahia, Piauí, Tocantins and Maranhão (Bueno, 2012). The Phanerozoic sequence is represented, from base to top, by groups: Santa Fé, Permian-Carboniferous; Areado, Lower Cretaceous; and Mata da Corda and Urucuia, Upper Cretaceous (Campos and Do Carmo, 2005; Zalán and Silva, 2007) (Fig. 3).

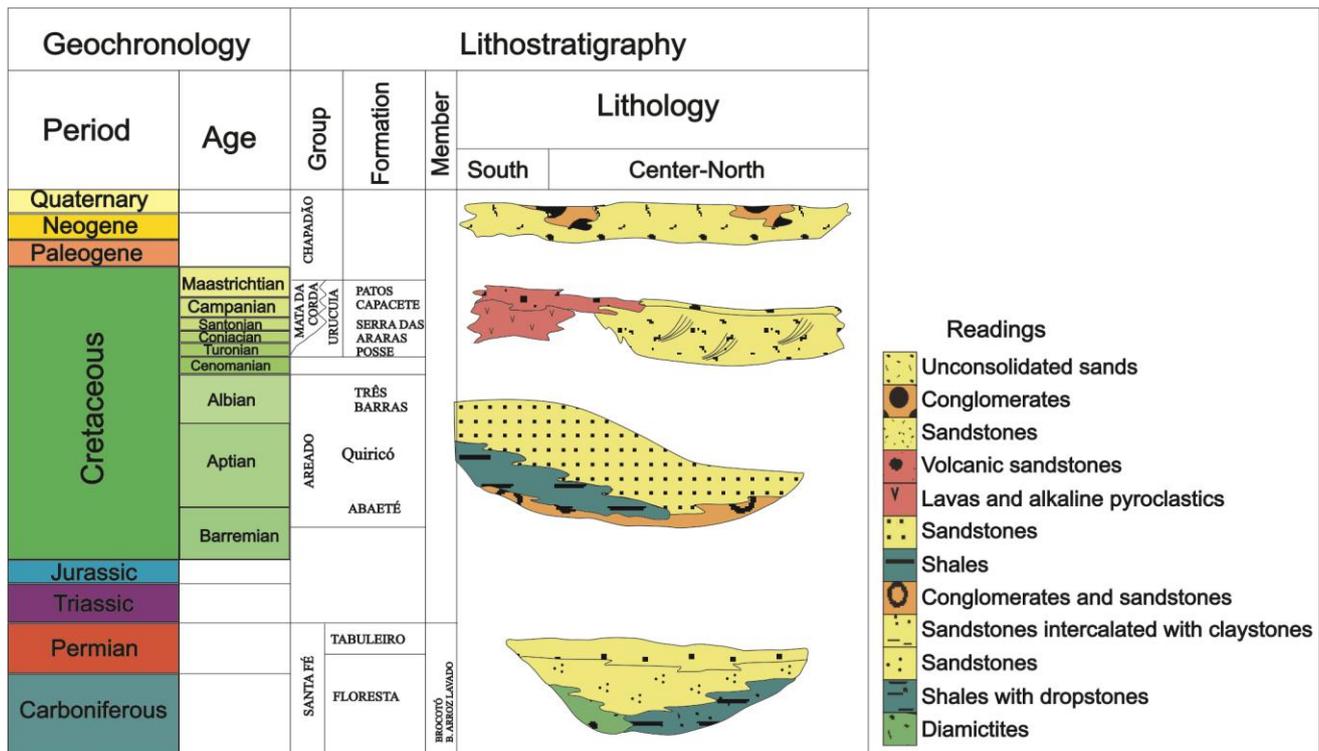


Figure 3. Chronostratigraphic column representing the Phanerozoic sequence of the São Francisco basin (Do Carmo et al., 2004a, adapted according to Campos and Dardenne, 1997b).

The Areado Group presents a broad stratigraphic variation and ample lateral variation of lithofacies, product of the simultaneous action of several depositional environments. From base to top, three formations with partially coeval deposition compose the Areado Group: Abaeté, Quiricó e Três Barras. The Abaeté Formation presents two distinct sedimentary contexts; the southern portion of the basin was deposited by alluvial fans, and is composed of immature matrix-supported conglomerates; while the rest of the basin it was deposited by braided river systems, and is composed of mature grain-supported conglomerates (Campos and Dardenne, 1997b; Campos and do Carmo, 2005).

The Abaeté Formation is distributed mainly in the central-south portion of the basin, while the north portion is discontinuous. It is restricted to the base of the Areado Group, constituting a stratigraphic guide of the basin, once it marks the beginning of said group. The thickness of this formation varies from a few centimeters to 2 meters (Campos and Dardenne, 1997b). The Abaeté Formation was divided into two members by Sgarbi et al. (2001): Carmo and Canabrava. The Carmo Member is characterized by matrix-supported conglomerate facies, lithic sandstones and pelites. The Canabrava Member is characterized by clast-supported conglomerate facies and quartz sandstones (Sgarbi et al., 2001).

The Quiricó Formation was deposited in a lacustrine system, and is composed of siltstones, which occur interstratified and predominate at the base of the sequence; fine, medium and coarse sandstones in the intermediate portion; and shales and micritic limestones, more frequent in the upper part of the sequence. This is the only formation of the Areado Group in which ostracod fossils have been recovered to date (Campos and Dardenne, 1997b; Campos and do Carmo, 2005). Locally, in the Presidente Olegário County, Minas Gerais State, a black shale occurs, rich in organic matter and with the occurrence of *Dastilbe moraesi* Silva Santos in Scorza and Silva Santos, 1955 and remains of plants (Campos and Dardenne, 1997b; Campos and do Carmo, 2005).

The Quiricó Formation presents occurrences that show a wide geographic distribution, with an elongated morphology from south to north of the basin. Isolated portions of the formation, with predominantly shallow thickness, indicate that there were several water bodies, connected in periods of greater humidity, and isolated in arid periods, instead of a single large lake (Sgarbi et al., 2001). The thickness of this formation can vary from 100 meters at the basin's depocenter, to a few meters at the edges of the lacustrine system. It is superimposed on the Abaeté Formation or can directly cover the metasediments of the Bambuí Group, and laterally it can occur interdigitated with the Três Barras Formation. In the sequences close to the edges of the lacustrine system, evaporites and carbonate crusts were recorded, since these regions were more susceptible to variations in the water level. There is also a strong eolian influence, composing several levels of laterally continuous sandstones composed of aeolian sand grains, showing that it occurred simultaneously with the deposition of the pelites, migration and reworking of dunes (Campos and Dardenne, 1997b).

The Três Barras Formation presents the largest lithological diversity and the largest volume of rocks, and was deposited by a sequence of fluvial-deltaic and eolic fluvial systems, composed of heterogeneous sandstones (Campos and Dardenne, 1997b; Campos and do Carmo, 2005). This formation presents an unconformity, that separates the sedimentary succession into a lower stratigraphic unit, representing a wet eolian system, and an upper stratigraphic unit, representing a dry eolian system (Mescolotti et al., 2019). This unconformity is proposed by Mescolotti et al. (2019) as Cenomanian to Coniacian, because the lower stratigraphic unit interdigitates with the upper portion of the Quiricó Formation, and the upper stratigraphic unit is overlaid by the Mata da Corda Group.

The Três Barras Formation has a thickness of tens of meters, reaching up to 150 m in the southern portion of the basin. Towards the north, it becomes thinner. Two members make up this Formation: Chitinos Member, product of deposition in a fluvio-deltaic environment and meandering fluvial environment, composed of sigmoidal fine sandstone facies, tabular fine sandstones and medium

conglomeratic sandstones that constitute floodplains; Olegário Member, composed of eolian sandstones, and predominant both in area of occurrence and volume. The Olegário Member is subdivided into two environments, an environment produced by aeolian dunes, and one by interdunes (Sgarbi et al., 2001). It is important to point out that Mescolotti et al. (2019) do not attribute the wet eolian system and the dry eolian system to members Chitinos and Olegário, therefore, this lithostratigraphic attribution remains uncertain.

In tectonic terms, the Areado Group is inserted in the context of the Barremian-Aptian tectonic stage, which coincides with the opening of the South Atlantic in its extensional phase, which corresponds to the first record of mechanical subsidence of the basin, enabling the sedimentation of the Areado Group (Campos and Dardenne, 1997a). The sedimentary evolution of the Areado Group, therefore, took place during the crustal subsidence, where initially there was filling by conglomerates and sandstones from the Abaeté Formation, deposited in alluvial and fluvial fan systems; followed by the evolution of a fluvio-lacustrine system in the central portion of the basin, enabling the sedimentation of the Quiricó Formation; the lower portion of the Três Barras Formation characterizes a fluvio-deltaic system sedimentation; and finally, a desert system predominated in the region, responsible for the formation of eolian dunes and interdunes of the upper portion of the Três Barras Formation, at the end of the Early Cretaceous (Fragoso et al., 2011).

3. MATERIAL AND METHODS

The present thesis encompasses the results from Leite (2017), Leite et al. (2018), Leite and Do Carmo (2021) and unpublished results. Fieldwork trips were conducted and five sections were described; 293 samples were collected and analyzed (Tab. 1).

Table 1. Number of samples collected in each section studied by the present thesis. A total of 293 samples were studied.

Stratotype section of the Quiricó Formation	Hypostratotype section of the Tereza Farm	São Bento Farm section	Sono river section	São José Farm section
154 samples	53 samples	69 samples	14 samples	3 samples

For each stratigraphic section distinct approaches were conducted, and some were already published: two articles (Leite et al., 2018; Leite and Do Carmo, 2021) and one Master of Science

dissertation (Leite, 2017). Leite (2017) and Leite et al. (2018) approached the upper portion of the stratotype section of the Quiricó Formation, the Tereza Farm section and the São José Farm section, describing the outcrops and conducting the taxonomy of limnic ostracods. Leite and Do Carmo (2021) described the full stratotype section and proposed the Tereza Farm section as a hypostratotype section; both sections are also described herein.

As for unpublished data, the present thesis describes in detail other sections for the first time, which are the São Bento Farm section, the Sono river section and the São José Farm section. The present thesis presents for the first time the detailed taxonomy of the lower stratotype section, the São Bento Farm section and the Sono river section, and also presents the summary of ostracod taxonomy for the upper stratotype section, the hypostratotype section of the Tereza Farm and the São José Farm section. Finally, it is presented herein the first biostratigraphic zonation based on ostracods for the Quiricó Formation, as well as paleozoogeographic and paleoenvironment approach.

The study of the São Francisco basin, with the goal of describing the stratotype section and hypostratotype section, as well as other sections of the Quiricó Formation, began with Leite (2017). Fieldwork trips were carried out between 2015 and 2019, and allowed the identification of the main outcrops of the Quiricó Formation (Fig. 1). The stratotype section of the Quiricó Formation was initially studied under the ostracod taxonomic perspective by Leite (2017) and Leite et al. (2018). This section, however, was initially identified as the “São José Farm section by the banks of the São José creek”. Posteriorly, it was concluded that the sedimentary succession of the Quiricó Formation, begins on the banks of the Quiricó creek, where the inferior contact with the Abaeté Formation is, and continues to the banks of the São José creek, thus constituting the stratotype section of the Quiricó Formation.

Lithostratigraphic columns were prepared for each studied section, presenting fossiliferous intervals and detailed sampling, as well as the layers where ostracods were recovered. The classification of lithofacies based on their primary depositional attributed follows Miall (1996), regarding bedding, grain size, texture and sedimentary structures, as well as biogenic structures and fossils.

Leite et al. (2018) detailed the ostracod taxonomy of the upper portion of the stratotype section, then, of the Tereza Farm section and of the São José Farm section. The present thesis approaches the ostracod taxonomy of the lower portion of the stratotype section of the Quiricó Formation, of the São Bento Farm section and of the Sono river section. From the integration of ostracod taxonomy from Leite et al. (2018) with data from the present thesis, the first biozonation for the Quiricó Formation is

proposed herein. The biostratigraphic methodology follows the International Stratigraphic Guide (Murphy and Salvador, 1999). Biozones were coded as OSF (ostracod São Francisco).

3.1. Curatorship and laboratory methodology

The collected samples, were identified with the GPS number and stratigraphic level, properly stored and housed on the Micropaleontology Laboratory, Micropaleontological Collection of the Geosciences Museum (Institute of Geosciences, University of Brasília), under the prefix MP. The recovered ostracods selected for the identification of species were illustrated under SEM and are part of the Research Collection of the Geosciences Museum (Institute of Geosciences, University of Brasília), housed in the Micropaleontology Laboratory, under the prefix CP.

Sample preparation followed the standard methodology for the recovery of mineralized microfossils in sedimentary rocks. The material was first manually fragmented in small parts, to obtain 60 g; then further with the help of hydrogen peroxide (H₂O₂), which reacts with the organic matter. Then the material was washed through a descending sequence of sieves of 600, 250, 150, 90 and 53 µm, and the material smaller than 53 µm was stored, as described by Do Carmo et al. (2011) and Denezine et al. (2022, preprint). The material from each sieve was oven dried and picked under stereomicroscope.

4. STUDIED SECTIONS

Five sections are described herein: 1. Stratotype section of the Quiricó Formation, Presidente Olegário County; 2. Hypostratotype section of the Tereza Farm, João Pinheiro County; 3. São Bento Farm section, Carmo do Paranaíba; 4. Sono river section, João Pinheiro County; 5. São José Farm section, Presidente Olegário County. The formal description of the stratotype section of the Quiricó Formation, as well as the description and proposal of the hypostratotype section of the Tereza Farm proposed herein are published in the article entitled “DESCRIPTION OF THE STRATOTYPE SECTION AND PROPOSAL OF HYPOSTRATOTYPE SECTION OF THE LOWER CRETACEOUS QUIRICÓ FORMATION, SÃO FRANCISCO BASIN, BRAZIL” (Leite and Do Carmo, 2021).

The designation of the Tereza Farm section as a hypostratotype section complements the lithostratigraphic and chronostratigraphic definition of the stratotype section, due to abundant fossiliferous occurrences and complete sedimentary sequence of the Areado Group. The three other

sections studied, mentioned previously, are not designated as hypostratotype sections as they are less complete when compared to the Tereza Farm section.

4.1. Stratotype section of the Quiricó Formation, Presidente Olegário County

The stratotype section of the Quiricó Formation begins in the banks of the Quiricó creek, where the base of the section is, and after approximately 5 km extends to the banks of the São José creek, where the top of the section is, Presidente Olegário County, Minas Gerais State, Brazil (Figs 1, 2). The coordinates of the section (UTM), Datum WGS84, are: for the base of the section, 23K, 38225.00 mE, 7972508.00 mN; for the top of the section, 23K, 387776.00 mE, 7968917.00 mN. A total of 154 samples were collected in this section (Fig. 4).

The three formations of the Areado Group – Abaeté, Quiricó and Três Barras –, as well as the Santa Fé Group outcrop in this locality (Figs 5, 6) (Leite and Do Carmo, 2021). In the banks of the Quiricó creek, the Quiricó Formation rests conformably over the Abaeté Formation, 5 m thick, composed by conglomerates (massive gravel, matrix-supported facies = Gmm; deposited in braided river system with high energy) and sandstone with limestone nodules (sand, fine to medium, with nodules facies = Sfn; deposited in braided river system with low energy) (Fig. 5: A). In turn, the Abaeté Formation is in erosional contact with the Santa Fé Group, approximately 4 m thick, composed by fine red sandstone, friable (sand, fine facies = Sf; deposited by glacial braided river system). In the banks of the São José creek, the Quiricó Formation, about 63 m thick, is in conformable contact with the Três Barras Formation, at least 30 m thick, composed by layers of fine/medium red sandstone, with thin layers of chert, up to 1 cm thick (Sand, fine to medium, with layers of chert facies = Smf; deposited in eolian system) (Leite and Do Carmo, 2021).

The Quiricó Formation's base is composed by layers of fine red sandstone with carbonate cement, intercalated with thin layers of limestone (Sand, fine, intercalated with layers of limestone facies = Sfi; deposited in lacustrine system, proximal) (Fig. 5: B, C), followed by a thick package of red-yellow sandstone with carbonate cement, with claystone lenses (Fig. 5: D), intercalated with layers of evaporite with desert roses (Sand, fine, with claystone lenses, intercalated with evaporite facies = Sfe; deposited in lacustrine system, proximal, with high salinity), and ostracod occurrence (Fig. 5: E) (Leite and Do Carmo, 2021).

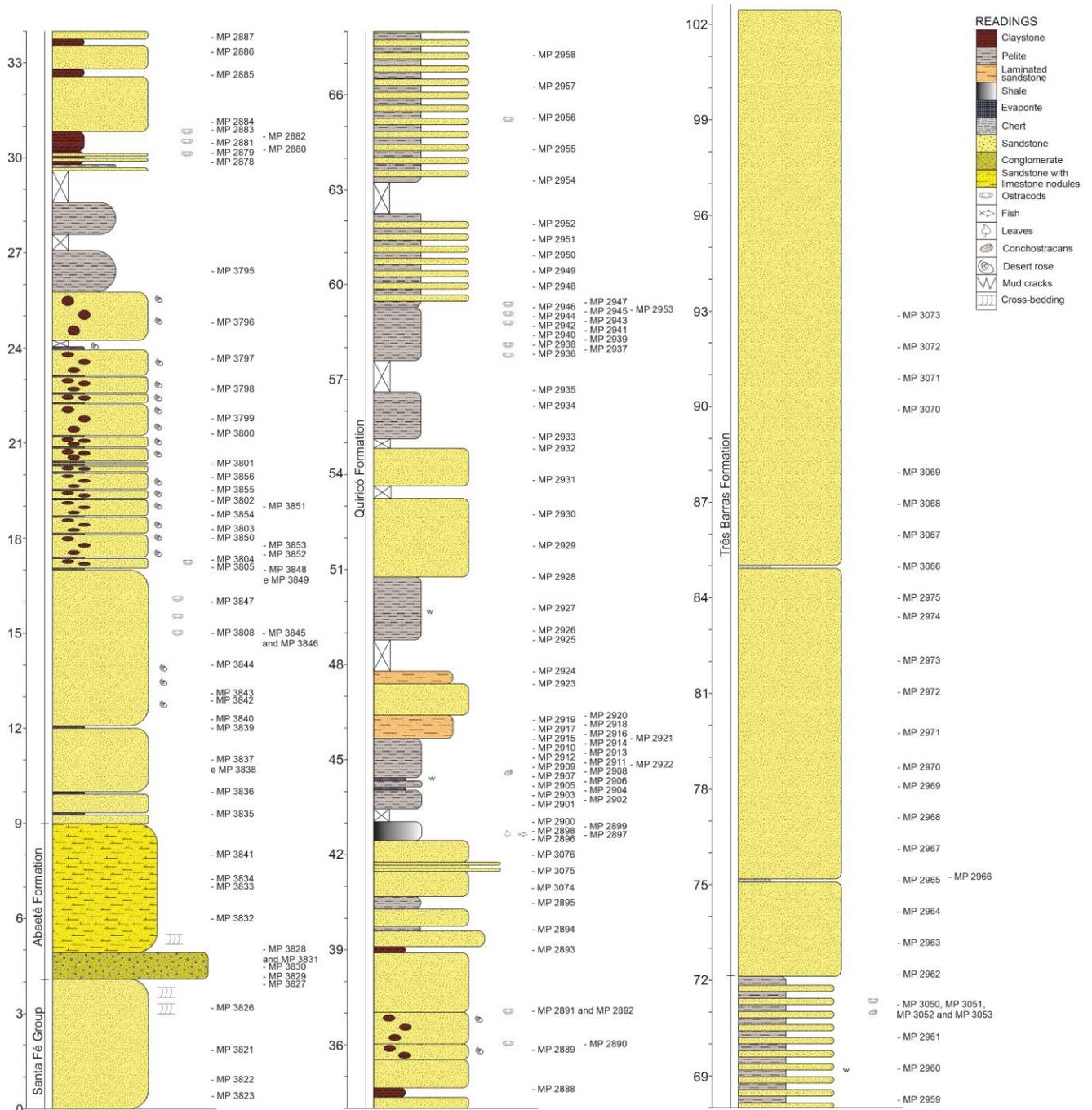


Figure 4. Collected samples (MP) from the stratotype section of the Quiricó Formation, Presidente Olegário County, Minas Gerais State, Brazil (adapted from Leite, 2017).

The upper package is composed by layers of pelite (Silt, mud facies = Fsm; deposited in lacustrine system, distal), followed by layers of fine red sandstone with carbonate cement, with some presence of claystone lenses, intercalated with claystone layers (Sand, fine, intercalated with claystone layers facies = Sfm; deposited in lacustrine system, proximal, with high salinity), with ostracod occurrence. Overlaid by a thick layer of black shale, rich in organic matter (Shale, rich in organic matter facies = Fso; deposited in lacustrine system, distal) (Leite and Do Carmo, 2021).

The following package is composed by layers of green laminated pelite with claystone lenses, intercalated with thin layers of evaporite (Silt, mud, with claystone lenses, intercalated with evaporite facies = Fce; deposited in lacustrine system, with periods of dryness and subaerial exposure), and mud cracks (Fig. 6: F). Followed by layers of finely laminated sandstone with clay blades (Sand, fine, laminated facies = Sfl; deposited in lacustrine system, proximal, with low energy), intercalated with fine red sandstone with carbonate cement (Sand, fine, with carbonate cement facies = Sfc; deposited in lacustrine system, proximal). The following package consists of a rhythmite, composed by layers of sandstone and layers of pelite (Sand, silt, mud facies = Sfr; deposited in lacustrine system, variant energy, with periods of dryness and subaerial exposure), with mud cracks, ostracod and conchostacans in the top portion (Fig. 6: G) (Leite and Do Carmo, 2021).

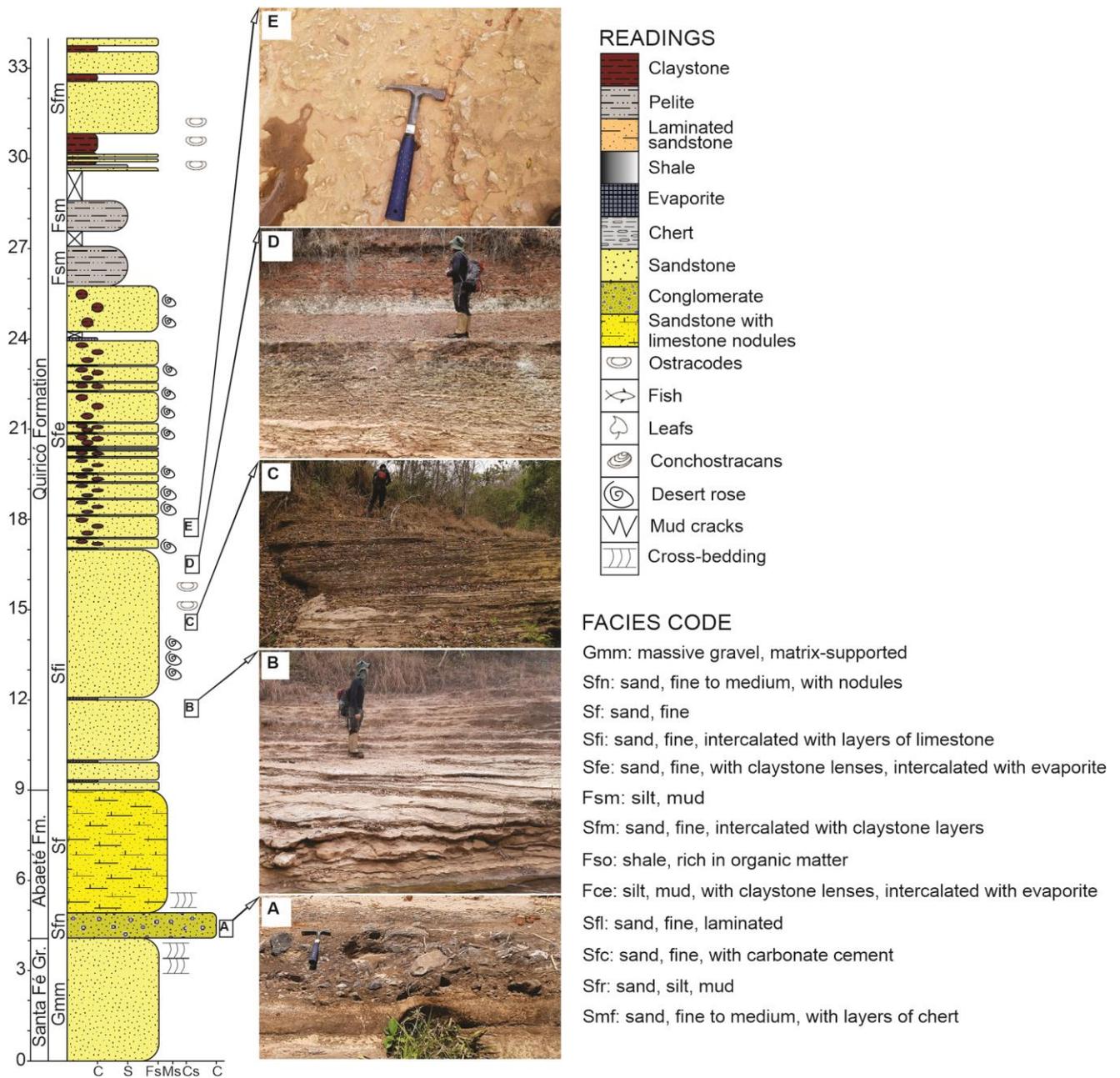


Figure 5. Lithostratigraphy of the Areado Group in the stratotype section of the Quiricó Formation, Presidente Olegário County, Minas Gerais State, Brazil. First part of the section, from 0 m to 34 m. A) conglomerate of the Abaeté Formation. B) layers of fine sandstone intercalated with thin layers of calcite. C) layers of fine sandstone intercalated with thin layers of calcite. D) layers of fine sandstone with claystone lenses. E) surface with desert roses (Leite and Do Carmo, 2021).

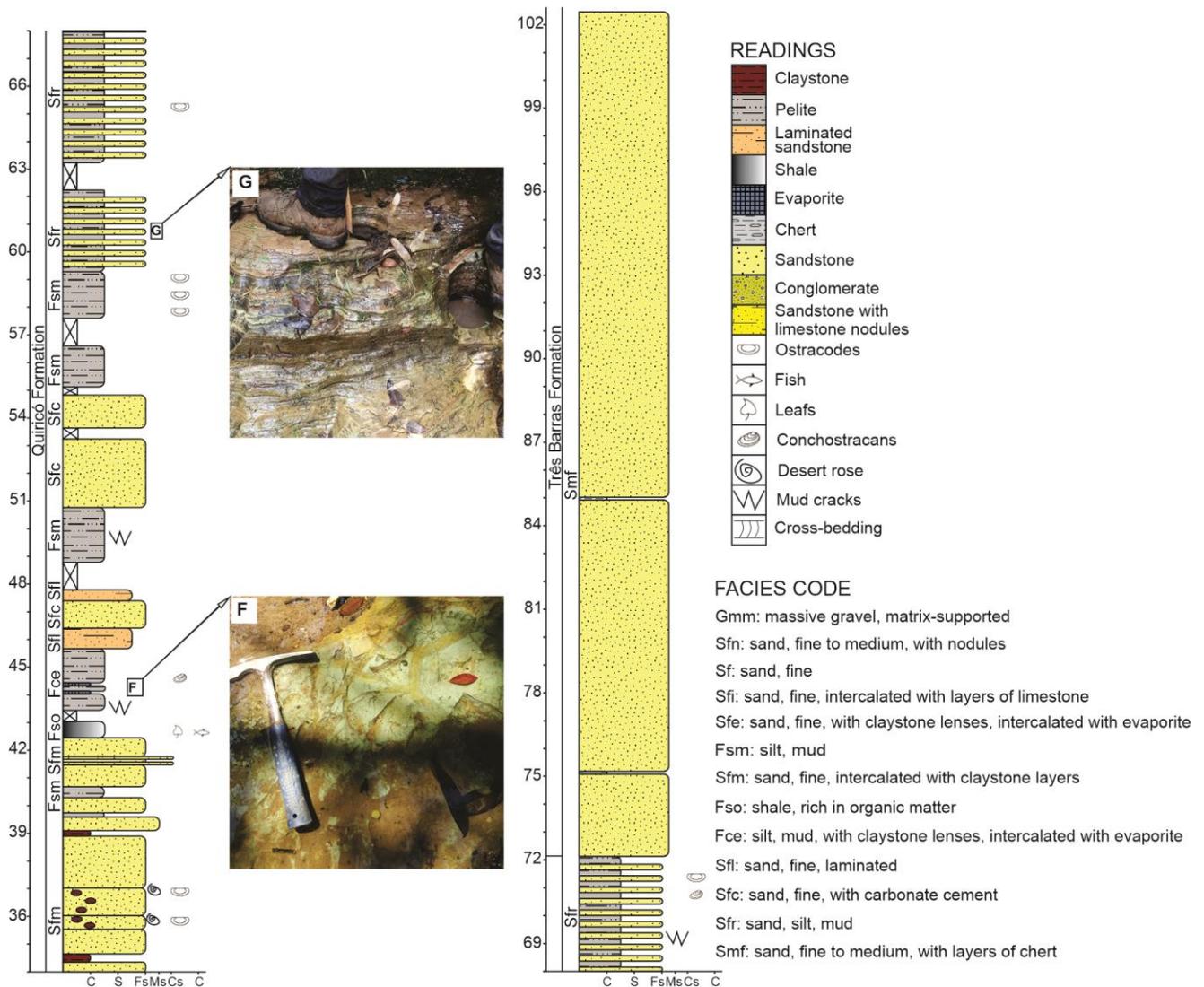


Figure 6. Lithostratigraphy of the Areado Group in the stratotype of the Quiricó Formation, Presidente Olegário County, Minas Gerais State, Brazil. Second part of the section, from 34 m to 102 m. F) layer with mud cracks. G) rhythmite package (Leite and Do Carmo, 2021).

4.2. Hypostratotype section of the Tereza Farm, João Pinheiro

The hypostratotype section of the Tereza Farm is located near Santa Luzia da Serra community, João Pinheiro County, Minas Gerais State, southeastern Brazil (Fig. 1). The coordinates of the section (UTM), Datum WGS84, are: 23K, 403859.00 mE, 8050999.00 mN. A total of 53 samples were collected in this section (Fig. 7).

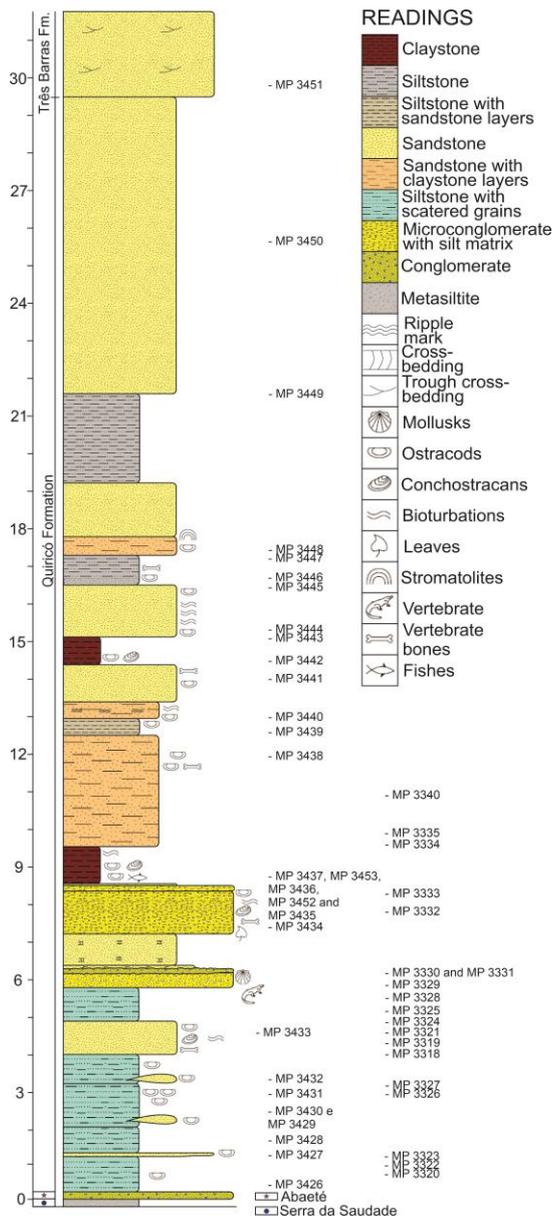


Figure 7. Collected samples (MP) from the hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, Brazil (Adapted from Leite, 2017).

The three formations of the Areado Group – Abaeté, Quiricó and Três Barras –, as well as the Serra da Saudade Formation, Bambuí Group, outcrop in this locality (Fig. 8) (Leite and Do Carmo, 2021). The Quiricó Formation rests conformably over the Abaeté Formation, a few centimeters thick, composed by matrix-supported conglomerates (gravel, matrix-supported facies = Gm; deposited by braided river system, high energy), which in turn is in erosional contact (disconformity) with the Serra da Saudade Formation, thickness undefined, composed by grey micaceous metasiltite. In the upper portion of the section, the Quiricó Formation, about 29 m thick, is in conformable contact with the

Três Barras Formation, thickness undefined, composed by coarse/very coarse kaolinitic sandstone, with trough cross-bedding, in which the grains are angular and poorly selected (Sand, coarse/very coarse, with trough cross-bedding facies = Scb; deposited by eolian system, migration of dunes) (Fig. 8: D) (Leite and Do Carmo, 2021).

The Quiricó Formation's base is composed by a package of red-brown siltstones with grains of medium sand scattered on the matrix and lenses of fine sandstone, intercalated with a thin layer of poorly selected very fine/coarse sandstone (Silt, with scattered sand grains and lenses of fine sandstone, intercalated with sand layers facies = Fgs; deposited in lacustrine system, variant energy), with ostracod occurrence. Followed by a layer of fine red sandstone with carbonate cement, with milimetric layers of grey sandstone (Sand, fine, with carbonate cement and fossils facies = Sff; deposited in lacustrine system, proximal), with conchostracans, ostracods, vertebrate bones and bioturbation. Overlaid by a layer of siltstone with carbonate cement, with scattered grains of sand (Silt, with scattered sand grains and carbonate cement facies = Fgc; deposited in lacustrine system, distal) (Leite and Do Carmo, 2021).

The next layer consists of red poorly selected very fine/coarse sandstone (Sand, very fine/coarse facies = Svc; deposited by aqueous flow generated by fluvial influence in lacustrine system), with vertebrate bones and mollusks, in erosive contact with a gray conglomerate (Gravel, matrix supported facies = Gmg; deposited by high energy aqueous flow generated by fluvial influence in lacustrine system). Followed by a layer of compact sandstone with trough cross-bedding (Sand, medium, with trough cross-bedding facies = Smt; deposited by unidirectional aqueous flow generated by fluvial influence in lacustrine system) overlaid by a layer of fine sandstone with cross-bedding (Sand, fine, with cross-bedding facies = Sfb; deposited by oscillatory aqueous flow generated by fluvial influence in lacustrine system) (Fig. 8: A) (Leite and Do Carmo, 2021).

The following package is composed of poorly selected very fine/coarse sandstone with carbonate cement (Sand, very fine/coarse, with carbonate cement facies = Spc; deposited by aqueous flow generated by fluvial influence in lacustrine system), with clay grains, vertebrate bones, leaves, bioturbations and ostracods, overlaid by microconglomerate with carbonate cement, with matrix of silt size and pebbles (Thin layer, gravel, with silt matrix facies = Gts; deposited by high energy aqueous flow generated by fluvial influence in lacustrine system), and a thin layer of fine gray fossiliferous sandstone with carbonate cement (Sand, fine, with carbonate cement and fossiliferous facies = Sff; deposited in lacustrine system, proximal) (Leite and Do Carmo, 2021).

The next layer consists of red claystone (Mud, fossiliferous facies = Fm; deposited in lacustrine system, distal), with conchostracans, ostracods, bioturbations and impressions of fish scales occurrences. Followed by a layer of finely laminated sandstone with carbonate cement, with millimetric layers of claystone (Sand, with layers of claystone facies = Scc; deposited in lacustrine system, proximal), the top of which consists of very thin layers of very fine sandstone, with ostracods and vertebrate bones. Overlaid by a layer of finely laminated siltstone, with millimetric to centimetric layers of fine sandstone (Silt, with layers of fine sandstone facies = Fs; deposited in lacustrine system, proximal to distal) ostracod occurrence and a layer of laminated sandstone with carbonate cement, with ripple marks (Sand, fine, laminated, with ripple marks facies = Slr; deposited in lacustrine system, proximal, under oscillatory flow) (Fig. 7: B) (Leite and Do Carmo, 2021).

The following package is composed of fine yellow sandstone with carbonate cement (Sand, fine, fossiliferous facies = Scf; deposited in lacustrine system, proximal), with vertebrate bones and ostracods, followed by a layer of red claystone with carbonate cement (Mud, fossiliferous facies = Fm; deposited in lacustrine system, distal), rich in ostracods and bioturbations and a layer of fine red sandstone with carbonate cement, with centimetric calcite-filled bioturbations (Sand, fine, with bioturbations facies = Sft; deposited in lacustrine system, proximal) (Fig. 7: C). Overlaid by a layer of compact yellow siltstone with carbonate cement, with sand grains scattered in the base (Silt, with scattered sand grains = Fsg; deposited in lacustrine system, distal), and ostracod occurrence, and a layer of fine laminated sandstone, with thin claystone layers (Sand, with claystone layers facies = Scc; deposited in lacustrine system, proximal), the top of which is marked by the occurrence of stromatolites.

The next layer consists of fine compact sandstone (Sand, fine, compact facies = Sfo; deposited in lacustrine system, proximal), followed by a layer of siltstone with sand grains scattered (Silt, with scattered sand grains = Fsg; deposited in lacustrine system, distal), and a thin layer of laminated sandstone with grains of coarse sand (Sand, with scattered grains of coarse sand facies = Scs; deposited in lacustrine system, proximal).

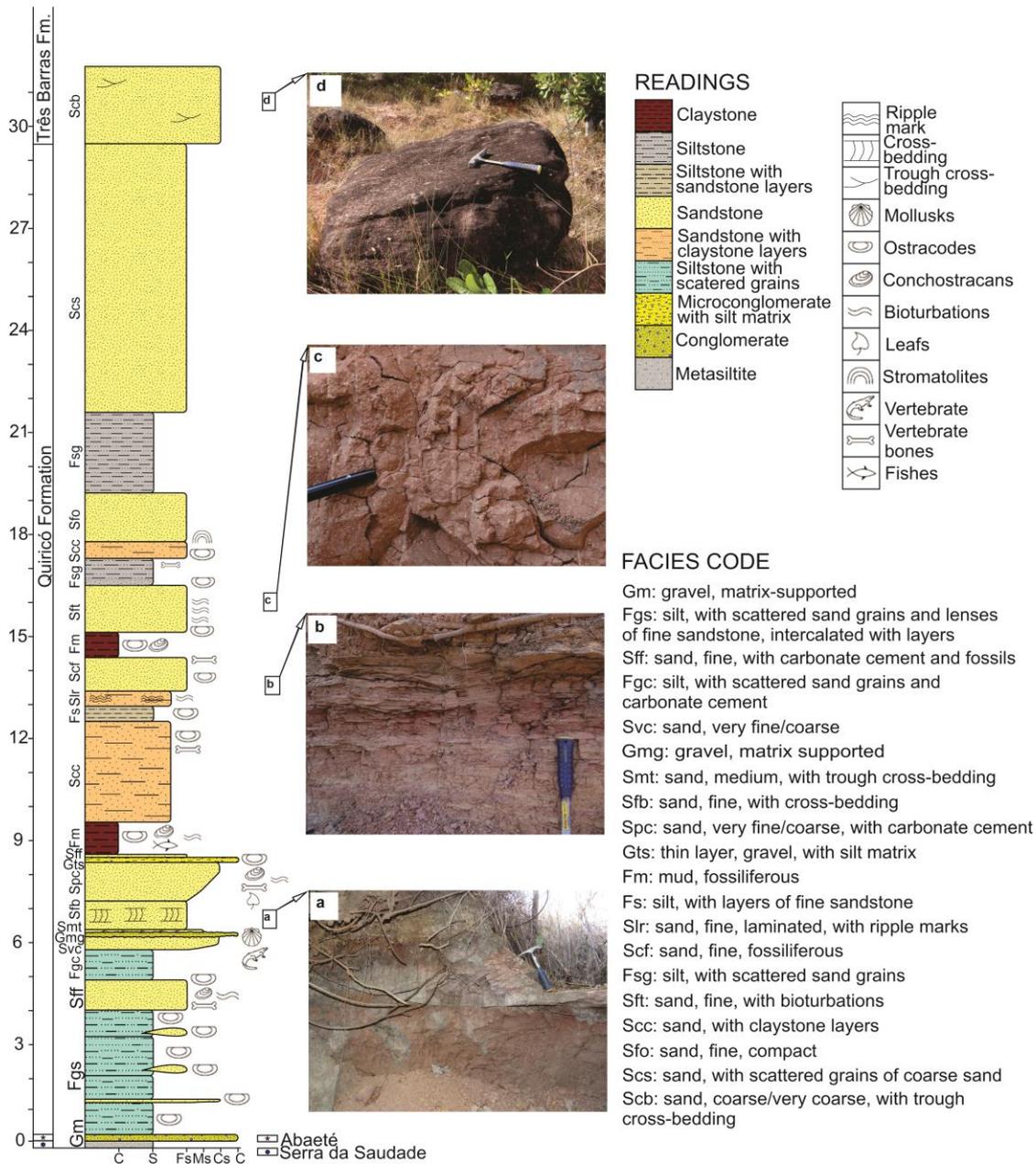


Figure 8. Lithostratigraphy of the Areado Group in the hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, Brazil. A) microconglomerate overlaid by sandstone. B) very fine sandstone intercalated with laminated siltstone. C) bioturbation. D) sandstone with cross-bedding (Leite and Do Carmo, 2021).

4.3. São Bento Farm Section, Carmo do Paranaíba

The São Bento Farm section is located near the São Bento creek, Carmo do Paranaíba County, Minas Gerais State, southeastern Brazil (Fig. 1). The coordinates of the section (UTM), Datum WGS84, are: 23K, 368571.00mE, 7908266.00mN. A total of 69 samples were collected in this section (Fig. 9).

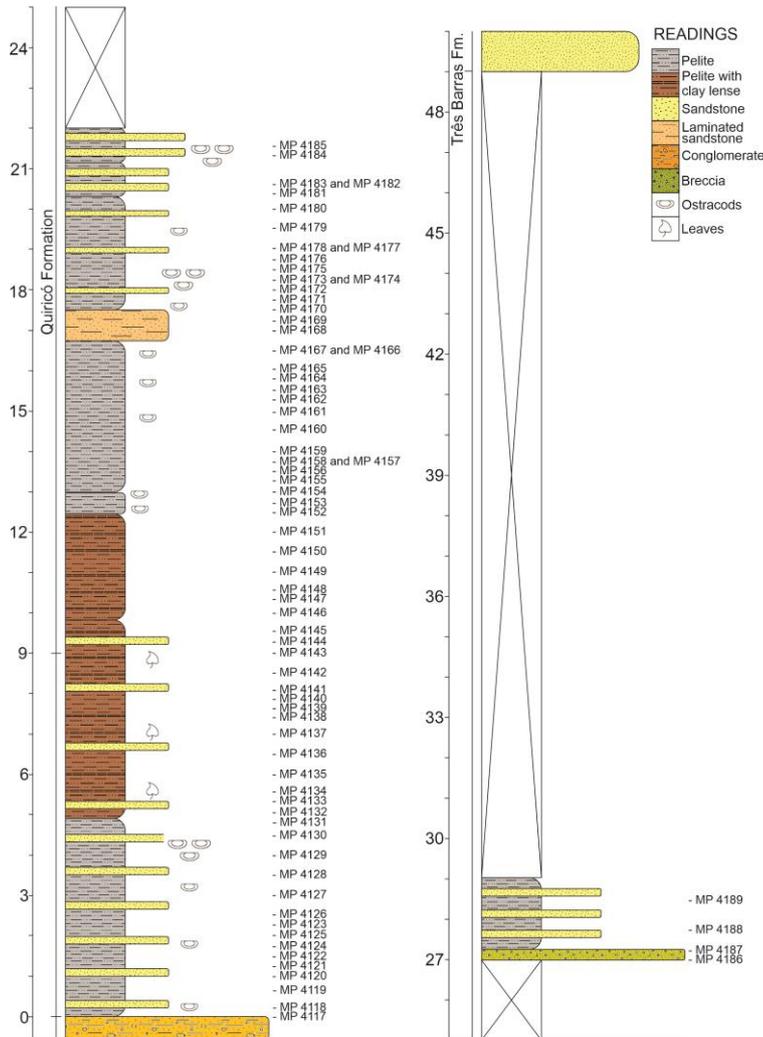


Figure 9. Collected samples (MP) from the São Bento Farm section, Carmo do Paranaíba County, Minas Gerais State, Brazil.

The Quiricó and Três Barras formations, from the Areado Group, as well as the Jequitaiá Formation, outcrop in this locality (Fig. 10). The Quiricó Formation is in erosional contact (disconformity) with the Jequitaiá Formation, thickness undefined, composed of conglomerates, with fine schist matrix, in which the grains are coble size. In the upper portion of the outcrop, the contact between the Quiricó Formation – thickness undefined due to covered portions – and the Três Barras formation is covered. The Três Barras Formation, thickness undefined, is composed by coarse sandstone (Sand, coarse facies = Sc; deposited by eolian system).

The Quiricó Formation's base is composed by layers of micaceous red pelite, intercalated with thin milimetric to centimetric layers of white micaceous sandstone with carbonate cement (Silt, mud,

intercalated with sand, very fine = Fss; deposited in lacustrine system, distal, with variant energy), with ostracod occurrence. Followed by layers of purple pelite with carbonate cement, with claystone lenses, rich in organic matter, with leaf occurrences, intercalated with millimetric layers of sandstone with carbonate cement (Silt, mud, with claystone lenses, intercalated with sand, very fine facies = Fcs; deposited in lacustrine system, distal, with variant energy), followed by layers of purple pelite with carbonate cement, with claystone lenses, rich in organic matter (Silt, mud, with claystone lenses and organic matter facies = Fco; deposited in lacustrine system, distal) (Fig. 10: A, B, C).

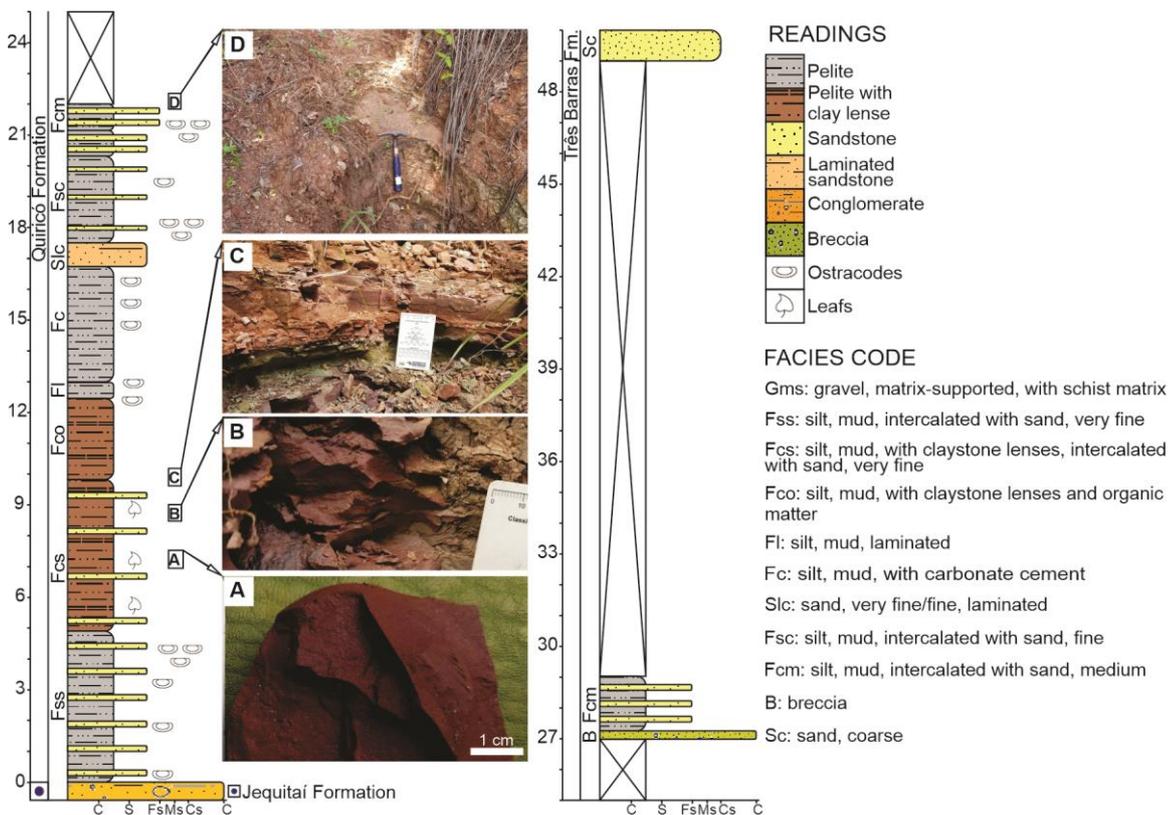


Figure 10. Lithostratigraphy of the Areado Group in the São Bento Farm section, Carmo do Paranaíba County, Minas Gerais State, Brazil. A) pelite layer with leaf occurrence. B) pelite layer rich in organic matter. C) pelite layer with claystones lenses, intercalated with layers of fine sandstone. D) pelite layer intercalated with thin layers of fine sandstone.

The following layers consists of laminated micaceous pelite (Silt, mud, laminated facies = Fl; deposited in lacustrine system, distal), with ostracod occurrence, overlaid by a thick layer of pelite with carbonate cement, with ostracod occurrence (Silt, mud, with carbonate cement facies = Fc; deposited in lacustrine system, distal). Followed by a centrimetric layer of laminated very fine/fine white sandstone with carbonate cement (Sand, very fine/fine, laminated, with carbonate cement facies = Slc; deposited in lacustrine system, distal to proximal).

The overlying package of the Quiricó Formation consists of layers of red micaceous pelite with carbonate cement, intercalated with thin layers of fine sandstone with carbonate cement (Silt, mud, intercalated with sand, fine facies = Fsc; deposited in lacustrine system, variant energy) (Fig.10: D), and layers of red micaceous pelite with carbonate cement, intercalated with thin layers of medium sandstone with carbonate cement (Silt, mud, intercalated with sand, medium facies = Fcm; deposited in lacustrine system, variant energy), with the occurrence of a plurimillimetric layer of breccia with pelitic matrix, and grains of coarse sand size (Breccia facies = B; deposited by debris flow in lacustrine system).

4.4. Sono river section, João Pinheiro

The Sono river section is located near the bridge over the Sono river, on the road BR-040, João Pinheiro County, Minas Gerais State, southeastern Brazil (Fig. 1). The coordinates of the section (UTM), Datum WGS84, are: 23K, 396080.00mE, 8012948.00mN. A total of 14 samples were collected in this section (Fig. 11).

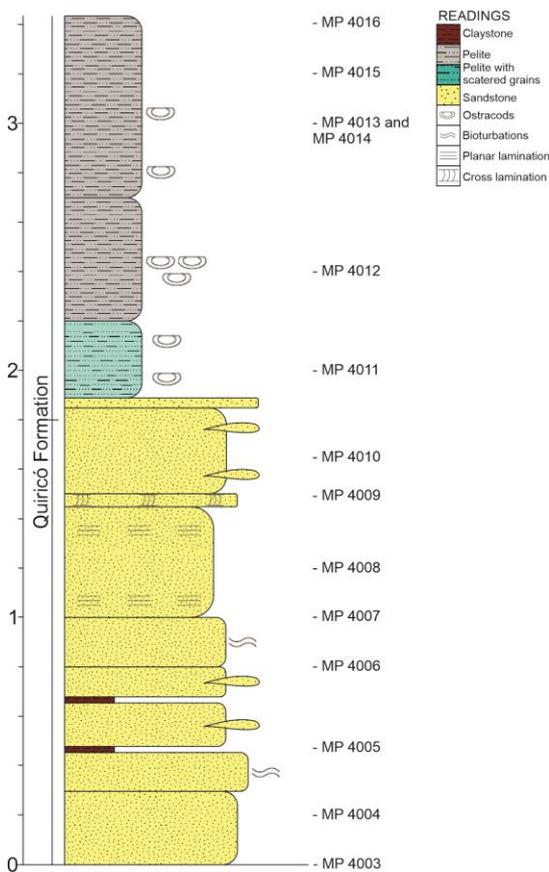


Figure 11. Collected samples (MP) from the Sono river section, João Pinheiro County, Minas Gerais State, Brazil.

Only the Quiricó Formation is exposed in this section (Fig. 12). Quiricó Formation's base is composed by a layer of fine red sandstone (Sand, fine facies = Sfi; deposited in lacustrine system, proximal), followed by a layer of medium/coarse red-pinkish sandstone (Sand, medium/coarse, with bioturbations facies = Scb; deposited in lacustrine system, proximal), with lenses of white sandstone, and occurrence of bioturbations (Fig. 12: A). The following package consists of layers of fine/medium red sandstone with carbonate cement, with lenses of coarse white sandstone, intercalated with thin layers of claystone (Sand, fine/medium, with lenses and intercalated with claystone layers = Sll; deposited in lacustrine system, proximal with variant energy). Overlaid by a layer of fine/medium sandstone, with bioturbation occurrence (Sand, fine/medium, with bioturbations facies = Smb; deposited in lacustrine system, proximal).

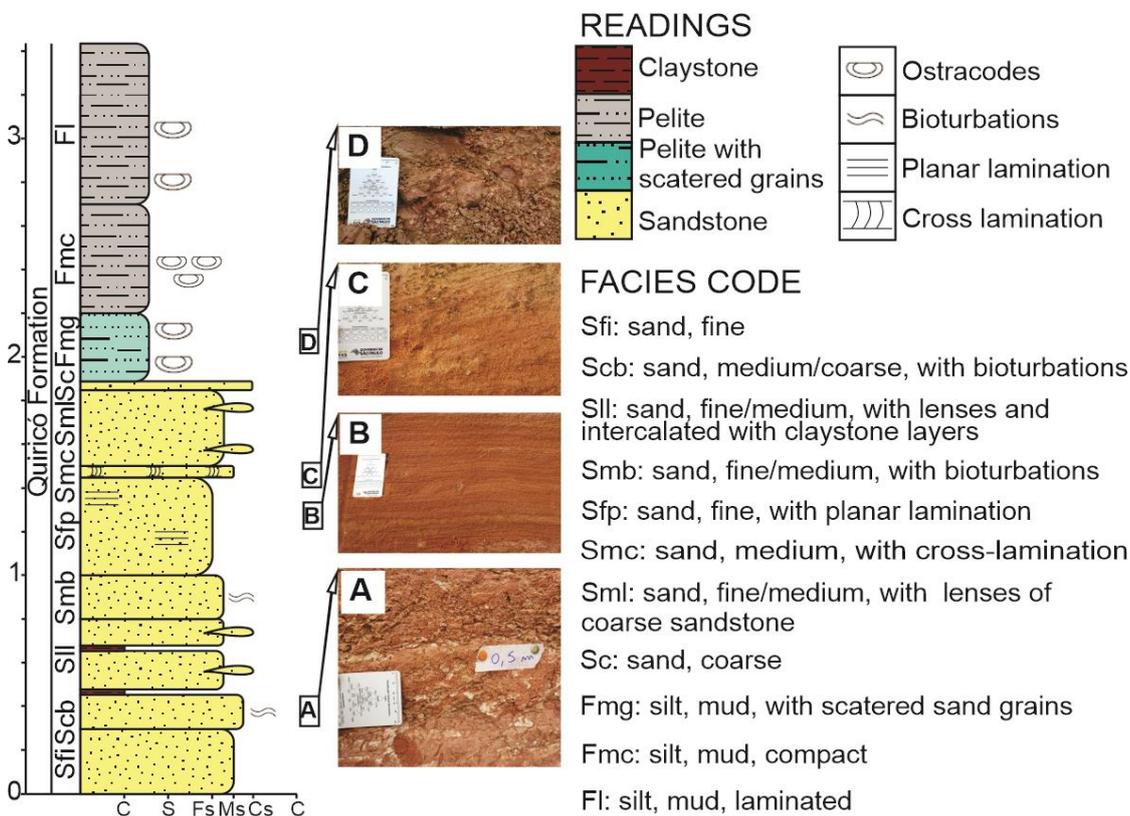


Figure 12. Lithostratigraphy of the Quiricó Formation in the Sono river section, João Pinheiro County, Minas Gerais State, Brazil. A) sandstone layer with bioturbation. B) fine sandstone layer with planar lamination. C) fine sandstone layer with cross lamination. D) pelite layer with scattered grains.

The following layers is composed of fine red sandstone with carbonate cement, with planar lamination (Sand, fine, with planar lamination facies = Sfp; deposited by unidirectional flow in lacustrine system, proximal) (Fig. 12: B). Followed by a layer of medium red sandstone, with cross-

lamination (Sand, medium, with cross-lamination facies = Smc; deposited by oscillatory flow in lacustrine system, proximal) (Fig. 12: C). Overlaid by a layer of fine/medium red sandstone with carbonate cement, with lenses of coarse white sandstone (Sand, fine/medium, with lenses of coarse sandstone facies = Sml; deposited in lacustrine system, proximal), in which the top is marked by a centimetric thin layer of coarse white sandstone (Sand, coarse facies = Sc; deposited in lacustrine system, proximal).

The following package consists of a layer of compact red pelite with carbonate cement, with scattered sand grains and ostracod occurrence (Silt, mud, with scattered sand grains facies = Fmg; deposited in lacustrine system, distal) (Fig. 12: D), followed by a layer of yellow compact pelite (Silt, mud, compact facies = Fmc; deposited in lacustrine system, distal), rich in ostracods, in which the top consists of yellow laminated pelite (Silt, mud, laminated facies = Fl; deposited in lacustrine system, distal), with ostracod occurrence.

4.5. São José Farm section, Presidente Olegário

The São José Farm section is located in an intermittent drainage of the Quiricó creek, Presidente Olegário County, Minas Gerais State, southeastern Brazil (Fig. 1). The coordinates of the section (UTM), Datum WGS84, are: 23K, 387673.00mE, 7968100.00mN. A total of three samples were collected in this section (Fig. 13).

Only the Quiricó Formation is exposed in this section (Fig. 14). The Quiricó Formations' base is composed by very fine/fine red sandstones with carbonate cement (Sand, very fine/fine facies = Svf; deposited in lacustrine system, proximal), followed by a layer of fine/medium brown sandstone with carbonate cement, with lenses of green claystone (Sand, fine/medium, with lenses facies = Scl; deposited in lacustrine system, proximal, with variant energy), in which the top is marked by a layer of medium white sandstone with carbonate cement (Sand, medium facies = Sm; deposited in lacustrine system, proximal).

The following sequence is pelitic with carbonate cement, composed by a layer of green compact pelite with ostracod occurrence, with a milimetric thin layer of white claystone (Silt, mud, compact facies = Fpc; deposited in lacustrine system, distal), followed by a layer of laminated green-red pelite, with lenses of fine sandstone and ostracod, fossil fish and leaf impressions occurrences (Silt, mud, laminated, with fossils facies = Flf; deposited in lacustrine system, distal), and finally a layer of limestone in which the top consists of a red laminated pelite, with milimetric thin layers of claystone (Limestone facies = L; deposited in lacustrine system, distal).

The top of the sequence is composed by the papyraceous black shale, rich in organic matter (Shale, papyraceous facies = Fsp; deposited in lacustrine system, distal), with the fish fossil *Dastilbe moraes* Silva Santos, 1955 in Scorza and Silva Santos, 1955 and leaf impressions (Fig. 14: A, B), followed by a layer of black shale, rich in organic matter, carbonatic (Shale, rich in organic matter facies = Fso; deposited in lacustrine system, distal).

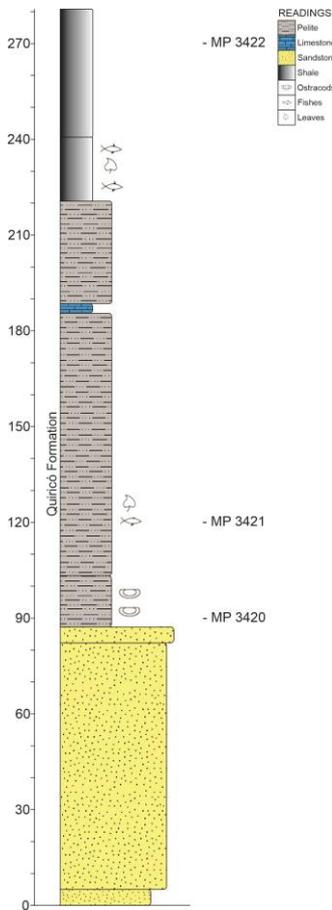


Figure 13. Collected samples (MP) from the São José Farm section, Presidente Olegário County, Minas Gerais State, Brazil (Adapted from Leite, 2017).

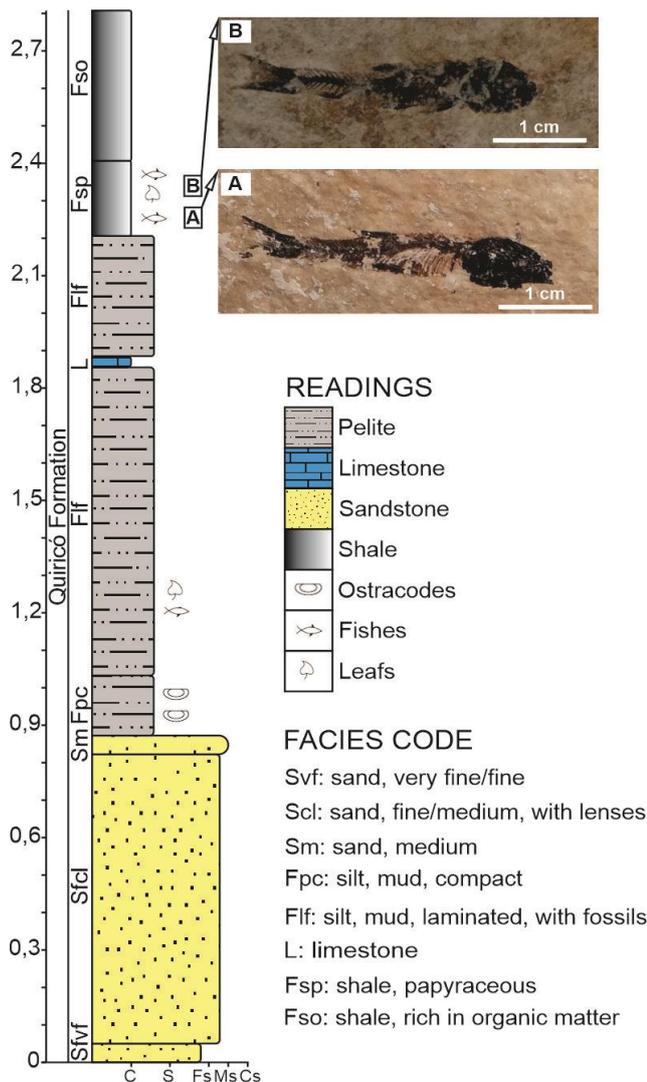


Figure 14. Lithostratigraphy of the Quiricó Formation in the São José Farm section, Presidente Olegário County, Minas Gerais State, Brazil. A and B) surface of the papyraceous shale with the fish *Dastilbe moraesii* Silva Santos, 1955 in Scorza and Silva Santos (1955).

5. OSTRACOD TAXONOMY

Twenty-one species of ostracods occur in the five studied sections of the Quiricó Formation approached in the present thesis: 1. *Harbinia* aff. *Harbinia angulata* (Krömmelbein and Weber, 1971); 2. *Harbinia symmetrica* (Krömmelbein and Weber, 1971); 3. *Harbinia* aff. *Harbinia salitrensis* (Krömmelbein and Weber, 1971); 4. *Harbinia alta* Antonietto *et al.*, 2012; 5. *Harbinia* aff. *Harbinia crepata* Do Carmo *et al.*, 2013; 6. *Brasacypris ovum* Krömmelbein, 1965b; 7. *Brasacypris* aff. *Brasacypris morigerata* Musacchio, 1973; 8. *Brasacypris fulfaroi* Dias-Brito *et al.*, 2001; 9. *Cypridea hystrix* Krömmelbein, 1962; 10. *Cypridea conjugata* Krömmelbein and Weber, 1971; 11. *Cypridea* aff. *Cypridea infima* Krömmelbein and Weber, 1971; 12. *Cypridea* aff. *Cypridea jequiensis*

Krömmelbein and Weber, 1971; 13. *Cypridea* sp.; 14. *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni, 1991; 15. *Damonella* aff. *Damonella ultima* (Krömmelbein and Weber, 1971); 16. *Penthesilenula martinsi* (Silva, 1978); 17. *Penthesilenula pinto* Leite et al., 2018; 18. *Alicenula longiformis* Leite et al., 2018; 19. *Timiriasevia sanfranciscanensis* Leite et al., 2018; 20. *Wolburgiopsis plastica* (Musacchio, 1970); 21. *Wolburgiopsis chinamuertensis* (Musacchio, 1970).

The ostracod taxonomy of the lower portion of the stratotype section of the Quiricó Formation, of the hypostratotype section of the Tereza Farm and of the São José Farm section is presented in the article entitled “TAXONOMY OF LIMNIC OSTRACODA (CRUSTACEA) FROM THE QUIRICÓ FORMATION, LOWER CRETACEOUS, SÃO FRANCISCO BASIN, MINAS GERAIS STATE, SOUTHEAST BRAZIL” (Leite et al., 2018). Of the 21 species, 16 were registered in Leite et al. (2018), and their taxonomy is presented in order to depict the species recovered from the five studied sections by the present thesis. As for the other five species of the total, two species were also recovered from the São Bento Farm section by Do Carmo et al. (2004a) and other three species were recovered from the Quiricó Formation, with their occurrences reported for the first time in the present thesis (Tab. 2).

The 16 species recovered by Leite et al. (2018), from the upper portion of the stratotype section of the Quiricó Formation, from the hypostratotype section of the Tereza Farm and from the São José Farm section are: 1. *Harbinia* aff. *Harbinia angulata*; 2. *Harbinia symmetrica*; 3. *Harbinia* aff. *Harbinia salitrensis*; 4. *Harbinia alta*; 5. *Harbinia* aff. *Harbinia crepata*; 6. *Brasacypris ovum*; 7. *Brasacypris fulfaroi*; 8. *Cypridea hystrix*; 9. *Cypridea conjugata*; 10. *Cypridea infima*; 11. *Cypridea jequiensis*; 12. *Neuquenocypris* (*Protoneuquenocypris*) *antiqua*; 13. *Penthesilenula martinsi*; 14. *Penthesilenula pinto*; 15. *Alicenula longiformis*; 16. *Timiriasevia sanfranciscanensis* (Tab. 2). Especially *Harbinia symmetrica*, *Harbinia* aff. *H. salitrensis*, *Cypridea hystrix*, *Cypridea conjugata*, *Cypridea infima*, *Cypridea jequiensis*, *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* and *Timiriasevia sanfranciscanensis* were not recovered in the sections restricted to the present thesis – lower stratotype section, São Bento Farm section and Sono river section – (Tab. 2).

Table 2. Species of ostracods recovered from the Quiricó Formation in the five studied sections by the present thesis, compared to Leite et al. (2018), with emphasis on the species restricted to the present thesis.

Upper stratotype section, Tereza Farm São José Farm Leite et al., 2018	Lower stratotype section, São Bento Farm, Sono river Record restricted to the present thesis	Species from the five studied sections
<i>Harbinia aff. Harbinia angulata</i>	<i>Harbinia aff. Harbinia angulata</i>	<i>Harbinia aff. Harbinia angulata</i>
<i>Harbinia symmetrica</i>		<i>Harbinia symmetrica</i>
<i>Harbinia aff. Harbinia salitrensis</i>		<i>Harbinia aff. Harbinia salitrensis</i>
<i>Harbinia alta</i>	<i>Harbinia alta</i>	<i>Harbinia alta</i>
<i>Harbinia aff. Harbinia crepata</i>	<i>Harbinia aff. Harbinia crepata</i>	<i>Harbinia aff. Harbinia crepata</i>
<i>Brasacypris ovum</i>	<i>Brasacypris ovum</i>	<i>Brasacypris ovum</i>
	<i>Brasacypris aff. Brasacypris morigerata</i>	<i>Brasacypris aff. Brasacypris morigerata</i>
<i>Brasacypris fulfaroi</i>	<i>Brasacypris fulfaroi</i>	<i>Brasacypris fulfaroi</i>
		<i>Cypridea hystrix</i>
<i>Cypridea hystrix</i>		<i>Cypridea conjugata</i>
<i>Cypridea infima</i>		<i>Cypridea aff. Cypridea infima</i>
<i>Cypridea jequiensis</i>		<i>Cypridea aff. Cypridea jequiensis</i>
		<i>Cypridea sp.</i>
<i>Neuquenocypris (Protoneuquenocypris) antiqua</i>		<i>Neuquenocypris (Protoneuquenocypris) antiqua</i>
	<i>Damonella aff. Damonella ultima</i>	<i>Damonella aff. Damonella ultima</i>
<i>Penthesilenula martinsi</i>	<i>Penthesilenula martinsi</i>	<i>Penthesilenula martinsi</i>
<i>Penthesilenula pintoii</i>	<i>Penthesilenula pintoii</i>	<i>Penthesilenula pintoii</i>
<i>Alicenula longiformis</i>	<i>Alicenula longiformis</i>	<i>Alicenula longiformis</i>
<i>Timiriasevia sanfranciscanensis</i>		<i>Timiriasevia sanfranciscanensis</i>
	<i>Wolburgiopsis plastica</i>	<i>Wolburgiopsis plastica</i>
	<i>Wolburgiopsis chinamuertensis</i>	<i>Wolburgiopsis chinamuertensis</i>

The taxonomy of recovered ostracods from the lower portion of the stratotype section of the Quiricó, São Bento Farm section and Sono river section, is presented herein, in which 12 species were recovered: 1. *Harbinia* aff. *Harbinia angulata*; 2. *Harbinia alta*; 3. *Harbinia* aff. *Harbinia crepata*; 4. *Brasacypris ovum*; 5. *Brasacypris* aff. *Brasacypris morigerata*; 6. *Brasacypris fulfaroi*; 7. *Damonella* aff. *Damonella ultima*; 8. *Penthesilenula martinsi*; 9. *Penthesilenula pinto*; 10. *Alicenula longiformis*; 11. *Wolburgiopsis plastica*; and 12. *Wolburgiopsis chinamuertensis*. Especially *Brasacypris* aff. *Brasacypris morigerata* and *Damonella* aff. *Damonella ultima* are recovered for the first time from the Quiricó Formation (Tab. 2).

The species of *Cypridea* were analyzed, with the objective of reexamining the taxonomy, after the discussion raised by Coimbra (2020). A discussion regarding each species and its taxonomic attribution is presented in the remarks. It is important to point out that one new species, *Cypridea* sp., was identified from the material illustrated by Leite et al. (2018). This matter is presented as remarks in the systematic taxonomy and will be published as a reply in the “*Revista Brasileira de Paleontologia*”.

The suprageneric taxonomy follows Martin and Davis (2001), Hou et al. (2002), Horne and Colin (2005), Liebau (2005), Carignano and Cusminsky (2015) and Carignano et al. (2017). The number of specimens is classified as: rare, from 1 to 5 specimens; frequent, from 6 to 10 specimens; and abundant, above 10 specimens.

Subclass OSTRACODA Latreille, 1802

Order PODOCOPIIDA Sars, 1866

Suborder CYPRIDOCOPINA Jones, 1901

Superfamily CYPRIDOIDEA Baird, 1845

Family QUADRACYPRIDIDAE Hou et al., 2002

Subfamily QUADRACYPRIDINAE Hou et al., 2002

Genus *Harbinia* Tsao, 1959 emend. Hou, 1984

1965a *Hourcqia* Krömmelbein p. 68-69 (non *Hourcqia africana africana* Krömmelbein, and *Hourcqia africana confluens* Krömmelbein and Weber, 1971).

1972 *Pattersoncypris* Bate, p. 380-381.

2012a *Kroemmelbeincypris* Poropat and Colin, p. 715.

Type species. Harbinia hapla Tsao, 1959

Remarks. The suprafamiliar classification follows Liebau (2005); for family and other infrafamilial taxa, classification follows Hou et al. (2002), which proposed the family Quadracyprididae, subfamily Quadracypridinae, encompassing the genera *Quadracypris*, *Nanxiongium*, *Harbinia*, and *Sinocypris*. *Harbinia* is discussed extensively by Do Carmo et al. (2008) due to its similarity to *Pattersoncypris* Bate, 1972. The type species *Pattersoncypris micropapillosa* Bate, 1972 is a junior synonym of *Harbinia* Tsao, 1959. The subspecies described by Krömmelbein and Weber (1971) belonging to *Hourcquia* Krömmelbein, 1965a (i.e., *Hourcquia angulata angulata* Krömmelbein and Weber, 1971; *Hourcquia angulata salitrensis* Krömmelbein and Weber, 1971; *Hourcquia angulata sinuata* Krömmelbein and Weber, 1971; and *Hourcquia angulata symmetrica* Krömmelbein and Weber, 1971) were reassigned to *Harbinia* and elevated to species. Poropat and Colin (2012a) revised the genera *Hourcquia* Krömmelbein, 1965a, *Pattersoncypris* Bate, 1972, and *Harbinia* Tsao, 1959 and revalidated *Pattersoncypris*, encompassing the species *Harbinia micropapillosa*, *Harbinia salitrensis* and *Harbinia sinuata*. They also proposed the Genus *Kroemmelbeincypris* Poropat and Colin, 2012a, encompassing the species *Harbinia angulata* and *Harbinia symmetrica*. That proposal was based on the inclined posterior margin, which would differentiate those species from *Harbinia*. However, several characteristics described for *Kroemmelbeincypris* (e.g., valve overlap, outline, and ornamentation pattern) are also present in *Harbinia*. Tomé et al. (2014) invalidated the *Kroemmelbeincypris* due to the small variation associated with polymorphism present in some species of *Harbinia*, and accepted the validity of *Pattersoncypris*.

Harbinia aff. *Harbinia angulata* (Krömmelbein and Weber, 1971)

Figura 15, A

1971? *Hourcquia angulata angulata* Krömmelbein and Weber, p. 81, pl. 6, figs. 23–26.
 2002? *Pattersoncypris angulata angulata* (Krömmelbein and Weber); Coimbra et al., p. 691, fig. 4.29.
 2008? *Harbinia angulata* (Krömmelbein and Weber); Do Carmo et al., p. 795, fig. 6.11.
 2012a? *Kroemmelbeincypris angulata* (Krömmelbein and Weber); Poropat and Colin, p. 709, fig. 4.5.
 2014? *Pattersoncypris angulata* (Krömmelbein and Weber); Tomé et al., p. 165, fig. 10G–I.
 2018 *Harbinia* aff. *Harbinia angulata* (Krömmelbein and Weber); Leite et al., p. 5, fig. 3 1-3.
 2022? *Hourcquia angulata angulata* Krömmelbein and Weber, Bate et al., p. 79, fig. 11, 3a-c.
Holotype. Carapace (BfB, type Nr. 7795), Post-Bahia Series, Riachuelo Layers, Alagoas State, Brazil (Krömmelbein and Weber, 1971).

Occurrence. Brazil: Sergipe-Alagoas basin, Riachuelo Formation, upper Aptian (Krömmelbein and Weber, 1971); Araripe basin, Santana Formation, Romualdo Member, Aptian (Silva-Telles Jr. and Viana, 1990; Poropat and Colin, 2012a); Cedro basin, deposits correlated to the Crato Formation, Aptian (Tomé, 2007); Jatobá basin, Serra Negra, deposits correlated to the Crato Formation, upper Aptian (Tomé et al., 2014); São Francisco basin, Quiricó Formation, Lower Cretaceous, Aptian (Leite et al., 2018).

Stratigraphic range. Aptian (based on the above listed occurrence).

Materials. Six intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, Brazil. In Leite et al. (2018), rare in layer MP-2882; frequent in layer MP 2922; abundant in layers MP 2883, MP 2889. In the present thesis, rare in layer MP 2798; frequent in layer MP 2794 (Fig. 17).

Illustrated material. 0.728 mm length, 0.489 mm height, 0.220 mm width.

Remarks. The specimens are identified as *Harbinia* aff. *H. angulata* due to the greatest length from the carapace dislocated to the dorsal margin, as well as a posterior lump in some younger instars (Tomé et al., 2014). However, this species remains in affinity due to poor preservation and signs of dissolution. Valve overlap relation is compared to *Hourcquia africana* Krömmelbein, 1965a, in which the right valve overlaps the left one, therefore, *Harbinia angulata* presents an inverse valve relation.

Harbinia symmetrica (Krömmelbein and Weber, 1971)

1971 *Hourcquia angulata symmetrica* Krömmelbein and Weber, p. 81, pl. 6, fig. 25.

1990 *Cultella* sp. 1 Dépêche et al., p. 308, pl. 2, fig. 2.

1990 *Pattersoncypris* cf. *angulata angulata* (Krömmelbein and Weber); Musacchio, p. 564, pl. 2, fig. 2.

1990 *Hourcquia angulata symmetrica* (Krömmelbein and Weber); Silva-Telles Jr. and Viana, p. 325, pls. 1, 3, fig. 8.

1999 *Pattersoncypris angulata symmetrica* (Krömmelbein and Weber); Bate, p. 289.

2002 *Pattersoncypris angulata symmetrica* (Krömmelbein and Weber); Coimbra et al., p. 690, fig. 4.30.

2004a *Harbinia symmetrica* (Krömmelbein and Weber); Do Carmo et al., p. 144, fig. 4.1.

2004a *Harbinia* sp. 1 Do Carmo et al., p. 144, fig. 4.2.

2006 *Harbinia* aff. *H. symmetrica* (Krömmelbein and Weber); Ramos et al., p. 344, fig. 4M-P.

2008 *Harbinia symmetrica* (Krömmelbein and Weber); Do Carmo et al., p. 795, fig. 6.9.

2012a *Kroemmelbeincypris symmetrica* (Krömmelbein and Weber); Poropat and Colin, p. 709, fig. 6.9.

2018 *Harbinia symmetrica* (Krömmelbein and Weber); Leite et al., p.5, fig. 3 4-6.

2022 *Hourcquia angulata symmetrica* Krömmelbein and Weber, Bate et al., p. 79, fig. 11, 5a-c.

Holotype. Carapace (BfB, type Nr. 7797), from the Codó layers, Maranhão State, Brazil (Krömmelbein and Weber, 1971).

Occurrence. Brazil: Araripe Basin, Rio da Batateira Formation, and Santana Formation, Crato, Ipubi, and Romualdo members, Aptian (Coimbra et al., 2002), *Harbinia* spp. 201–218 Zone, NRT-O11 (Do Carmo et al., 2008), Alagoas Stage (Schaller, 1969; Moura, 1987), upper Aptian–lower Albian (Antonietto et al., 2012); Grajaú Basin, Codó Formation, Aptian (Krömmelbein and Weber, 1971; Ramos et al., 2006); São Francisco Basin, Quiricó Formation, Lower Cretaceous, Aptian (Leite et al., 2018). Africa: Gabon Basin, Gamba Formation; Congo and Cabinda basins, Chela Formation (Grosdidier et al., 1996; Bate, 1999).

Stratigraphic range. Aptian (based on the above listed occurrence).

Materials. In Leite et al. (2018), four intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, Brazil: rare in layers MP-2879, MP-2882, MP-2885; abundant in layer MP-2883 (Fig. 17).

Harbinia aff. *Harbinia salitrensis* (Krömmelbein and Weber, 1971)

1971? *Hourcquia angulata salitrensis* Krömmelbein and Weber, p. 81, pl. 6, fig. 26.

1972? *Pattersoncypris angulata salitrensis* (Krömmelbein and Weber); Bate, p. 389, fig. 11.

2006? *Harbinia salitrensis* (Krömmelbein and Weber); Ramos et al., p. 344, fig. 4Q-T.

2008? *Harbinia salitrensis* (Krömmelbein and Weber); Do Carmo et al., p. 795, fig. 6.8.

2012? *Harbinia salitrensis* (Krömmelbein and Weber); Antonietto et al., p. 662, fig. 4 1-10.

2012a? *Pattersoncypris salitrensis* (Krömmelbein and Weber); Poropat and Colin, p. 709, fig. 4.3.

2014? *Pattersoncypris salitrensis* (Krömmelbein and Weber); Tomé et al., p. 165, fig. 10G-I.

2018 *Harbinia* aff. *Harbinia salitrensis* (Krömmelbein and Weber); Leite et al., p. 5, fig. 3 7-9

2022? *Hourcquia angulata salitrensis* Krömmelbein and Weber, Bate et al., p. 79, fig. 11, 6a-c.

Holotype. Carapace (BfB, type Nr. 7798), from the Santana layers, Pernambuco State, Brazil (Krömmelbein and Weber, 1971).

Occurrence. Brazil: Araripe Basin, Santana Formation, Romualdo Member, Aptian (Krömmelbein and Weber, 1971; Poropat and Colin, 2012a; Antonietto et al., 2012; Tomé et al., 2014); Grajaú Basin,

Codó Formation, Aptian (Do Carmo et al., 2008); São Francisco Basin, Quiricó Formation, Lower Cretaceous, Aptian (Leite et al., 2018).

Stratigraphic range. Aptian (based on the above listed occurrence).

Materials. In Leite et al. (2018), five intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, Brazil: rare in layers MP-2882, MP-2890; frequent in layer MP-2922; abundant in layers MP-2879, MP-2883 (Fig. 17).

Harbinia alta Antonietto et al., 2012

Figura 15, B

1989 *Hourcquia angulata angulata* Krömmelbein and Weber; Viana et al., p. 216, fig. 2a–c.

1990 *Hourcquia angulata angulata* Krömmelbein and Weber; Dépêche et al., p. 304, pl. 1, figs. 1, 2.

1990 *Hourcquia angulata angulata* Krömmelbein and Weber; Silva-Telles Jr. and Viana, p. 320, pl. 3. fig. 3.

2006 *Harbinia angulata* (Krömmelbein and Weber); Ramos et al., p. 344, fig. 4E–H.

2006 *Harbinia* sp. Ramos et al., p. 344, fig. 4U–Y.

2012 *Harbinia alta* Antonietto et al., p. 662, fig. 4 11-20.

2013 *Harbinia alta* Antonietto et al.; Do Carmo et al., p. 94, fig. 3 5-8.

2018 *Harbinia alta* Antonietto et al.; Leite et al., p.5, fig. 3 10-12.

Holotype. Carapace (CP-584), Romualdo Member, Santana Formation, Pernambuco State (Antonietto et al., 2012).

Occurrence. Brazil: Grajaú basin, Codó Formation, upper Aptian (Ramos et al., 2006); Araripe basin, Santana Formation, Crato, Ipubi and Romualdo members, Aptian-Albian (Viana et al., 1989; Silva-Telles Jr. and Viana, 1990; Antonietto et al., 2012); *Harbinia* spp. 201-218 Zone, NRT-O11 (Do Carmo et al., 2008), Alagoas Stage (Schaller, 1969; Moura, 1987), upper Aptian-lower Albian (Antonietto et al., 2012); Potiguar basin, Alagamar Formation, middle-upper Aptian (Do Carmo et al., 2013); São Francisco basin, Quiricó Formation, Lower Cretaceous, Aptian (Leite et al., 2018), Barremian-Aptian, present thesis.

Stratigraphic range. Barremian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. Five intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, southeastern Brazil. In Leite et al. (2018), rare in layer MP 2889; abundant in

layers MP 2879, MP 2889. In the present thesis, rare in layer MP-3855; frequent in layer MP-3853 (Fig. 17).

Illustrated material. 0.738 mm length, 0.5 mm height, 0.177 mm width.

Remarks. The species identified as *Hourcquia angulata angulata* Krömmelbein and Weber, 1971 in Viana et al. (1989), Dépêche et al. (1990) and Silva-Telles Jr and Viana (1990), and identified as *Harbinia angulata* (Krömmelbein and Weber, 1971) in Ramos et al. (2006), belongs to *Harbinia alta*. They are different from that described by Krömmelbein and Weber (1971) in the height-length ratio and ornamentation.

Harbinia aff. Harbinia crepata Do Carmo et al., 2013

Figura 15, C

1990 Gen. indet. sp. aff. 207 Silva-Telles and Viana, p. 326, pl. 2, figs. 1, 3.

2013? *Harbinia crepata* Do Carmo et al., p. 96, fig. 3 9-18.

2018 *Harbinia aff. Harbinia crepata* Do Carmo et al.; Leite et al., p.5, fig. 3 13-15.

Holotype. Carapace (MP-O-1579), Alagamar Formation, Ceará State, Brazil (Do Carmo et al., 2013).

Occurrence. Brazil: Araripe basin, Santana Formation, Crato Member, Aptian (Silva-Telles and Viana, 1990); Potiguar basin, Alagamar Formation, middle-upper Aptiano (Do Carmo et al., 2013); São Francisco basin, Quiricó Formation, Lower Cretaceous, Aptiano (Leite et al., 2018), Barremian-Aptian, present thesis.

Stratigraphic range. Barremian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. Three intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, southeastern Brazil. In Leite et al. (2018), abundant in layers MP 2883, MP 2889. In the present thesis, rare in layer MP-3802 (Fig. 17).

Illustrated material. 0.843 mm length, 0.485 mm height, 0.354 mm width.

Remarks. *Harbinia crepata* differs from *Harbinia sinuata* (Krömmelbein and Weber, 1971), *Harbinia salitrensis* (Krömmelbein and Weber, 1971) and *Harbinia micropapillosa* (Bate, 1972) due to its subtriangular elongated outline and its less-inclined hinge line (Do Carmo et al., 2013). The specimens recovered are better preserved than *Harbinia alta* and *Harbinia aff. Harbinia angulata*, with some degree of dissolution.

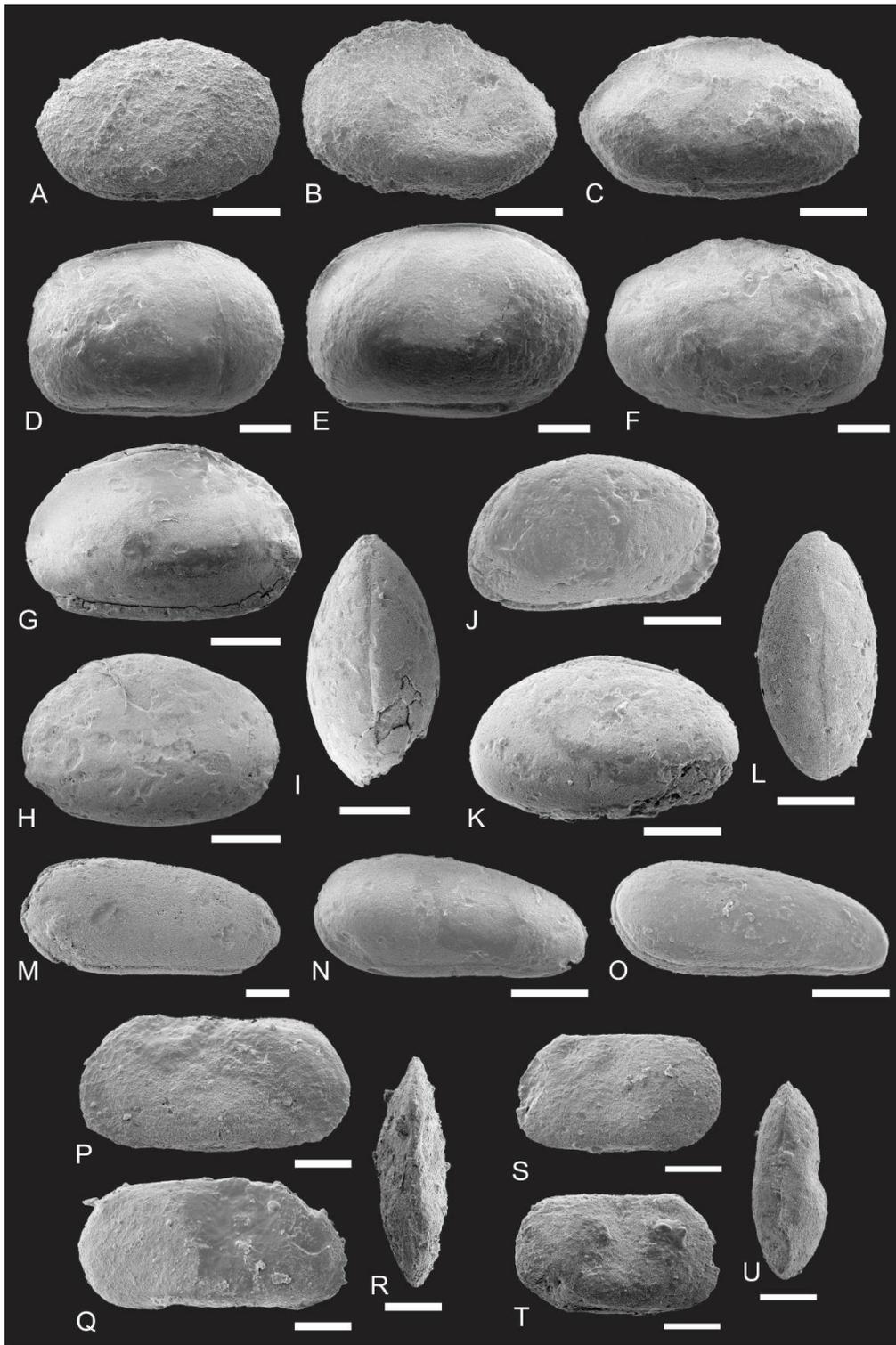


Figure 15. A, *Harbinia* aff. *Harbinia angulata* (Krömmelbein and Weber, 1971), right lateral view (RLV). B, *Harbinia alta* Antonietto et al., 2012, left lateral view (LLV). C, *Harbinia* aff. *Harbinia crepata* Do Carmo et al., 2013, left lateral view (LLV). D-E, *Brasacypris ovum* Krömmelbein, 1965b; D, female, right lateral view (RLV); E, male, right lateral view (RLV). F, *Brasacypris fulfaroi* Dias-Brito et al., 2001, left lateral view (LLV). G-I, *Brasacypris* aff. *Brasacypris morigerata* Musacchio, 1973; G, right lateral view (RLV); H, left lateral view (LLV); I, dorsal view (DV). J-L, *Damonella* aff.

Damonella ultima (Krömmelbein and Weber, 1971); J, right lateral view (RLV); K, right lateral view (LLV); L, dorsal view (DV). M, *Penthesilenula martinsi* (Silva, 1978), right lateral view (RLV). N, *Penthesilenula pintoii* Leite et al., 2018, right lateral view (RLV). O, *Alicenula longiformis* Leite et al., 2018, right lateral view (RLV). P-R, *Wolburgiopsis plastica* (Musacchio, 1970); P, right lateral view (RLV); Q, left lateral view (LLV); R, dorsal view (DV). S-U, *Wolburgiopsis chinamuertensis* (Musacchio, 1970); S, right lateral view (RLV); T, left lateral view (LLV); U, dorsal view (DV). Scale bars: M, P-U = 100 μm ; A-F, J-L, N-O = 200 μm ; G-I = 500 μm .

Family CYPRIDIDAE Baird, 1845

Subfamily CYPRIDINAE Baird, 1845

Genus *Brasacypris* Krömmelbein, 1965b emend. Leite et al., 2018

Type species. Brasacypris ovum Krömmelbein, 1965b.

Remarks. The suprafamiliar classification follows Liebau (2005). The original description left the genus in Incertae Family. Do Carmo et al. (2004a) and Do Carmo et al. (2013) attributed *Brasacypris* to the Cypridinae Subfamily. When comparing *Brasacypris* to *Cyprinotus* Brady, 1886, another member of the Cypridinae Subfamily, they differ at the oval outline in lateral view and convex margin of *Brasacypris* (Do Carmo et al., 2004a; Do Carmo et al., 2013). Krömmelbein (1965b) considered the diagnosis of *Brasacypris ovum* as the genus' diagnosis, since it was until then monospecific. Taking into consideration the sexual dimorphism and variations in the carapace outline from a species belonging to this genus, a new diagnosis was proposed by Leite et al. (2018), emended from Krömmelbein (1965b), considering that in lateral view, the dorsal margin presents variations, while *Brasacypris ovum* presents the greatest height anteriorly (end of the first third), *Brasacypris fulfaroi* and *Brasacypris morigerata* present the greatest height at antero-median position. As for the dorsal view, the greatest width is posteriorly (*Brasacypris ovum*) to median position (*Brasacypris fulfaroi* and *Brasacypris morigerata*).

Brasacypris ovum Krömmelbein, 1965b emend. Leite et al., 2018

Figura 15, D-E

1965b *Brasacypris ovum* Krömmelbein, p. 213, pl. 15, fig. 19.

2004a *Brasacypris ovum?*; Do Carmo et al., p. 144, fig. 4.4.

2018 *Brasacypris ovum* Krömmelbein; Leite et al., p. 8, fig. 4 1-6.

2018 non *Brasacypris ovum* Krömmelbein; Sousa et al., p. 30, fig. 5.1-22.

2021 non *Brasacypris ovum* Krömmelbein; Santos Filho et al., p. 6, fig. 5A-D.

2022 *Brasacypris ovum* Krömmelbein; Bate et al., p. 73, fig. 8, 4a-c.

Holotype. Carapace (SMF Xe 5369), Itaparica and Candeias formations, Bahia state, Brazil (Krömmelbein, 1965b).

Occurrence. Brazil: Tucano basin, Itaparica and Candeias formations, Lower Cretaceous (Krömmelbein, 1965b), Itaparica Formation-Lower Candeias interval (Krömmelbein, 1966), Rio da Serra Stage, Berriasian (Caixeta et al., 1994; Costa et al., 2007); São Francisco basin, Quiricó Formation, Lower Cretaceous, Valanginian-Aptian (Leite et al., 2018), Berriasian-Aptian, present thesis.

Stratigraphic range. Berriasian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. Six intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, southeastern Brazil. In Leite et al. (2018), rare in layers MP 2895, MP 2960. In the present thesis, rare in layers MP-3798, MP-3805, MP-3853, MP-3856 (Fig. 17). In Leite et al. (2018), 14 intervals from the hypostratotype section of the Tereza Farm, João Pinheiro, Minas Gerais State, southeastern Brazil: rare in layers MP 3318, MP 3327, MP 3335, MP 3426, MP 3428, MP 3436, MP 3438, MP 3442, MP 3443; frequent in layer MP 3429; abundant in layers MP 3326, MP 3431, MP 3434, MP 3437 (Fig. 20). In Leite et al. (2018), one interval from the São José Farm, Presidente Olegário County, Minas Gerais State, southeastern Brazil: abundant in layer MP 3421 (Fig. 21). In the present thesis, five intervals from the São Bento Farm, Carmo do Paranaíba, Minas Gerais State, southeastern Brazil: rare in layers MP-4172, MP-4181, MP-4183; frequent in layers MP-4170, MP-4188 (Fig. 18). In the present thesis, four intervals from the Sono river, João Pinheiro, Minas Gerais State, southeastern Brazil: rare in layers MP-4005; frequent in layers MP-4004, MP-4011, MP-4012 (Fig. 19).

Illustrated material. Female, 0.978 mm length, 0.688 mm height, 0.532 mm width. Male, 1.116 mm length, 0.780 height, 0.497 mm width.

Remarks. Leite et al. (2018) proposed a new diagnosis and description for *Brasacypris ovum* Krömmelbein, 1965b based on the occurrence of two morphotypes: one short in lateral view, more rounded, with the greatest height in lateral view, and greatest width in dorsal view, attributed to females; one elongated in lateral view, attributed to males. Both specimens occur in the studied sections approached herein. Also, both morphotypes are egg-shaped in lateral view, and biconvex in dorsal view; with the anterior margin evenly rounded, and the posterior margin shorter and more closely rounded; the greatest height corresponding to the anterior cardinal angle; and the left valve larger than the right valve, with a strong overlap all through the carapace, well-marked over the ventral

margin. All these characteristics are described for *Brasacypris ovum* by Krömmelbein (1965b). Sousa et al. (2018) emended *Brasacypris ovum*, due to the occurrence of specimens with nodules. In their emended description, Sousa et al. (2018) discoursed the overlap of the carapace in the recovered specimens, stating the overlap is normal, which would mean that it is identical to the overlap described by Krömmelbein (1965b) – left valve larger than right valve, surpassing it in all the margins, specially over the ventral margin –. However, in fig. 51-26 from Sousa et al. (2018), where several instars are illustrated, it is possible to observe that several specimens present the right valve larger than left valve, especially in dorsal view (fig. 5.1-3; fig. 5.4-6; fig. 5.8-10; fig. 5.14-16), which would mean that several specimens recovered present an inverse valve overlap. Moreover, it would mean that the inversion of overlap would be occurring during the molting process, since three instars without nodules, illustrated in fig. 5.11-13, 17-19, 20-22, present a normal valve overlap. Although the shape in lateral view of the specimens illustrated by Sousa et al. (2018) present some similarities with the *Brasacypris ovum* by Krömmelbein (1965b), this inverse valve overlap, so notably present in several specimens illustrated, could mean that the specimens are not *Brasacypris ovum*. Santos Filho et al. (2021) attributed large specimens recovered to *Brasacypris ovum*, following the position adopted by Sousa et al. (2018). However, there seems to be some problems regarding the generic attribution of the specimens illustrated in fig. 5A and 5B to *Brasacypris ovum*. The specimen illustrated in fig. 5A by Santos Filho et al. (2021), differently from the original *Brasacypris ovum* by Krömmelbein (1965b) – in which the anterior margin is broad and evenly rounded and the posterior margin is lower and more closely rounded –, the anterior margin is broad, but not evenly rounded, and the posterior margin is higher and broader than the anterior margin; this seems to indicate that the specimen in question is not attributed to *Brasacypris ovum*. The specimen illustrated in fig. 5B by Santos Filho et al. (2021), is more elongated than the original *Brasacypris ovum* by Krömmelbein (1965b), and even more elongated than the specimens attributed to the species in question by Sousa et al. (2018), resembling *Brasacypris fulfaroi* Dias-Brito et al., 2001; this could indicate that the specimen illustrated in fig. 5B by Santos Filho et al. (2021) is not attributed to *Brasacypris ovum*.

Brasacypris aff. *Brasacypris morigerata* Musacchio, 1973

Figura 15, G-I

1973? *Brasacypris morigerata* Musacchio, p. 40, pl. 4, figs. 6-8, 12, 16-17.

Holotype. Carapace (MLP n° 11926), Neuquén river, Neuquén Province, Argentina (Musacchio, 1973).

Occurrence. Argentina: Neuquén river, Neuquén Province, Upper Cretaceous (Musacchio, 1973; Ballent et al., 2011b). Brazil: São Francisco basin, Quiricó Formation, Lower Cretaceous, Barremian?-Aptian?, in the present thesis.

Stratigraphic range. Barremian? to the Upper Cretaceous (based on the above listed occurrence).

Materials. Two intervals from the section of the Sono river, João Pinheiro, Minas Gerais, southeaster Brazil: rare in layers MP-4004, MP-4006 (Fig. 19).

Illustrated material. 1.994 mm length, 1.294 mm height, 1.071 width.

Remarks. In the present work few specimens were recovered, and are poorly preserved and dissolved.

Brasacypris fulfaroi Dias-Brito et al., 2001

Figura 15, F

1960 Gen. et sp. indet Grekoff, p. 32, pl. 6, figs. 37, 38.

2001 *Brasacypris fulfaroi* Dias-Brito et al., p. 295, pl. 6, figs. 9–14.

2018 *Brasacypris fulfaroi* Dias-Brito et al.; Leite et al., p. 8, fig. 4 7-9.

Holotype. Carapace (UNESP- λ -BU45), Adamantina Formation, São Paulo State, Brazil (Dias-Brito et al., 2001).

Occurrence. Brazil: Paraná basin, Bauru Group, Adamantina Formation, Upper Cretaceous (Dias-Brito et al., 2001); São Francisco basin, Quiricó Formation, Lower Cretaceous, Valanginian-Aptian? (Leite et al., 2018), Berriasian-Aptian, present thesis.

Stratigraphic range. Berriasian to Turonian-Santonian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), 10 intervals from the hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, southeastern Brazil: rare in layers MP 3318, MP 3322, MP 3333, MP 3429, MP 3434, MP 3436, MP 3442, MP 3443; frequent in layer MP 3431; abundant in layer MP 3326 (Fig. 20). In Leite et al. (2018), one interval from the São José Farm section, Presidente Olegário County, Minas Gerais State, southeastern Brazil: abundant in layer MP 3421 (Fig. 21). In the present thesis, four intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, southeastern Brazil: rare in layers MP-3851, MP-3853, MP-3855, MP-3856 (Fig. 17). In the present thesis, one interval from the São Bento Farm, Carmo do Paranaíba, Minas Gerais State, southeastern Brazil: abundant in layer MP-4188 (Fig. 18). In the present thesis, four intervals from the Sono river, João Pinheiro, Minas Gerais State, southeastern Brazil: abundant in layer MP-4012; frequent in layers MP-4004; rare in layers MP-4005, MP-4011 (Fig. 19).

Illustrated material. 1.075 mm length, 0.694 mm height, 0.430 mm width.

Remarks. In the present work, the specimens are well preserved, but smaller than originally described by Dias-Brito et al. (2001), in which the holotype length is ~1.683 mm. Leite et al. (2018), recovered specimens from the Tereza Farm and the São José Farm, and interpreted that the species was attributed to the Valanginian-Aptian? interval.

Family CYPRIDEIDAE Baird, 1845 emend. Martin, 1940

Subfamily CYPRIDEINAE Martin, 1940

Genus *Cypridea* Bosquet, 1852

Type species. *Cypridea granulosa* Sowerby, 1836 (designated by Sylvester-Bradley, 1949).

Remarks. The suprafamiliar classification follows Liebau (2005), and Sames (2011) for family and other infrafamilial taxa. When Bosquet (1852) proposed the genus, he did not provide a diagnosis, indicating only the ventral beak as the main characteristic. Jones (1885) described the genus in greater detail, and determined a diagnosis based on the ventral beak, notch, and carapace ornamentation. During the following years, several authors (Anderson, 1939; Sylvester-Bradley, 1949; Martin, 1958; Moore and Pitrat, 1961; Van Morkhoven, 1963; Horne and Colin, 2005; Do Carmo et al., 2008; Sames, 2011) proposed diagnoses for the genus, with some variability, as well as several subgenera and subspecies. Sylvester-Bradley (1949), particularly, determined the ventral beak in each valve, as well as the ventral notch, as a distinct diagnostic characteristic. Do Carmo et al. (2008), following Morkhoven (1963), included the genus *Hourcqia* Krömmelbein, 1965a as a synonym of *Cypridea*. On the other hand, Sames (2011) followed Moore and Pitrat (1961), where several subgenera are included.

Cypridea hystrix Krömmelbein, 1962

1962 *Cypridea hystrix* Krömmelbein, p. 507, pl. 55, fig. 18.

2018 *Cypridea hystrix* Krömmelbein; Leite et al., p. 8, fig. 4 10-12.

2018 non *Cypridea hystrix* Krömmelbein; Leite et al., p. 8, fig. 4 13-14.

2022 *Cypridea hystrix* Krömmelbein; Bate et al., p. 61, fig. 2, 11 a-c.

Holotype. Carapace (SMF Xe 4173) from the lower Ilha Formation layers, upper portion, Bahia State, Brazil (Krömmelbein, 1962).

Occurrence. Brazil: Recôncavo Basin, Ilhas Formation, Rio da Serra Stage, Lower Cretaceous (Krömmelbein, 1962; Poropat and Colin, 2012b); *Paracypridea brasiliensis* Zone, NRT-O04, with occurrence well marked in subzones *Paracypridea bicallosa*, NRTO04.3, and *Paracypridea maacki*,

NRT-O04.4, respectively (Viana et al., 1971; Cunha and Moura, 1979; Regali and Viana, 1989), Valanginian (Caixeta et al., 1994); São Francisco Basin, Quiricó Formation, Lower Cretaceous, Valanginian (Leite et al., 2018), Valanginian-Hauterivian, present thesis.

Stratigraphic range. Valanginian-Hauterivian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), seven intervals from the hypostratotype section of the Tereza Farm, João Pinheiro, Minas Gerais State, Brazil: rare in layers MP-3323, MP-3324, MP-3325, MP-3428, MP-3434, MP-3437; rare in layer MP-3326, as determined by the present work, once it was determined that *Cypridea hystrix* does not present males specimens (Fig. 20).

Remarks. Leite et al. (2018) proposed a new diagnosis and new description for *Cypridea hystrix* Krömmelbein, 1962 based on the occurrence of broader specimens, attributed to females of *Cypridea hystrix*, and narrower specimens, attributed to males. These narrower specimens were attributed to *Cypridea hystricoides* Krömmelbein, 1962, and due to similarities with *Cypridea hystrix*, the first was considered the male and a junior synonym of the latter. Coimbra (2020) argued that in the original description of Krömmelbein, 1962, not only *Cypridea hystricoides* was shorter than *Cypridea hystrix*, but both cardinal angles were more marked in *Cypridea hystricoides*, and specially the smaller nodules were less numerous and the larger nodules much more developed when compared to *Cypridea hystrix*. Santos Filho et al. (2021) recovered specimens with very large nodules, attributed to *Cypridea hystricoides*, without the occurrence of *Cypridea hystrix* in assemblage, and pointed out several relevant differences between the species in question, thus revalidating *Cypridea hystricoides*. Considering this discussion, and further analysis on the specimens recovered from the Quiricó Formation, it is concluded that *Cypridea hystricoides* is not the male of *Cypridea hystrix*, and thus the emend with new diagnosis and new description from Leite et al. (2018) are invalid. Regarding the interpretation by Coimbra (2020) that the specimen illustrated in fig. 4.10-12 in Leite et al. (2018) belongs to a different species than *Cypridea hystrix*, the first was based on carapace size; the holotype of Krömmelbein (1962) is larger than the specimens illustrated in Leite et al. (2018), however, variability in carapace size can occur within a population (Boomer et al., 2003), and within the same species, in different locations (Ramos et al., 2015). Also, Coimbra (2020) pointed out that in the specimen illustrated in fig. 4.10-12 in Leite et al. (2018) and in the description, the greatest width was described to be posteriorly, and is in fact immediately after half-length; the same is true for the *Cypridea hystrix* described by Krömmelbein (1962), who described the greatest width, in dorsal view, “behind the middle”. Also, Coimbra (2020) pointed out that the beak furrow described by

Krömmelbein (1962) is deep, reaching far above, ending approximately before the “eye thorn”, and the same is true for the *Cypridea hystrix* illustrated in Leite et al. (2018), in which the beak furrow ends roughly before the pronounced nodule in the antero-dorsal region. Regarding nodules and ornamentation, Coimbra (2020) pointed out that the diagnosis and description in Leite et al. (2018) differ from the original text in Krömmelbein (1962), and that is true; while analyzing in detail both the diagnosis and description in Leite et al. (2018), it is possible to conclude that they do not convey with the accuracy of Krömmelbein (1962) the specimens recovered and illustrated from the Quiricó Formation. However, it is possible to observe that the specimen illustrated in fig. 4.10-12 in Leite et al. (2018), along with other specimens recovered, present similarities with the *Cypridea hystrix* described by Krömmelbein (1962); other than the greatest width and beak furrow discussed above, the position of nodules, larger and smaller, the general shape of the carapace of the *Cypridea hystrix* described by Krömmelbein (1962) and the specimens recovered by Leite et al. (2018) are similar, and the subtle differences in nodule size and number is attributed to preservation and phenotypic control. Therefore, the species from the Quiricó Formation, along with the specimen illustrated in fig. 4.10-12, remains as *Cypridea hystrix*. Regarding the specimen illustrated in fig. 4.13-14 in Leite et al. (2018), that was attributed to the male of *Cypridea hystrix*, it is agreed with the position of Coimbra (2020) that it is not *Cypridea hystricoides*, and is indeed a different species, *Cypridea* sp. 1, which will be discussed below; therefore, in the seven intervals from the hypostratotype section of the Tereza Farm where *Cypridea hystrix* was recovered, in layer MP-3326, three of the six carapaces recovered (Leite et al., 2018), and in layer MP-3428, one of the two carapaces recovered (Leite et al., 2018), are not attributed to *Cypridea hystrix*. It is important to point out the need for further analysis and discussion on the possibility of phenotypic control of nodules in *Cypridea*; not only it is possible to see evidences of it in *Cypridea conjugata* and *Cypridea hystrix* from Leite et al. (2018), it is also possible to point that characteristic out in the *Cypridea hystricoides* recovered from Santos Filho et al. (2021) in which the three nodules in the anterior margin of the original *Cypridea hystricoides* in Krömmelbein (1962) are not present; this could be due to preservation conditions or indicate that some nodules are bigger or smaller due to phenotypical conditions.

Cypridea conjugata Krömmelbein and Weber, 1971 emend. Leite et al., 2018

1971 *Cypridea conjugata* Krömmelbein and Weber, p. 71, pl. 1, figs 4, 5.

2018 *Cypridea conjugata* Krömmelbein and Weber; Leite et al., p. 10, fig. 5 1-7.

2022 *Cypridea conjugata* Krömmelbein and Weber; Bate et al., p. 75, fig. 9, 9 a-c.

Holotype. Left valve (BfB, type Nr. 7772) from the São Sebastião layers, Bahia State, Brazil (Krömmelbein and Weber, 1971).

Occurrence. Brazil: Recôncavo Basin, São Sebastião Formation, Lower Cretaceous (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b), Barremian (Silva et al., 2007). São Francisco basin, Quiricó Formation, Lower Cretaceous, Valanginian (Leite et al., 2018), Valanginian-Hauterivian, present thesis.

Stratigraphic range. Valanginian-Barremian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), four intervals from the hypostratotype section of the Tereza Farm, João Pinheiro, Minas Gerais State, Brazil: rare in layers MP-3324, MP-3326, MP-3431; abundant in layer MP-3434 (Fig. 20).

Remarks. Leite et al. (2018) proposed a new diagnosis and new description due to the occurrence of specimens attributed to *Cypridea conjugata* with and without nodules, as well as with nodules, but poorly developed. Coimbra (2020) argued that several characteristics of the specimen illustrated in fig. 5.1-3 from Leite et al. (2018) are different from the original *Cypridea conjugata* by Krömmelbein and Weber, 1971. These characteristics are mainly the length/height ratio (the specimen from Leite et al. (2018) is more elongated), and the beak extending beyond the ventral margin in the holotype and not in the specimen illustrated by Leite et al. (2018). However, the specimen illustrated in fig. 5.1-3 from Leite et al. (2018) was poorly chosen, thus presenting this elongation more pronounced than other specimens from the same sample (layer MP-3434); from the 25 carapaces in layer MP-3434 (Leite et al., 2018), only two are more elongated. It is worth mentioning that although in the specimen illustrated in fig. 5.1-3 the nodules are far less when compared to the holotype, and the discussion for that matter is explored in Leite et al. (2018), the nodules that are present are in the same position as the *Cypridea conjugata* by Krömmelbein and Weber, 1971. In the original description, Krömmelbein and Weber (1971) stated that the intraspecific variability could not be assessed with certainty based on the specimens available, and the form of the bigger and smaller nodules varied, but not its location and arrangement (loosely translated from German). With that, the more elongated form, present in the specimen from fig. 5.1-3 from Leite et al. (2018), and more rounded trapezoidal form, present in the holotype and other specimens from the Quiricó Formation (including the specimen from Leite et al. (2016)) (Fig. 16), could be due to the possible variability within the species, attributed to ontogeny perhaps. With that, the specimens recovered from the Quiricó Formation remains attributed to

Cypridea conjugata, and the emend made by Leite et al. (2018), approaching the variability of nodules, is valid.

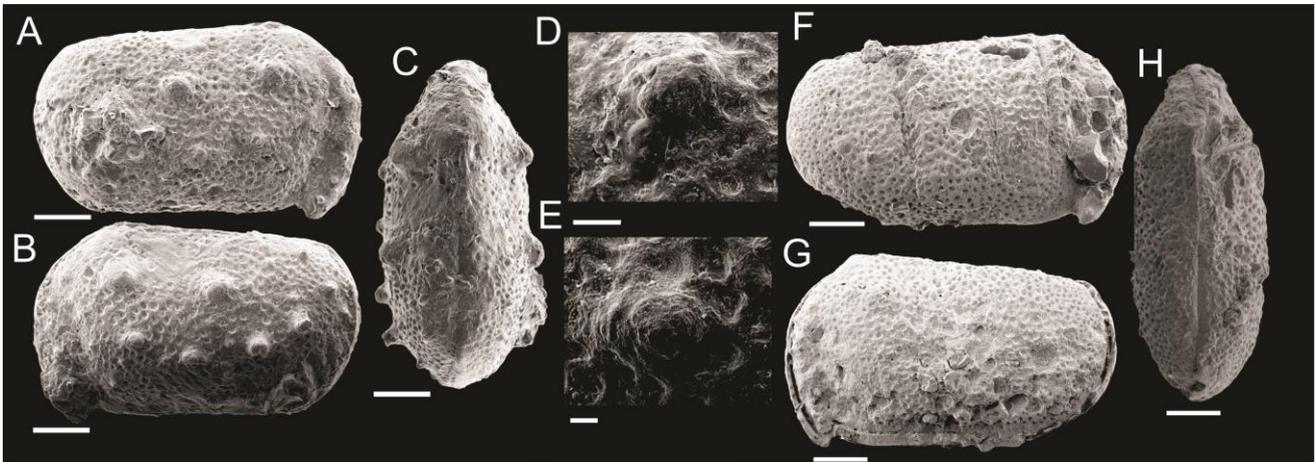


Figure 16. A-E, *Cypridea conjugata* Krömmelbein and Weber, 1971, morphotype with nodules; A, right lateral view (RLV); B, left lateral view (LLV); C, dorsal view (DV); D-E, detail of nodule with pore canals in the noddled area. F-H, *Cypridea conjugata* Krömmelbein and Weber, 1971, morphotype without nodules; F, right lateral view (RLV); G, left lateral view (LLV); H, dorsal view (DV). Scale bars: A-C, F-H = 200 μm ; D = 50 μm ; E = 20 μm (Leite et al., 2016).

Cypridea aff. *Cypridea infima* Krömmelbein and Weber, 1971

1971? *Cypridea infima* Krömmelbein and Weber, p. 71, pl. 1, fig. 3.

2018? *Cypridea infima* Krömmelbein and Weber; Leite et al., p. 10, fig. 5 8-13.

2022? *Cypridea infima* Krömmelbein and Weber; Bate et al., p. 75, fig. 9, 8 a-c.

Holotype. Carapace (BfB, type Nr. 7770) from the Candeias layers, lower and middle portions, Bahia State, Brazil (Krömmelbein and Weber, 1971).

Occurrence. Brazil: Recôncavo Basin, Candeias Formation, lower and middle portions, Lower Cretaceous, (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b), Berriasian–Valanginian (Silva et al., 2007); São Francisco Basin, Quiricó Formation, Lower Cretaceous, Valanginian–Hauterivian/Aptian? (Leite et al., 2018), Berriasian–Barremian, present thesis.

Stratigraphic range. Berriasian–Barremian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), eight intervals from the hypostratotype section of the Tereza Farm, João Pinheiro, Minas Gerais State, Brazil: rare in layers MP-3318, MP-3322, MP-3427, MP-3428, MP-3431, MP-3433, MP-3434, MP-3444 (Fig. 20).

Remarks. Leite et al. (2018) proposed a new diagnosis and new description based on the occurrence of a punctate ornamentation and porecanals along the carapace, claiming that Krömmelbein and Weber (1971) described only the porecanals through the carapace. Coimbra (2020) drew attention to the mistranslation made by Leite et al. (2018), in which Krömmelbein and Weber (1971) used the expression “Pore-Grübchen” translated to pore cavities, to refer to a punctate or finely reticulate ornamentation, meaning that the authors were not referring to normal porecanals; therefore, Krömmelbein and Weber (1971) described correctly the ornamentation of *Cypridea infima*, and the emend made by Leite et al. (2018) is invalid. Additionally, Coimbra (2020), although affirming that the *Cypridea infima* illustrated by Leite et al. (2018) and the holotype bear similarities, also states that there are differences. First, the transition from the dorsal to the anterior and posterior margins of the *Cypridea infima* of Krömmelbein and Weber (1971) is really rounded, with indistinct cardinal angles; the same is true for the *Cypridea infima* illustrated by Leite et al. (2018), in which it is possible to observe a small mark of abrasion in the mid to posterodorsal area in dorsal view, probably caused by diagenetic factors, creating the false impression of slightly marked posterior cardinal angle, in lateral view. Regarding ornamentation, other than the finely punctate all through the carapace, the *Cypridea infima* illustrated by Leite et al. (2018) also presents small nodules; however, *Cypridea* seems to present a phenotypical control for nodules, either in its occurrence or in its size, as it is possible to observe in *Cypridea hystricoides* and *Cypridea conjugata* discussed in the present work. Regarding the beak and the beak furrow, the holotype of *Cypridea infima* presents a wide beak, and the beak furrow is not very deep, reaching up to about half the height; the beak in the *Cypridea infima* illustrated by Leite et al. (2018) appears to be similar in width, although not so wide as the original, and the height of the beak furrow is not easily determined in the illustration. As for the overlap of the left valve over the right valve, in the *Cypridea infima* of Krömmelbein and Weber (1971), this overlap occurs only in the anterior and posteroventral margins, and in the *Cypridea infima* illustrated by Leite et al. (2018), the left valve also overlaps the right valve in the ventral margin; that overlap is present in the illustrated specimen, but not in other specimens attributed to the species, and could be attributed to some external factor, such as diagenesis (the right valve was pressed into the left valve). All characteristics of the specimen illustrated by Leite et al. (2018) seem to indicate that the species is indeed *Cypridea infima*, however, due to the valve overlap and the small differences in the beak and beak furrow, the first species will be left in affinity with the later.

Cypridea aff. *Cypridea jequiensis* Krömmelbein and Weber, 1971

1971? *Cypridea jequiensis* Krömmelbein and Weber, p. 75, pl. 3, fig. 11.

2018? *Cypridea jequiensis* Krömmelbein and Weber; Leite et al., p. 10, fig. 5 14-16.

2022? *Cypridea conjugata* Krömmelbein and Weber; Bate et al., p. 77, fig. 10, 3 a-c.

Holotype. Carapace (BfB, type Nr. 7781) from the Post-Bahia Series, Jiquiá layers, Alagoas State, Brazil (Krömmelbein and Weber, 1971).

Occurrence. Brazil: Sergipe-Alagoas Basin, Jiquiá Formation, Post-Bahia Series, Lower Cretaceous (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b; Antonietto, 2015), Penedo Formation?, Barremian?–Aptian, Subzone *Cypridea faveolata*, BRT-O09.3, upper portion of Zone *Petrobrasia diversicostata*, NRT-O09 (Moura, 1987; Rangel et al., 1994); São Francisco Basin, Quiricó Formation, Lower Cretaceous, Valanginian (Leite et al., 2018), Valanginian-Hauterivian, present thesis.

Stratigraphic range. Valanginian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), four intervals from the hypostratotype section of the Tereza Farm, João Pinheiro, Minas Gerais State, Brazil: rare in layers MP-3318, MP-3325, MP-3327; abundant in layer MP-3324 (Fig. 20).

Remarks. Leite et al. (2018) attributed the recovered specimens to *Cypridea jequiensis* due to the smooth surface and trapezoidal shape, without providing further characteristics. Coimbra et al. (2020), while comparing the specimen illustrated in Leite et al. (2018) and the original *Cypridea jequiensis* by Krömmelbein and Weber, 1971, pointed out some differences. Regarding the size of the carapace, the original *Cypridea jequiensis* by Krömmelbein and Weber, 1971 is much larger than the *Cypridea jequiensis* illustrated in Leite et al. (2018), with the holotype measuring 0.88 mm in length and 0.60 mm in height, and Krömmelbein and Weber (1971) even stated that the species can reach approximately 1.00 mm in length; however, variability in carapace size can occur within a population (Boomer et al., 2003), and within the same species, in different locations (Ramos et al., 2015), and size alone is not a determining factor to separate two specimens that might belong to the same species. Regarding the anterior margin, Coimbra et al. (2020) pointed out that the specimens from the Quiricó Formation is more rounded, and that difference is not evident in the specimen illustrated by Leite et al. (2018); when comparing both specimens, the holotype and the one illustrated by Leite et al. (2018), it is possible to see that both anterior margins are broadly rounded and very similar. In relation to the beak, Coimbra et al. (2020) argues that it is more pronounced in the original *Cypridea jequiensis* by Krömmelbein and Weber, 1971, and again that difference is not evident between the holotype and the

specimen illustrated by Leite et al. (2018); when comparing both specimens, the beak structure is very similar, even the beak furrow, described by Krömmelbein and Weber (1971) as shallow and indistinct, not reaching high up (loosely translated from German), which is also observed in the specimen illustrated by Leite et al. (2018). As for the dorsal view, in which the holotype is more elongated and bears a more pronounced sulcus, some specimens of the Quiricó Formation are similar to the holotype, others, such as the one illustrated by Leite et al. (2018) are not, and for that reason, the species from the Quiricó Formation will be left in affinity.

Cypridea sp.

2018 *Cypridea hystrix* Krömmelbein; Leite et al., p. 668, fig. 4.13-14

Occurrence. Brazil: São Francisco Basin, Quiricó Formation, Lower Cretaceous, Valanginian (Leite et al., 2018).

Stratigraphic range. Valanginian (based on the above listed occurrence).

Materials. In Leite et al. (2018), two intervals from the hypostratotype section of the Tereza Farm, João Pinheiro, Minas Gerais State, Brazil: rare in layers MP-3326, MP-3428 (Fig. 20).

Remarks. Leite et al. (2018) originally attributed the specimen illustrated in fig. 4.13-14 as the male of *Cypridea hystrix* Krömmelbein, 1962 based on the occurrence of this specimen, and others like it, in assemblage with the species in question. However, after Coimbra (2020) came forth with a discussion regarding the species of *Cypridea* of the Quiricó Formation, and after further analysis of the specimens recovered, it is concluded that the specimen illustrated in fig. 4.13-14 from Leite et al. (2018) is not attributed to *Cypridea hystrix*. *Cypridea* sp. 1 presents some resemblance with *Cypridea hystrix*, being more elongated in lateral view and narrower in dorsal view, but the nodules, when preserved, are in different positions from *Cypridea hystrix*. The specimen illustrated in fig. 4.13-14 from Leite et al. (2018) from layer MP-3326, along with two other specimens from the same layer, and a specimen from layer MP-3428, are poorly preserved, and, therefore, it was not possible to described a new species from them. With that, these specimens are left in open, and are classified as *Cypridea* sp. 1.

Family ILYOCYPRIDIDAE Kaufmann, 1900

Genus *Neuquenocypris* Musacchio, 1973

Type species. *Ilyocypris (Neuquenocypris) calfucurensis* Musacchio, 1973.

Remarks. The classification follows Liebau (2005). Originally, *Neuquenocypris* was described as a subgenus of *Ilyocypris* Brady and Norman, 1889. Posteriorly, *Neuquenocypris* was repositioned to

genus level, and three subgenera were described: *Neuquenocypris* (*Neuquenocypris*), *Neuquenocypris* (*Protoneuquenocypris*), and *Neuquenocypris* (*Alleniella*) (Musacchio and Simeoni, 1991). Species of *Neuquenocypris* usually have the right valve larger than the left one, smooth anterodorsal sulcus and nodules, and carapace well ornamented with spines, nodules, pustules, papillae, and denticles (Musacchio and Simeoni, 1991).

Neuquenocypris (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni, 1991

1991 *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni, p. 368, figs. 9, 11, 14–17.

2011a *Neuquenocypris antiqua* (Musacchio and Simeoni); Ballent et al., p. 545, figs. 3.1, 3.6.

2017 *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni; Carignano et al., p. 211, fig. 5A-B.

2018 *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni; Leite et al., p. 10, fig. 5 17-19.

Holotype. Carapace (BA-G-CM 91/1) from Pozo D-129 Formation, Cerro Chenques, in Chubut Province, Argentina (Musacchio and Simeoni, 1991).

Occurrence. Argentina: Pozo D-129 Formation in Cerro Chenques, Chubut Province, Barremian–Aptian (Musacchio and Simeoni, 1991; Carignano et al., 2017); Austral Basin, Piedra Clavada Formation, Santa Cruz, lower to upper Albian (Ballent et al., 2011a). Brazil: São Francisco Basin, Quiricó Formation, Lower Cretaceous, Valanginian (Leite et al., 2018), Valanginian-Hauterivian, present thesis.

Stratigraphic range. Valanginian-Albian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), three intervals from the hypostratotype section of the Tereza Farm, João Pinheiro, Minas Gerais State, Brazil: rare in layers MP-3318, MP-3429, MP-3434 (Fig. 20).

Family CANDONIDAE Kaufmann, 1900

Subfamily CYCLOCYPRIDINAE Kaufmann, 1900

Genus *Damonella* Anderson, 1966

Type species. *Cypris pygmaea* Anderson, 1940.

Remarks. The classification above subfamily follows Liebau (2005), and the rest follows Carignano et al. (2017). Originally, *Damonella* Anderson, 1966 was attributed to the Ilyocyprididae Family

Kaufmann, 1900, however Carignano et al. (2017) repositioned the genus in the Cycloocypridinae Subfamily Kaufmann, 1900, Candonidae Family Kaufmann, 1900. Such reattribution was due to the genus' muscle scar pattern, the narrow internal lamellae, with an internal margin subparallel to the external margin. Additionally, the inclusion of the genus in the Cycloocypridinae Subfamily is supported by the outline of the carapace, in lateral and dorsal views, in which the greatest height is behind the medium region, and there is the presence of a narrow internal lamellae, as well as absence of anterior beak (Carignano et al., 2017).

Damonella aff. *Damonella ultima* (Krömmelbein and Weber, 1971)

Figura 15, J-L

1971 *Reoncavona? ultima* Krömmelbein and Weber, p. 86, pl. 9, Fig. 39 a-c.

1987 *Reoncavona? cf. ultima* Krömmelbein and Weber; Hechem et al., p. 15, Fig. 2C.

1989 *Reoncavona? ultima* Krömmelbein and Weber; Musacchio, p. 843, pl. 2, Figs. 10-11.

2014 *Damonella ultima* (Krömmelbein and Weber); Tomé et al., p. 161, Fig. 7 T-X.

2017 *Damonella ultima* (Krömmelbein and Weber); Carignano et al., p. 214, Fig. 5 Q-T; p. 215, Fig. 7 A-E.

2022 *Reoncavona? ultima* Krömmelbein and Weber; Bate et al., p. 81, fig. 12, 4 a-c.

Holotype. Carapace (BfB, type Nr. 7813), core SV-1-BA, 1.065-1.110 m depth, Recôncavo basin, Bahia State, Brazil (Krömmelbein and Weber, 1971).

Occurrence. Argentina: Upper section of the Pozo D-129 Formation, Golfo de São Jorge basin, Sierra Silva, Chubut Province; YPF Core Codo del Senguerr x-1, Pozo D-129 Formation, Golfo de São Jorge basin, Santa Cruz Province; upper Barremian-Aptian (Carignano et al., 2017). Brazil: mid-upper section of the São Sebastião Formation, Recôncavo basin (Krömmelbein and Weber, 1971), Jiquiá Stage (Tomé et al., 2014), upper Barremian-lower Aptian (Silva et al., 2007); deposits from the Jatobá basin, Serra Negra, correlated to the Crato Formation, upper Aptian (Tomé et al., 2014); Zone *Petrobrasias diversicostata*, NRT-O09, with occurrence in the *Bisulcoypris postangularis* Subzone, NRT-O09.1, and the *Cypridea (Sebastianites) fida minor* Zone, NRT-O08, with occurrences well marked in subzones *Cypridea (Sebastianites?) mira*, NRT-O08-3, and *Petrobrasias capivarensis*, NRT-O08.2, and occurrence in the *Cypridea (Sebastianites?) sostensis sostensis* Subzone, NRT-O08.1 (Viana et al., 1971; Cunha and Moura, 1979), upper Barremian (Caixeta et al., 1994); São Francisco basin, Quiricó Formation, Lower Cretaceous, Barremian, in present thesis.

Stratigraphic range. Barremian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. Four intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, southeastern Brazil: rare in layers MP-3851, MP-3856; frequent in layer MP-3854; abundant in layer MP-3854 (Fig. 17). Six intervals from the São Bento Farm, Carmo do Paranaíba, Minas Gerais State, southeastern Brazil: rare in layers MP-4134, MP-4167, MP-4171; frequent in layers MP-4169, MP-4172; abundant in layer MP-4170 (Fig. 18).

Illustrated material. 0.738 mm length, 0.453 mm height, 0.259 mm width.

Remarks. Originally, the species was attributed to *Reconconvona* Krömmelbein, 1962, however with reservations. Posteriorly, Tomé et al. (2014), from the internal view of loose valves, described the internal morphology, including small teeth at the cardinal angle of the right valve; this characteristic was also described by Anderson (1966) for *Damonella denticulata* Anderson (1966). Additionally, Tomé et al. (2014) observed several similarities of *Damonella ultima* with *Damonella? tinkoussouensis* Grosdidier, 1967, and reattributed the species to the *Damonella* Genus. The specimens recovered are poorly preserved or dissolved.

Suborder DARWINULOCOPINA Sohn, 1988

Superfamily DARWINULOIDEA Brady and Norman, 1889

Family DARWINULIDAE Brady and Norman, 1889

Genus *Penthesilenula* Rossetti and Martens, 1998

Type species. *Darwinula incae* Delachaux, 1928 (Rossetti and Martens, 1998).

Remarks. The classification follows Liebau (2005). A taxonomic review of Darwinulidae from Recent and Holocene resulted in the description of three new genera: *Alicenula* Rossetti and Martens, 1998, *Vastalenula* Rossetti and Martens, 1998, *Penthesilenula* Rossetti and Martens, 1998 (Rossetti and Martens, 1998). *Penthesilenula* Rossetti and Martens, 1998 differs from *Darwinula* Brady and Robertson, 1885 and *Alicenula* Rossetti and Martens, 1998 on the square shape of the carapace in lateral view, and the presence of internal teeth on the left valve. The height-length ratio shows that the greatest height is near the middle portion of the carapace, giving a less elongated and more sub-quadrated outline when compared to other genera of Darwinulidae.

Penthesilenula martinsi (Silva, 1978)

Figura 15, M

1978 *Darwinula martinsi* Silva, p. 1031, pl. 1, Figs 1, 2.

2004a *Darwinula* sp. 4 Do Carmo et al., p. 144, Fig. 4.13–4.18.

2004b *Darwinula martinsi* Silva; Do Carmo et al., p. 155, Fig. 3.21–3.27.

2018 *Penthesilenula martinsi* (Silva); Leite et al., p. 14, fig. 6 1-3.

Holotype. Carapace (Nº. 42), Santana Formation, Crato municipality, Ceará State, Brazil (Silva, 1978).

Occurrence. Brazil: Araripe basin, Santana Formation, Crato Member and base of the Ipubi Member (Silva, 1978; Silva-Telles Jr. and Viana, 1990; Colin and Dépêche, 1997), Aptian (Coimbra et al., 2002); Potiguar basin, Alagamar Formation, middle-upper Aptian (Do Carmo et al., 2013); São Francisco basin, Quiricó Formation, Lower Cretaceous, Valanginian (Leite et al., 2018), Valanginian-Aptian, present thesis.

Stratigraphic range. Valanginian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), three intervals from the hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, southeastern Brazil: abundant in layers MP 3318, MP 3428, MP 3436 (Fig. 20). In the present thesis, five intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, southeastern Brazil: rare in layers MP-3798, MP-3851, MP-3854; abundant in layers MP-3853, MP-3856 (Fig. 17). In the present thesis, five intervals from the São Bento Farm, Carmo do Paranaíba, Minas Gerais State, southeastern Brazil: rare in layers MP-4184; abundant in layers MP-4167, MP-4170, MP-4172, MP-4174 (Fig. 18). In the present thesis, two intervals from the Sono river, João Pinheiro, Minas Gerais State, southeastern Brazil: rare in layers MP-4012; abundant in layers MP-4011 (Fig. 19).

Illustrated material. 0.615 mm length, 0.277 mm height, 0.230 mm width.

Remarks. The type material for *Darwinula martinsi* Silva, 1978 is misplaced, therefore the species was redescribed from the type locality by Do Carmo et al. (2004b), which determined neotypes. Tomé et al. (2014) considered this species as a junior synonym for *Alicenula leguminella* (Forbes in Lyell, 1855). However, the material illustrated by Tomé et al. (2014) differs from *Alicenula leguminella* do to the narrowly rounded anterior and other diagnostic characteristics. Leite et al. (2018) analyzed the neotypes identified as *Darwinula martinsi*, and reassigned the species to *Penthesilenula martinsi* (Silva, 1978), based on the sub-quadrate shape of the carapace in lateral view. Also, the height/length ratio is about de 0.5 mm (Ballent and Díaz, 2012).

Penthesilenula pintoi Leite et al., 2018

Figure 15, N

2018 *Penthesilenula pintoi* Leite et al., p. 14 fig. 6 4-7.

Holotype. Carapace (CP-871), Quiricó Formation, banks of the São José creek, São José Farm, Presidente Olegário, Minas Gerais State, Brazil (Leite et al., 2018).

Occurrence. Brazil: São Francisco basin, Quiricó Formation, Lower Cretaceous, Valanginian-Aptian (Leite et al., 2018), Berriasian-Aptian, present thesis.

Stratigraphic range. Berriasian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. Ten intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, southeastern Brazil. In Leite et al. (2018), rare in layer MP 2884; abundant in layers MP 2895, MP 2960. In the present thesis, rare in layers MP-3805, MP-3851; frequent in layers MP-3803, MP-3854; abundant in layers MP-3853, MP-3855, MP-3856 (Fig. 17). In Leite et al. (2018), 22 intervals from the hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, southeastern Brazil: rare in layers MP 3322, MP 3323, MP 3325, MP 3328, MP 3333, MP 3427, MP 3438, MP 3448; frequent in layers MP 3335, MP 3433; abundant in layers MP 3326, MP 3327, MP 3340, MP 3428, MP 3429, MP 3431, MP 3434, MP 3436, MP 3437, MP 3439, MP 3442, MP 3443 (Fig. 20). In Leite et al. (2018), one interval from the São José Farm section, Presidente Olegário County, Minas Gerais State, southeastern Brazil: rare in layer MP 3421 (Fig. 21). In the present thesis, ten intervals from the São Bento Farm, Carmo do Paranaíba, Minas Gerais State, southeastern Brazil: rare in layers MP-4155, MP-4168; frequent in layers MP-4169, MP-4181, MP-4183; abundant in layers MP-4166, MP-4167, MP-4170, MP-4174, MP-4184 (Fig. 18). In the present thesis, two intervals from the Sono river, João Pinheiro, Minas Gerais State, southeastern Brazil: abundant in layers MP-4012 and MP-4011 (Fig. 19).

Illustrated material. 0.719 mm length, 0.323 mm height, 0.268 mm width.

Remarks. Differs from *Penthesilenula martinsi* (Silva, 1978) due to its elongated shape, and anterior end narrowly rounded. The specimens of *Penthesilenula pintoi* recovered are closed carapaces, however, due to its sub-oval to sub-rectangular outline in lateral view and broadly rounded anterior end, when compared to *Alicenula* or *Darwinula*, it is possible to consider this generic attribution. Qin et al. (2018) identified a species of Darwinulid as *Alicenula leguminella* (Forbes in Lyell, 1855), however due to its sub-rectangular shape in lateral view it is possible to attribute this species to the *Penthesilenula* Genus, furthermore, it presents the dorsal margin slightly curved with a well-marked

inclination to the anterior margin, and a small concavity by the end of the first third, very similar to *Penthesilenula pintoii*, although it is larger in size.

Genus *Alicenula* Rossetti and Martens, 1998 emend. Leite et al., 2018

Type species. *Darwinula serricaudata* Klie, 1935 (Rossetti and Martens, 1998).

Remarks. The classification follows Liebau (2005). *Alicenula* was not originally described presenting teeth on the internal surface of the left valve. However, it was shown that species belonging to this genus present one anteroventral tooth near the interior margin and one tooth at the posterior caudal internal surface of the left valve (Martens et al., 2003; Ballent and Díaz, 2012). Leite et al. (2018) proposed a new diagnosis for the genus. Both *Alicenula* and *Darwinula* are elongated in lateral view, but differ in size and internal characteristics, considering that *Alicenula* has internal teeth on the left valve.

Alicenula longiformis Leite et al., 2018

Figure 15, O

2018 *Alicenula longiformis* Leite et al., p. 14, fig. 6 8-11.

Holotype. Carapace (CP-872), Quiricó Formation, Tereza Farm, João Pinheiro, Minas Gerais State, Brazil (Leite et al., 2018).

Occurrence. Brazil: São Francisco basin, Quiricó Formation, Lower Cretaceous, Valanginian to Barremian? (Leite et al., 2018), Valanginian-Barremian, present thesis.

Stratigraphic range. Valanginian-Barremian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), nine intervals from the hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, southeastern Brazil: rare in layer MP 3448; frequent in layers MP 3433, MP 3439, MP 3443; abundant in layers MP 3318, MP 3327, MP 3428, MP 3431, MP 3434 (Fig. 20). In Leite et al. (2018), one interval from the São José Farm Section, Presidente Olegário County, Minas Gerais State, southeastern Brazil: rare in layer MP 3421 (Fig. 21). In the present thesis, four intervals from the stratotype section of the Quiricó Formation, Presidente Olegário, Minas Gerais State, southeastern Brazil: rare in layers MP-3803, MP-3854, MP-3856; frequent in layer MP-3853 (Fig. 17). In the present thesis, six intervals from the São Bento Farm, Carmo do Paranaíba, Minas Gerais State, southeastern Brazil: rare in layers MP-4166, MP-4168, MP-4172; abundant in layers MP-4167, MP-4170, MP-4174 (Fig. 18). In the present thesis, two intervals from the Sono river, João

Pinheiro, Minas Gerais State, southeastern Brazil: rare in layer MP-4012; abundant in layer MP-4011 (Fig. 19).

Illustrated material. 0.731 mm length, 0.298 mm height, 0.258 mm width.

Remarks. Differs from *Penthesilenula martinsi* (Silva, 1978) due to its elongated shape, and narrowly rounded anterior end. The specimens recovered from the Quiricó Formation occur as closed carapaces, therefore it is not possible to analyze the internal structure, however, they are positioned in the *Alicenula* Genus.

Suborder CYTHEROCOPINA Gründel, 1967

Superfamily LIMNOCYTHEROIDEA Liebau, 2005

Family LIMNOCYTHERIDAE Klie, 1938

Subfamily TIMIRIASEVIINAE Mandelstam, 1947

Genus *Timiriasevia* Mandelstam, 1947

Type species. *Timiriasevia epidermiformis* Mandelstam, 1947.

Remarks. The supra-subfamiliar classification follows Liebau (2005). Sames (2009, 2011) is followed for subfamily and other categories. The Genus *Timiriasevia* Mandelstam, 1947, common in Cretaceous limnic deposits worldwide, has not been documented or recorded in Cretaceous sediments from the United States yet, however, it is found in Upper Jurassic sediments. This absence might result from misidentifications as *Metacypris* Brady and Robertson, 1870, due to the morphological similarities of young specimens of both genera (Sames, 2009, 2011). *Timiriasevia* Mandelstam, 1947, *Theriosynoecum* Branson, 1936, and *Metacypris* Brady and Robertson, 1870 are members of the subfamily Timiriaseviinae, due to the presence of simple porecanals, and an evident egg pouch in females. The nonsulcate genera *Gomphocythere* Sars, 1924 and *Timiriasevia* Mandelstam, 1947, as well as some species of the monosulcate *Metacypris* Brady and Robertson, 1870, usually have some indication of sulcus, such as a wide and shallow depression, causing a lateral constriction anteriorly in dorsal view. Females of *Timiriasevia* and *Metacypris* differ in dorsal view. *Metacypris* has a cordiform shape, while *Timiriasevia* is elongated oval to piriform with a small lateral constriction anteriorly. Moreover, *Metacypris* has a weak sulcus, which is absent in *Timiriasevia*.

Timiriasevia sanfranciscanensis Leite et al., 2018

2018 *Timiriasevia sanfranciscanensis* Leite et al., p. 14, fig. 6 12-18.

Holotype. Female carapace (CP-843), Quiricó Formation, Tereza Farm, João Pinheiro, Minas Gerais State, Brazil (Leite et al., 2018).

Occurrence. Brazil: hypostratotype section of the Tereza Farm section, João Pinheiro County, Minas Gerais State, Brazil, Quiricó Formation, Areado Group, São Francisco Basin, Lower Cretaceous, Valanginian (Leite et al., 2018), Berriasian-Valanginian, present thesis.

Stratigraphic distribution. Berriasian-Valanginian (based on the above listed occurrence and on data from the present thesis).

Materials. In Leite et al. (2018), four intervals from the hypostratotype section of the Tereza Farm, João Pinheiro, Minas Gerais State, Brazil: rare in layers MP-3318, MP-3322, MP-3433; frequent in layer MP-3427 (Fig. 20).

Subfamily LIMNOCYTHERINAE Klie, 1938

Genus *Wolburgiopsis* Uliana and Musacchio, 1978

Type species. *Wolburgia? neocretacea* Bertels, 1972.

Remarks. The classification above subfamily follows Liebau (2005), and the rest follows Carignano and Cusminsky (2015). Originally, *Wolburgiopsis* Uliana and Musacchio, 1978 was attributed to the Cytheroidea Baird, 1850 Superfamily, with familiar attribution uncertain. However, with similarities with Limnocytheridae Klie, 1938 Family, mainly regarding muscle scar pattern and presence of sub-vertical sulci (Do Carmo et al., 2004a). Carignano and Cusminsky (2015) repositioned the genus in the Limnocytherinae Klie, 1938 Subfamily, Limnocytheridae Klie, 1938 Family. The reattribution is due to the calcification of the carapace; sexual dimorphism, in which females don't present incubation pouch; vertical sulcus; and anti-merodont hinge (Carignano and Cusminsky, 2015).

Wolburgiopsis plastica (Musacchio, 1970)

Figure 15, P-R

1970 *Wolburgia plastica* Musacchio, p. 303, pl. 1, Figs. 1-5.

2004a *Wolburgiopsis plastica* (Musacchio); Do Carmo et al., p. 144, Fig. 4.19.

Holotype. Carapace (MLP 11330), "Margas y Calizas" Member, La Amarga Formation, China Muerta hill, Neuquén Province, Argentina (Musacchio, 1970).

Occurrence. Argentina: “Margas y Calizas” Member, La Amarga Formation, Neuquén Province, Barremian (Musacchio, 1970; Do Carmo et al., 2004a). Brazil: São Francisco basin, Quiricó Formation, Lower Cretaceous, Barremian (Do Carmo et al., 2004a), Barremian-Aptian, present thesis. *Stratigraphic range.* Barremian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. Three intervals from the São Bento Farm, Carmo do Paranaíba, Minas Gerais State, southeastern Brazil: rare in layers MP-4171, MP-4175; abundant in layers MP-4170 (Fig. 18).

Illustrated material. 0.486 mm length, 0.232 mm height, 0.121 width.

Remarks. The species was originally attributed to the *Wolburgia* Anderson, 1966 Genus, however Uliana and Musacchio (1978) reattributed several species that occur in the Cretaceous from Argentina, previously attributed to *Wolburgia*, to the new genus *Wolburgiopsis*. Considering the small size of the carapace, sub-trapezoidal to sub-rectangular outline, and elongated shape, it is possible to distinguish *Wolburgiopsis plastica* (Musacchio, 1970) from other *Wolburgiopsis* species.

Wolburgiopsis chinamuertensis (Musacchio, 1970)

Figure 15, S-U

1970 *Wolburgia plastica* Musacchio, p. 303, pl. 1, Figs. 6-8.

2004a *Wolburgiopsis plastica* (Musacchio); Do Carmo et al., p. 144, Fig. 4.20.

Holotype. Carapace (MLP 11336), “Margas y Calizas” Member, La Amarga Formation, China Muerta hill, Neuquén Province, Argentina (Musacchio, 1970).

Occurrence. Argentina: “Margas y Calizas” Member, La Amarga Formation, Neuquén Province, Barremian (Musacchio, 1970; Do Carmo et al., 2004a). Brazil: São Francisco basin, Quiricó Formation, Lower Cretaceous, Barremian (do Carmo et al., 2004a), Barremian-Aptian, present thesis. *Stratigraphic range.* Barremian-Aptian (based on the above listed occurrence and on data from the present thesis).

Materials. Three intervals from the São Bento Farm, Carmo do Paranaíba, Minas Gerais State, southeastern Brazil: rare in layers MP-4174, MP-4175; frequent in layer MP-4170 (Fig. 18).

Illustrated material. 0.366 mm length, 0.204 mm height, 0.134 mm width.

Remarks. The species was originally attributed to the *Wolburgia* Anderson, 1966 Genus, however Uliana and Musacchio (1978) reattributed several species that occur in the Cretaceous from Argentina, previously attributed to *Wolburgia*, to the new genus *Wolburgiopsis*. Considering the small size of the

carapace, sub-trapezoidal outline, and presence of nodules, it is possible to distinguish *Wolburgiopsis chinamuertensis* (Musacchio, 1970) from other *Wolburgiopsis* species.

6. STRATIGRAPHIC DISTRIBUTION OF OSTRACOD ASSEMBLAGE

Twenty-one species of ostracods were recovered in the five studied sections: stratotype section of the Quiricó Formation; hypostratotype section of the Tereza Farm; São Bento Farm section; Sono river section; and São José Farm section. The stratigraphic distribution of recovered ostracods in the hypostratotype section of the Tereza Farm and of the São José Farm section is approached in detail by (Leite, 2017; Leite et al., 2018), and will be summed up herein. The stratigraphic distribution of species from the stratotype, the Tereza Farm and the São Bento Farm sections is presented in the article entitled “BIOSTRATIGRAPHY OF LIMINIC OSTRACODA (CRUSTACEA) FROM THE QUIRICÓ FORMATION, LOWER CRETACEOUS OF THE SÃO FRANCISCO BASIN, MINAS GERAIS STATE, SOUTHEAST BRAZIL: AN APPROACH ON PALEOZOOGEOGRAPHIC EVOLUTION OF GONDWANA” (Leite et al., to be submitted. Appendix 1).

The recovered ostracod species are: 1. *Harbinia* aff. *Harbinia angulata* (Krömmelbein and Weber, 1971); 2. *Harbinia symmetrica* (Krömmelbein and Weber, 1971); 3. *Harbinia* aff. *Harbinia salitrensis* (Krömmelbein and Weber, 1971); 4. *Harbinia alta* Antonietto et al., 2012; 5. *Harbinia* aff. *Harbinia crepata* Do Carmo et al., 2013; 6. *Brasacypris ovum* Krömmelbein, 1965b; 7. *Brasacypris* aff. *Brasacypris morigerata* Musacchio, 1973; 8. *Brasacypris fulfaroi* Dias-Brito et al., 2001; 9. *Cypridea hystrix* Krömmelbein, 1962; 10. *Cypridea conjugata* Krömmelbein and Weber, 1971; 11. *Cypridea* aff. *Cypridea infima* Krömmelbein and Weber, 1971; 12. *Cypridea* aff. *Cypridea jequiensis* Krömmelbein and Weber, 1971; 13. *Cypridea* sp.; 14. *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni, 1991; 15. *Damonella* aff. *Damonella ultima* (Krömmelbein and Weber, 1971); 16. *Penthesilenula martinsi* (Silva, 1978); 17. *Penthesilenula pintoi* Leite et al., 2018; 18. *Alicenula longiformis* Leite et al., 2018; 19. *Timiriasevia sanfranciscanensis* Leite et al., 2018; 20. *Wolburgiopsis plastica* (Musacchio, 1970); 21. *Wolburgiopsis chinamuertensis* (Musacchio, 1970).

In the stratotype section of the Quiricó Formation, 11 species were recovered: 1. *Penthesilenula pintoi*; 2. *Brasacypris ovum*; 3. *Harbinia* aff. *Harbinia salitrensis*; 4. *Harbinia* aff. *Harbinia angulata*; 5. *Harbinia alta*; 6. *Harbinia* aff. *Harbinia crepata*; 7. *Harbinia symmetrica*; 8. *Penthesilenula martinsi*; 9. *Alicenula longiformis*; 10. *Damonella* aff. *Damonella ultima*; and 11. *Brasacypris fulfaroi*. The upper portion of the section, approached by Leite et al. (2018), is marked by the occurrence of assemblages of *Harbinia* Tsao, 1959 emend. Hou, 1984, as well as the occurrence of *Penthesilenula*

pintoi and *Brasacypris ovum*. The middle portion of the section encompasses the intervals with the greatest number of species, with the predominance of species of *Harbinia* and of *Penthesilenula pintoi*, and with the occurrence of *Brasacypris ovum*, *Penthesilenula martinsi*, *Alicenula longiformis*, *Damonella* aff. *Damonella ultima* and *Brasacypris fulfaroi*. No ostracods were recovered in the lower portion of the Quiricó Formation. Both *Penthesilenula pintoi* and *Brasacypris ovum*, occur all through the fossiliferous sequence, and *Penthesilenula pintoi* is the species with the greatest number of specimens (Fig. 17) (Leite et al., to be submitted. Appendix 1).

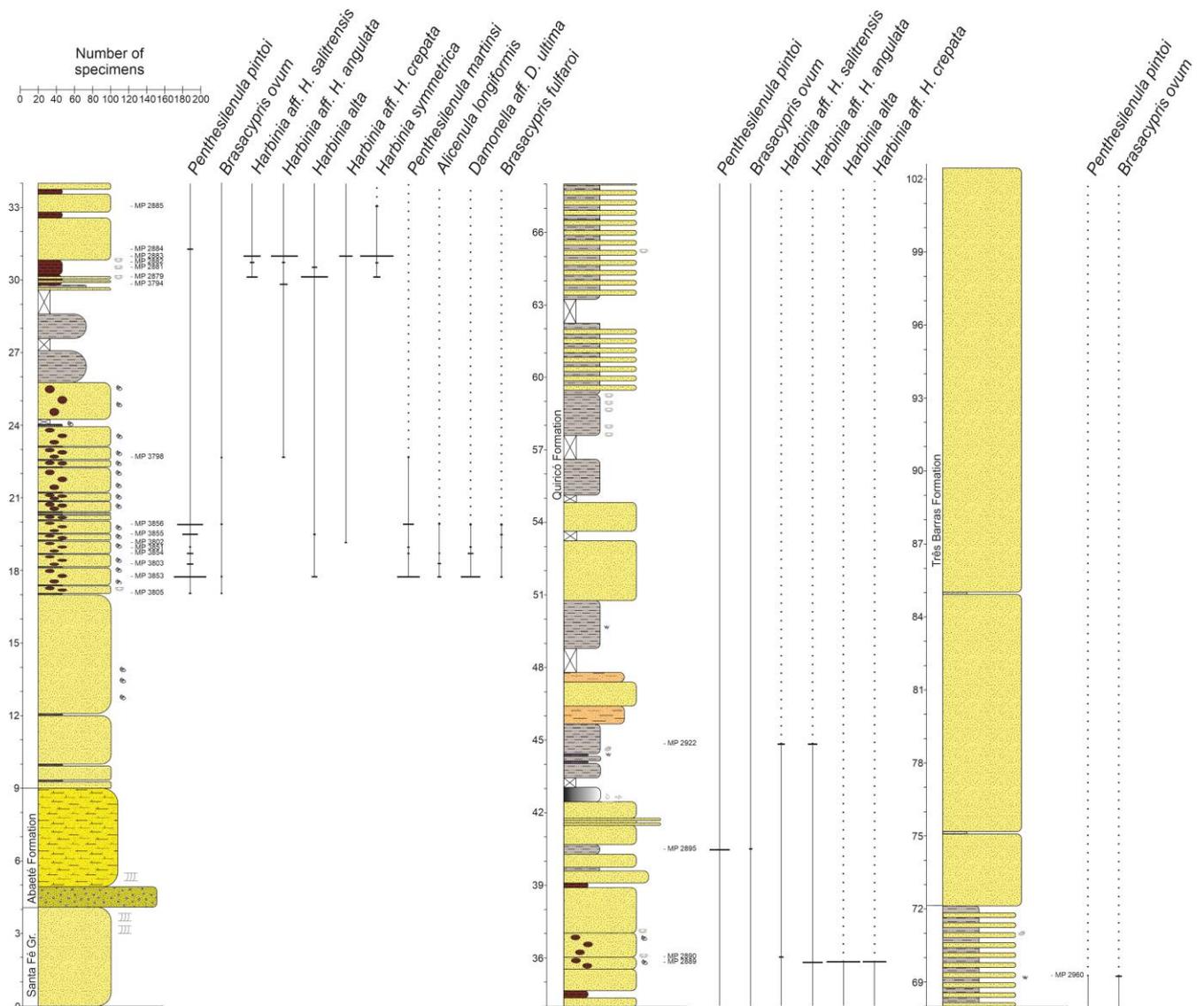


Figure 17. Stratigraphic distribution and number of ostracod specimens recovered in the stratotype section of the Quiricó Formation, Presidente Olegário County, Minas Gerais State, Brazil (modified from Leite et al., to be submitted. Appendix 1).

In the São Bento Farm section, eight species were recovered: 1. *Brasacypris ovum*; 2. *Brasacypris fulfaroi*; 3. *Penthesilenula martinsi*; 4. *Penthesilenula pinto*; 5. *Wolburgiopsis plastica*; 6. *Wolburgiopsis chinamuertensis*; 7. *Alicenula longiformis*; and 8. *Damonella* aff. *Damonella ultima*. The *Harbinia* spp. is not one species, but assemblages of specimens of *Harbinia* that were not identified at species level. The middle portion of the section encompasses the intervals with the greatest number of species, with the predominance of *Penthesilenula martinsi*, *Penthesilenula pinto* and *Alicenula longiformis*. In the upper portion, *Brasacypris ovum* and *Brasacypris fulfaroi*, occur in only one level. In the lower portion of the fossiliferous sequence, there is the occurrence of *Damonella* aff. *Damonella ultima*. This section is the only one with the occurrence of *Wolburgiopsis plastica* and *Wolburgiopsis chinamuertensis* (Fig. 18) (Leite et al., to be submitted. Appendix 1).

In the Sono river section, six species were recovered: 1. *Penthesilenula martinsi*; 2. *Penthesilenula pinto*; 3. *Alicenula longiformis*; 4. *Brasacypris ovum*; 5. *Brasacypris fulfaroi*; 6. *Brasacypris* aff. *B. morigerata*. The intervals with the greatest abundance of species and the greatest number of specimens are concentrated in the upper portion of the section, with *Penthesilenula martinsi*, *Penthesilenula pinto*, *Alicenula longiformis*, *Brasacypris ovum* and *Brasacypris fulfaroi*. *Brasacypris* aff. *Brasacypris morigerata* occurs in the base of the section, in assemblage with *Brasacypris ovum* and *Brasacypris fulfaroi* (Fig. 19).

In the hypostratotype section of the Tereza Farm, 12 species were recovered: 1. *Penthesilenula pinto*; 2. *Alicenula longiformis*; 3. *Cypridea* aff. *Cypridea infima*; 4. *Brasacypris fulfaroi*; 5. *Brasacypris ovum*; 6. *Cypridea hystrix*; 7. *Penthesilenula martinsi*; 8. *Cypridea conjugata*; 9. *Neuquenocypris* (*Protoneuquenocypris*) *antiqua*; 10. *Cypridea* aff. *Cypridea jequiensis*; 11. *Timiriasevia sanfranciscanensis*; *Cypridea* sp. (Fig. 20) (Leite et al., to be submitted. Appendix 1).

In the São José farm section, four species were recovered: 1. *Penthesilenula pinto*; 2. *Alicenula longiformis*; 3. *Brasacypris fulfaroi*; 4. *Brasacypris ovum* (Fig. 21) (Leite et al., to be submitted. Appendix 1).

Of the 21 species, only four occur in all five studied sections: *Penthesilenula pinto*, *Brasacypris ovum*, *Alicenula longiformis* and *Brasacypris fulfaroi*. All species of *Cypridea*, *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* and *Timiriasevia sanfranciscanensis* are exclusive of the Tereza Farm section. *Brasacypris* aff. *Brasacypris morigerata* is exclusive of the Sono river section. *Damonella* aff. *Damonella ultima* only occurs in the stratotype section and in the São Bento Farm section (Tab. 3).

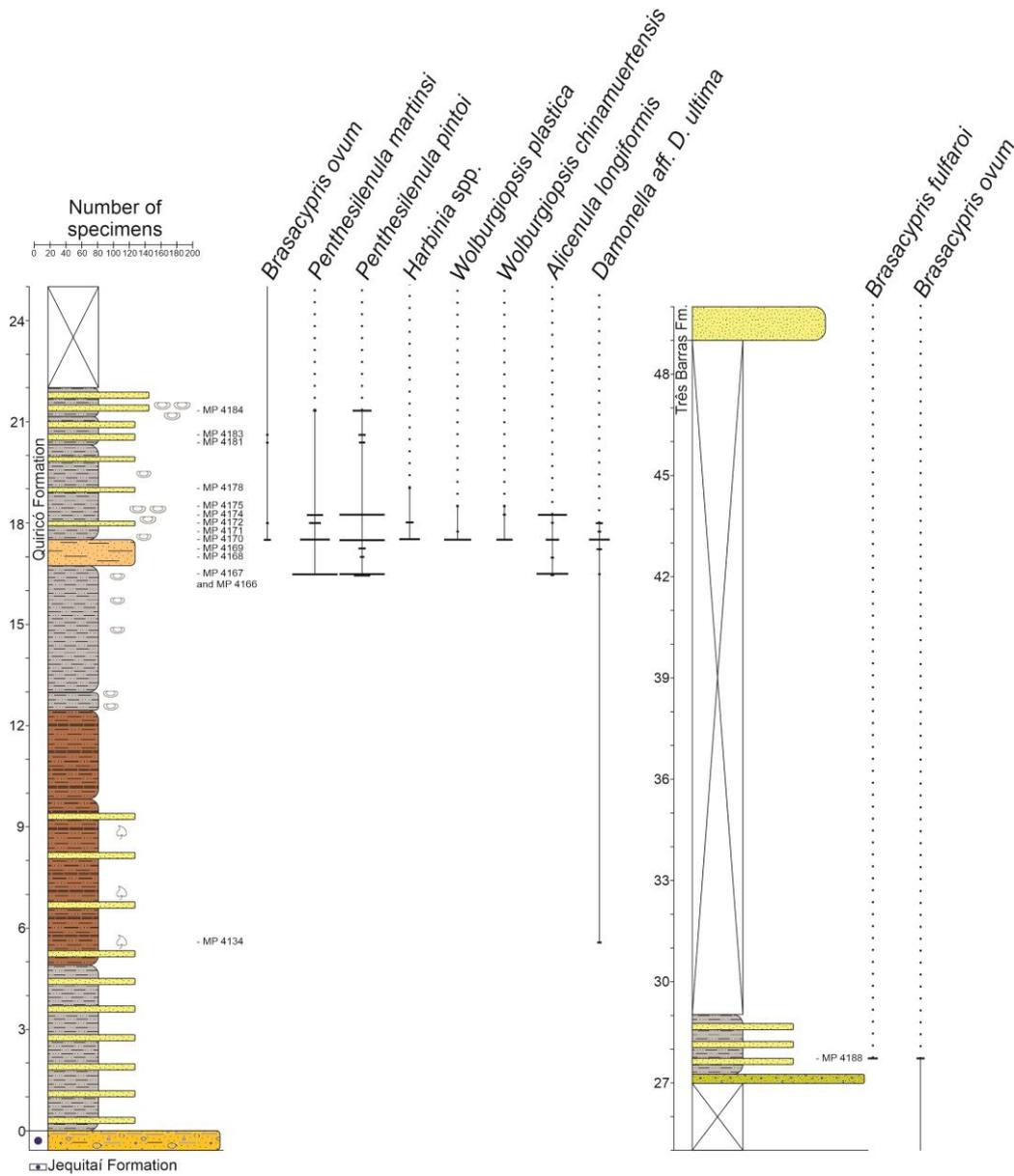


Figure 18. Stratigraphic distribution and number of ostracod specimens recovered in the São Bento Farm section, Carmo do Paranaíba County, Minas Gerais State, Brazil (modified from Leite et al., to be submitted. Appendix 1).

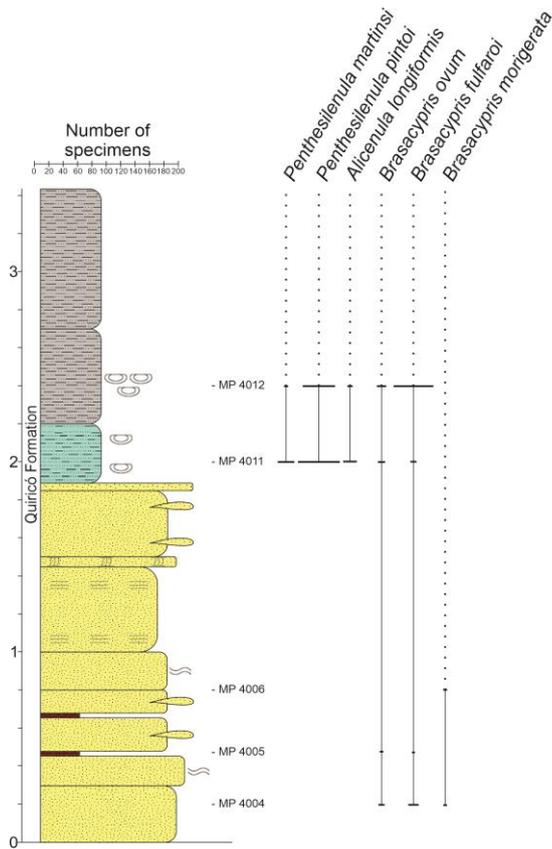


Figure 19. Stratigraphic distribution and number of ostracod specimens recovered in the Sono river section, João Pinheiro County, Minas Gerais State, Brazil.

Table 3. Ostracod species occurrence in the five studied sections.

Stratotype section	São Bento Farm section	Sono river section	Tereza Farm section	São José Farm section
<i>Harbinia</i> aff. <i>Harbinia angulata</i>				
<i>Harbinia</i> <i>symmetrica</i>				
<i>Harbinia</i> aff. <i>Harbinia salitrensis</i>				
<i>Harbinia alta</i>				
<i>Harbinia</i> aff. <i>Harbinia crepata</i>				
<i>Brasacypris ovum</i>	<i>Brasacypris ovum</i>	<i>Brasacypris ovum?</i>	<i>Brasacypris ovum?</i>	<i>Brasacypris ovum</i>
		<i>Brasacypris</i> aff. <i>Brasacypris</i> <i>morigerata</i>		
<i>Brasacypris</i> <i>fulfaroi</i>	<i>Brasacypris</i> <i>fulfaroi</i>	<i>Brasacypris</i> <i>fulfaroi</i>	<i>Brasacypris fulfaroi</i>	<i>Brasacypris</i> <i>fulfaroi</i>
			<i>Cypridea hystrix</i>	
			<i>Cypridea conjugata</i>	
			<i>Cypridea</i> aff. <i>Cypridea infima</i>	
			<i>Cypridea</i> aff. <i>Cypridea jequiensis</i>	
			<i>Cypridea</i> sp.	
			<i>Neuquenocypris</i> (<i>Protoneuquenocypris</i>) <i>antiqua</i>	
<i>Damonella</i> aff. <i>Damonella ultima</i>	<i>Damonella</i> aff. <i>Damonella ultima</i>			
<i>Penthesilenula</i> <i>martinsi</i>	<i>Penthesilenula</i> <i>martinsi</i>	<i>Penthesilenula</i> <i>martinsi</i>	<i>Penthesilenula</i> <i>martinsi</i>	
<i>Penthesilenula</i> <i>pintoi</i>	<i>Penthesilenula</i> <i>pintoi</i>	<i>Penthesilenula</i> <i>pintoi</i>	<i>Penthesilenula pintoi</i>	<i>Penthesilenula</i> <i>pintoi</i> (Leite et al., 2018)
<i>Alicenula</i> <i>longiformis</i>	<i>Alicenula</i> <i>longiformis</i>	<i>Alicenula</i> <i>longiformis</i>	<i>Alicenula longiformis</i>	<i>Alicenula</i> <i>longiformis</i>
			<i>Timiriasevia</i> <i>sanfranciscanensis</i> (Leite et al., 2018)	
	<i>Wolburgiopsis</i> <i>plastica</i>			
	<i>Wolburgiopsis</i> <i>chinamuertensis</i>			

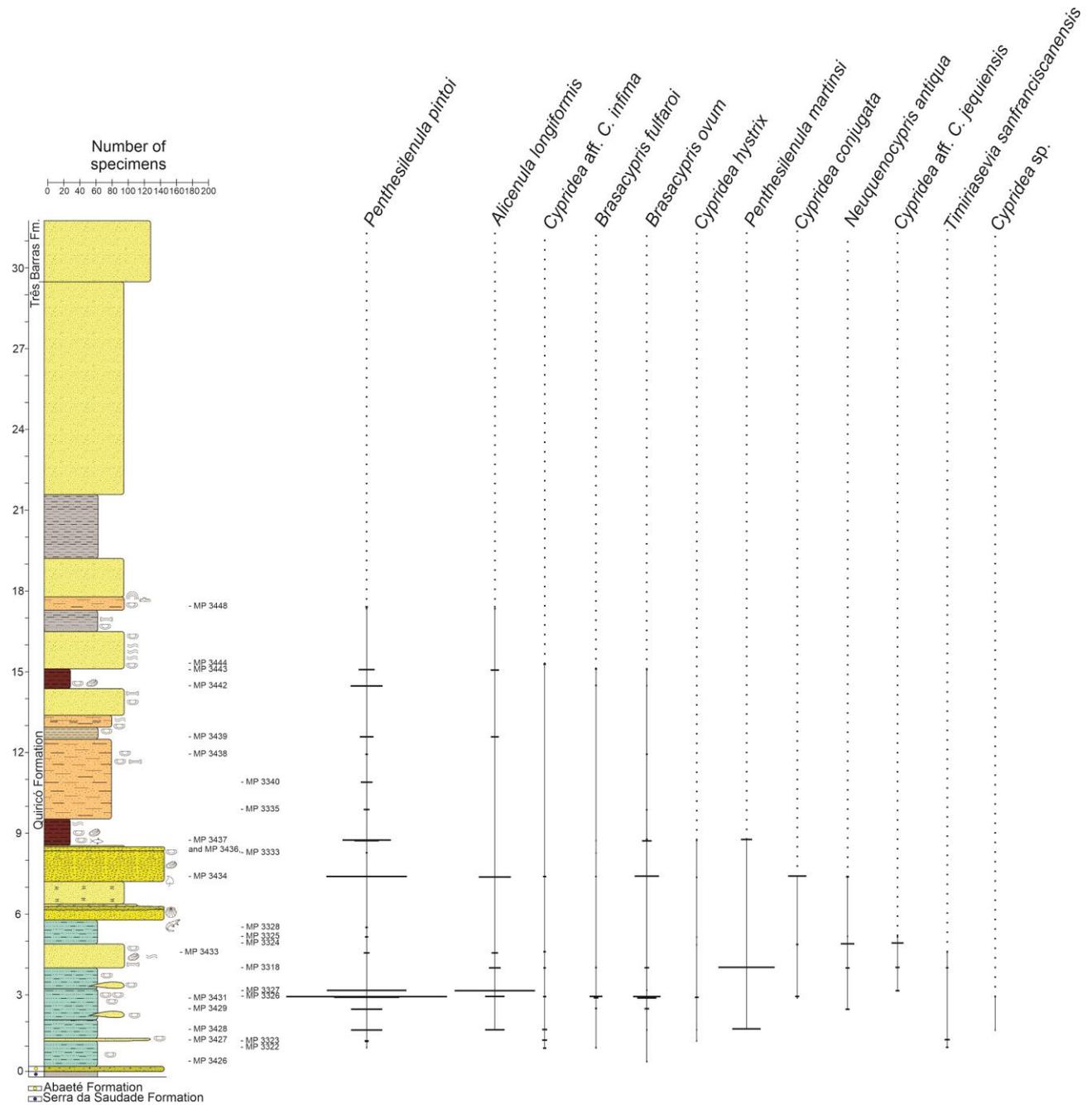


Figure 20. Stratigraphic distribution and number of ostracod specimens recovered in the hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, Brazil (Leite et al., to be submitted. Appendix 1).

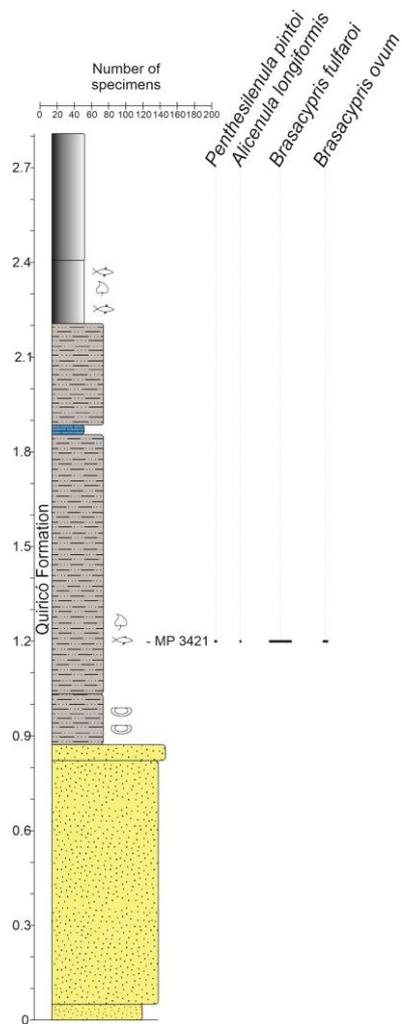


Figure 21. Stratigraphic distribution and number of ostracod specimens recovered in the São José Farm section, Presidente Olegário County, Minas Gerais State, Brazil.

7. BIOESTRATIGRAPHY

Three of the five studied sections were approached under the biostratigraphic perspective in the manuscript entitled “BIOSTRATIGRAPHY OF LIMINIC OSTRACODA (CRUSTACEA) FROM THE QUIRICÓ FORMATION, LOWER CRETACEOUS OF THE SÃO FRANCISCO BASIN, MINAS GERAIS STATE, SOUTHEAST BRAZIL: AN APPROACH ON PALEOZOOGEOGRAPHIC EVOLUTION OF GONDWANA” (Leite et al., to be submitted. Appendix 1). The sections approached due to the complete outcropping of the Quiricó Formation, with lower and upper contacts, are: stratotype section of the Quiricó Formation; hypostratotype section of the Tereza Farm; and São Bento Farm section. After the taxonomic analysis and integration of data with the studies by Leite (2017) and Leite et al. (2018), six biostratigraphic units are described and proposed, Zone *Brasacypris ovum*, OSF-0, and four zones within the *Penthesilenula pintoii* Superzone, OSF-1: 1. *Timiriasevia sanfranciscanensis* Zone, OSF-1.1; 2. *Cypridea hystrix* Zone, OSF-1.2; 3. *Alicenula longiformis* Zone, OSF-1.3; 4. *Harbinia* spp. Zone, OSF-1.4 (Fig. 22).

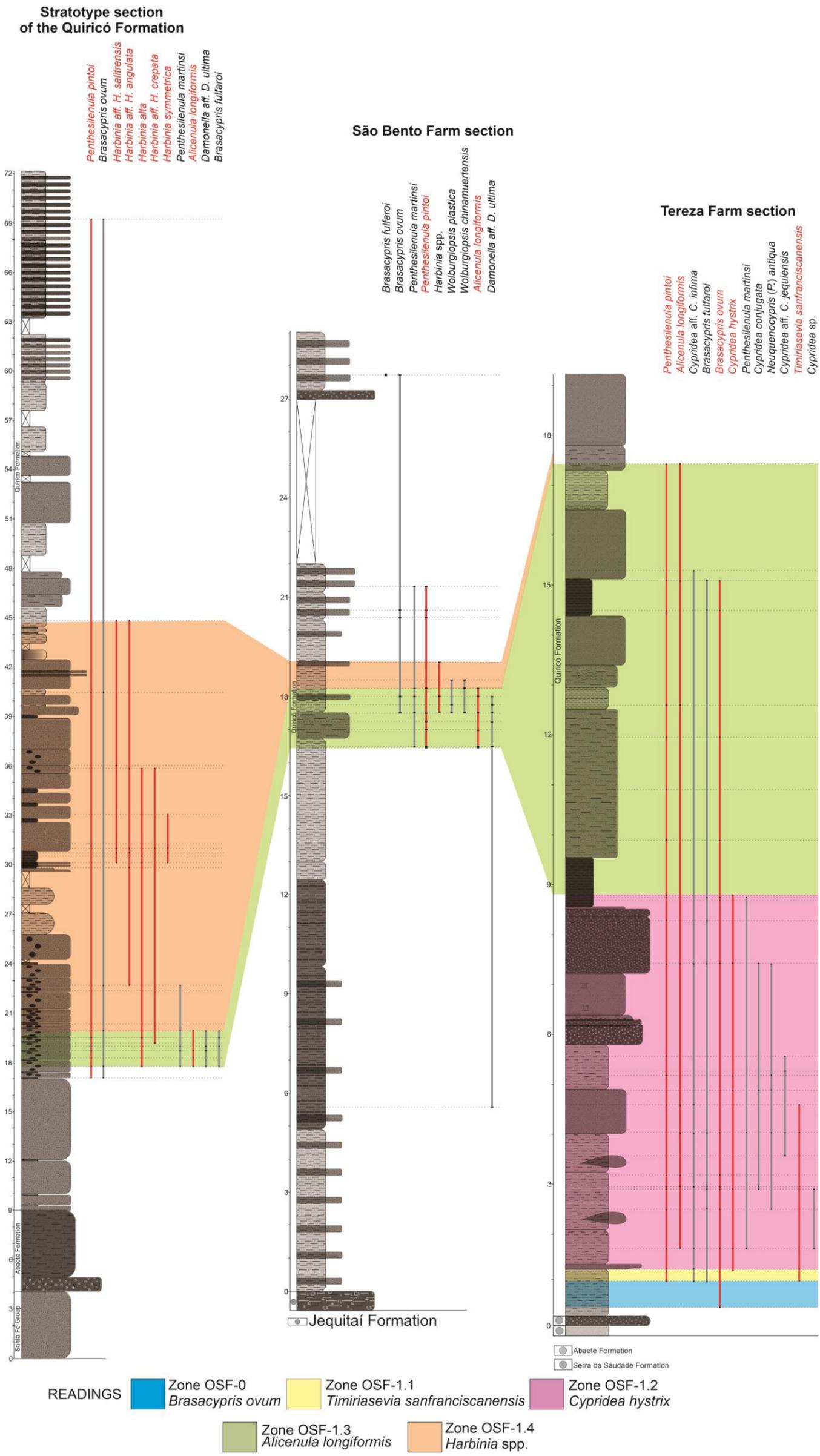


Figure 22. Lithostratigraphic logs of the stratotype section of the Quiricó Formation, São Bento Farm section and hypostratotype section of the Tereza Farm, with ostracod occurrences and biostratigraphic zones (Leite et al., to be submitted. Appendix 1).

The *Brasacypris ovum* Zone is a lowest-occurrence interval zone, which the lower and upper limits are defined by the first occurrences of *Brasacypris ovum* and *Timiriasevia sanfranciscanensis*, respectively. This zone only occurs at the hypostratotype section of the Tereza Farm (Fig. 22), it is the only zone not included in the *Penthesilenula pintoï* Superzone and it is the most basal zone of the Quiricó Formation. It corresponds to the Rio da Serra Local Stage O02 and is attributed to the Berriasian. The only species that occurs in this zone is *Brasacypris ovum*, which occurs in the Berriasian (Caixeta et al., 1994; Costa et al., 2007; Silva et al., 2007), of the Tucano basin, Itaparica and Candeias formations, attributed to the Rio da Serra Local Stage O02 (Krömmelbein, 1965b, 1966; Costa et al., 2007) (Leite et al., to be submitted. Appendix 1).

The *Penthesilenula pintoï* Superzone is a range zone, defined from the stratotype section of the Quiricó Formation and corresponds to the first and last occurrences of *Penthesilenula pintoï* (Fig. 22). The stratotype section of the Quiricó Formation and the São Bento Farm section encompass zones *Alicenula longiformis* and *Harbinia* spp. The hypostratotype section of the Tereza Farm encompasses zones *Timiriasevia sanfranciscanensis*, *Cypridea hystrix* and *Alicenula longiformis*. This superzone corresponds to local stages Rio da Serra O02, O03 and O04, Aratu O05, Buracica O08, Jiquiá O09, and Alagoas O11 and is attributed to the Berriasian-Aptian/Albian? interval. Specially in the stratotype section of the Quiricó Formation, upper portion of the fossiliferous interval, marked by only one level with *Penthesilenula pintoï* and *Brasacypris ovum* in assemblage, does not correspond to *Harbinia* spp. Zone, attributed to the Aptian. Therefore, the attribution of the top of the *Penthesilenula pintoï* Superzone to Aptian or post-Aptian is uncertain, that is why the top of this superzone is positioned in the Aptian/Albian? (Leite et al., to be submitted. Appendix 1).

The *Timiriasevia sanfranciscanensis* Zone is a lowest-occurrence interval zone, which the lower and upper limits are defined by the first occurrences of *Timiriasevia sanfranciscanensis* and *Cypridea hystrix*, respectively. This zone only occurs at the hypostratotype section of the Tereza Farm (Fig. 22). It corresponds to local stages Rio da Serra O02 and O03, and is attributed to the Berriasian. Species that occur in this zone are *Penthesilenula pintoï*, *Cypridea* aff. *Cypridea infima*, *Brasacypris fulfaroi* and *Brasacypris ovum*. Both *Brasacypris ovum* and *Cypridea* aff. *Cypridea infima* occur in the Berriasian (Caixeta et al., 1994; Costa et al., 2007; Silva et al., 2007), *Brasacypris ovum* in the Tucano basin, Itaparica and Candeias formations (Krömmelbein, 1965b, 1966) and *Cypridea* aff. *Cypridea infima* in the Recôncavo basin, Candeias Formation, lower and middle portions (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b). Therefore, the attribution of this zone to the Berriasian is based in the first occurrence of *Brasacypris ovum*, corroborated by the first occurrence of *Cypridea* aff. *Cypridea infima*. It is noteworthy that the niche occupied by species of the

Timiriaseviinae Subfamily suffered a decrease from the Late Jurassic-Early Cretaceous interval, which could be associated to the explosion of the Cypridoidea Superfamily (Collin and Danielopol, 1979). The appearance of *Timiriasevia sanfranciscanensis*, which occurs before the diversification of *Cypridea* in the stratotype, could be associated with the phenomenon described by Collin and Danielopol (1979), during the beginning of the Cretaceous, corroborated to the proposed age for this zone (Leite et al., to be submitted. Appendix 1).

The *Cypridea hystrix* Zone is a range zone defined by the first and last appearances of *Cypridea hystrix*. This zone only occurs at the hypostratotype section of the Tereza Farm (Fig. 22). It corresponds to local stages Rio da Serra O04 and Aratu O05, and is attributed to the Valanginian-Hauterivian interval. Species that occur in this zone are *Penthesilenula pintoii*, *Alicenula longiformis*, *Cypridea* aff. *Cypridea infima*, *Brasacypris fulfaroi*, *Brasacypris ovum*, *Penthesilenula martinsi*, *Cypridea conjugata*, *Neuquenocypris (Protoneuquenocypris) antiqua*, *Cypridea* aff. *Cypridea jequiensis*, *Timiriasevia sanfranciscanensis* and *Cypridea* sp. The Species *Cypridea hystrix* occurs in the Recôncavo basin, Ilhas Formation, attributed to the Valanginian-Hauterivian interval (Krömmelbein, 1962; Poropat and Colin, 2012b), and in the *Paracypridea brasiliensis* Zone, NRT-O04, with occurrences in subzones *Paracypridea bicallosa*, NRT-O04.3, and *Paracypridea maacki*, NRT-O04.4 (Viana et al., 1971; Cunha and Moura, 1979; Regali and Viana, 1989), attributed to the Rio da Serra Local Stage, Valanginian (Caixeta et al., 1994). Additionally, the fish *Mawsonia gigas* Mawson and Woodward, 1907, recovered and studied by Carvalho and Maisey (2008) in the Tereza Farm, in layers within the *Cypridea hystrix* Zone, and possibly by the lower portion of the *Alicenula longiformis* Zone, is typical of the Candeias Formation, attributed to the Rio da Serra Local Stage (Caixeta et al., 1994; Carvalho and Maisey, 2008). The attribution of this zone to the Valanginian-Hauterivian interval is based in the occurrence of *Cypridea hystrix*, and can be corroborated by the occurrence of *Mawsonia gigas* (Leite et al., to be submitted. Appendix 1).

The *Alicenula longiformis* Zone is a highest-occurrence interval zone, defined by the last occurrences of *Cypridea hystrix* and *Alicenula longiformis*, respectively, from the hypostratotype section of the Tereza Farm (Fig. 22). This zone occurs in all studied sections: stratotype section of the Quiricó Formation, hypostratotype section of the Tereza Farm and São Bento Farm section. It corresponds to local stages Buracica O08 and Jiquiá O09, and is attributed to the Barremian. Species that occur in this zone are *Cypridea* aff. *Cypridea infima*, *Penthesilenula pintoii*, *Wolburgiopsis plastica*, *Wolburgiopsis chinamuertensis*, *Penthesilenula martinsi*, *Brasacypris ovum*, *Brasacypris fulfaroi*, *Harbinia* spp., *Harbinia* aff. *Harbinia crepata* and *Harbinia alta*. *Alicenula longiformis* was described from the Quiricó Formation, and was recovered only in this formation so far, therefore, the chronostratigraphic positioning of this zone is based occurrence of other species. In the São Bento

Farm section, *Wolburgiopsis chinamuertensis* and *Wolburgiopsis plastica*, species attributed to the Barremian in Argentina (Musacchio, 1970; Do Carmo et al., 2004a), occur mainly in the *Alicenula longiformis* Zone, with just one level of occurrence within the *Harbinia* spp. Zone, corroborating with the attribution of Do Carmo et al. (2004a) for this section. Additionally, *Damonella ultima*, identified as *Damonella* aff. *Damonella ultima*, which only occurs in this zone, is restricted to the *Petrobrasia diversicostata* Zone, NRT-O09, with occurrence in the *Bisulcocypris postangularis* Subzone, BRT-O09.1, and in the *Cypridea (Sebastianites) fida minor* Zone, NRT-O08, with occurrences in subzones *Cypridea (Sebastianites?) mira*, NRT-O08.3, *Petrobrasia capivarensis*, NRT-O08.2, and *Cypridea (Sebastianites?) sostensis sostensis*, NRT-O08.1 (Viana et al., 1971; Cunha and Moura, 1979), attributed to the upper Barremian (Caixeta et al., 1994), corroborating to the positioning of Zone *Alicenula longiformis* in the Barremian (Leite et al., to be submitted. Appendix 1).

The *Harbinia* spp. Zone is an assemblage range zone, defined by the assemblage of *Harbinia* aff. *Harbinia salitrensis*, *Harbinia* aff. *Harbinia angulata*, *Harbinia alta*, *Harbinia* aff. *Harbinia crepata* and *Harbinia symmetrica*, from the stratotype section of the Quiricó Formation (Fig. 21). This zone occurs in the stratotype and in the São Bento Farm section. It corresponds to the Alagoas Local Stage O11 and is attributed to the Aptian. Species that occur in this zone are *Penthesilenula pintoii*, *Brasacypris ovum*, *Penthesilenula martinsi*, *Wolburgiopsis plastica* and *Wolburgiopsis chinamuertensis*. In the São Bento Farm section, this zone corresponds to the occurrence of *Harbinia* spp., defined by assemblages of species of *Harbinia* which were not identified at species level due to poor preservation and carapace deformation. *Harbinia* aff. *Harbinia salitrensis*, *Harbinia* aff. *Harbinia angulata* e *Harbinia symmetrica* occur exclusively in this zone, while *Harbinia alta* and *Harbinia* aff. *Harbinia crepata* occur in the *Alicenula longiformis* Zone. Specially *Harbinia symmetrica*, *Harbinia angulata*, *Harbinia alta* and *Harbinia salitrensis* belong to the *Harbinia* spp. 201-208 Zone, NRT-O11 (Do Carmo et al., 2008), attributed to the Alagoas Local Stage O11 (Schaller, 1969; Moura, 1987), dated as upper Aptian-lower Albian (Antonietto et al., 2012), corroborating to the positioning of the *Harbinia* spp. Zone in the Aptian (Leite et al., to be submitted. Appendix 1).

8. BIOSTRATIGRAPHIC CONTEXT OF THE RIO DO SONO AND SÃO JOSÉ FARM

In two sections, the Sono river section, João Pinheiro County, and the São José Farm section, Presidente Olegário County, only part of the Quiricó Formation outcrops, without lower or upper contact with other stratigraphic units, as was discussed previously (Figs 9, 10). With that, it is not possible to have a final remarks on stratigraphic distribution of ostracod species. For that reason, both

sections are not part of the biostratigraphic framework of the Quiricó Formation, and their biostratigraphic affinity is discussed herein.

In the Sono river section, the ostracod assemblage is: 1. *Penthesilenula martinsi* (Silva, 1978); 2. *Penthesilenula pintoii* Leite et al., 2018; 3. *Alicenula longiformis* Leite et al., 2018; 4. *Brasacypris ovum* Krömmelbein, 1965b; 5. *Brasacypris fulfaroi* Dias-Brito et al., 2001; 6. *Brasacypris* aff. *B. morigerata* Musacchio, 1973 (Fig. 19). The ostracod assemblage of the Sono river section, is very similar to the assemblage found in the *Alicenula longiformis* Zone, but without the occurrence of species typical of the *Cypridea hystrix* Zone and of species typical of the *Harbinia* spp. Zone. With that, this section could be within the *Alicenula longiformis* Zone, attributed to the Barremian.

In the São José Farm section, ostracods occur only in one layer, and the assemblage is: 1. *Penthesilenula pintoii* Leite et al., 2018; 2. *Alicenula longiformis* Leite et al., 2018; 3. *Brasacypris ovum* Krömmelbein, 1965b; 4. *Brasacypris fulfaroi* Dias-Brito et al., 2001 (Fig. 21). The ostracod assemblage of the São José section, is very similar to the Sono river section, with no species typical of the *Cypridea hystrix* Zone or the *Harbinia* spp. Zone, which could mean that this section is within the *Alicenula longiformis* Zone, attributed to the Barremian. However, due the occurrence of the papyraceous shale in this section, in which was identified the Palynozone *Transitoripollis crisopolensis* (P-230), attributed to the Aptian (Arai et al., 1989; Regali, 1989; Arai, 2001; Nascimento, 2013; Antunes et al., 2018), the positioning of this section might be Barremian-Aptian.

9. ANALYSIS ON PALEOZOOGEOGRAPHIC DISTRIBUTION

The paleozoogeographic context of ostracods from the Quiricó Formation, and the discussion regarding paleogeography and paleoenvironment is presented in the manuscript entitled “BIOSTRATIGRAPHY OF LIMINIC OSTRACODA (CRUSTACEA) FROM THE QUIRICÓ FORMATION, LOWER CRETACEOUS OF THE SÃO FRANCISCO BASIN, MINAS GERAIS STATE, SOUTHEAST BRAZIL: AN APPROACH ON PALEOZOOGEOGRAPHIC EVOLUTION OF GONDWANA” (Leite et al., to be submitted. Appendix 1). The paleozoogeography consists of six geochronological settings: Berriasian, Hauterivian, Valanginian, Barremian, Aptian and Albian (Fig. 23).

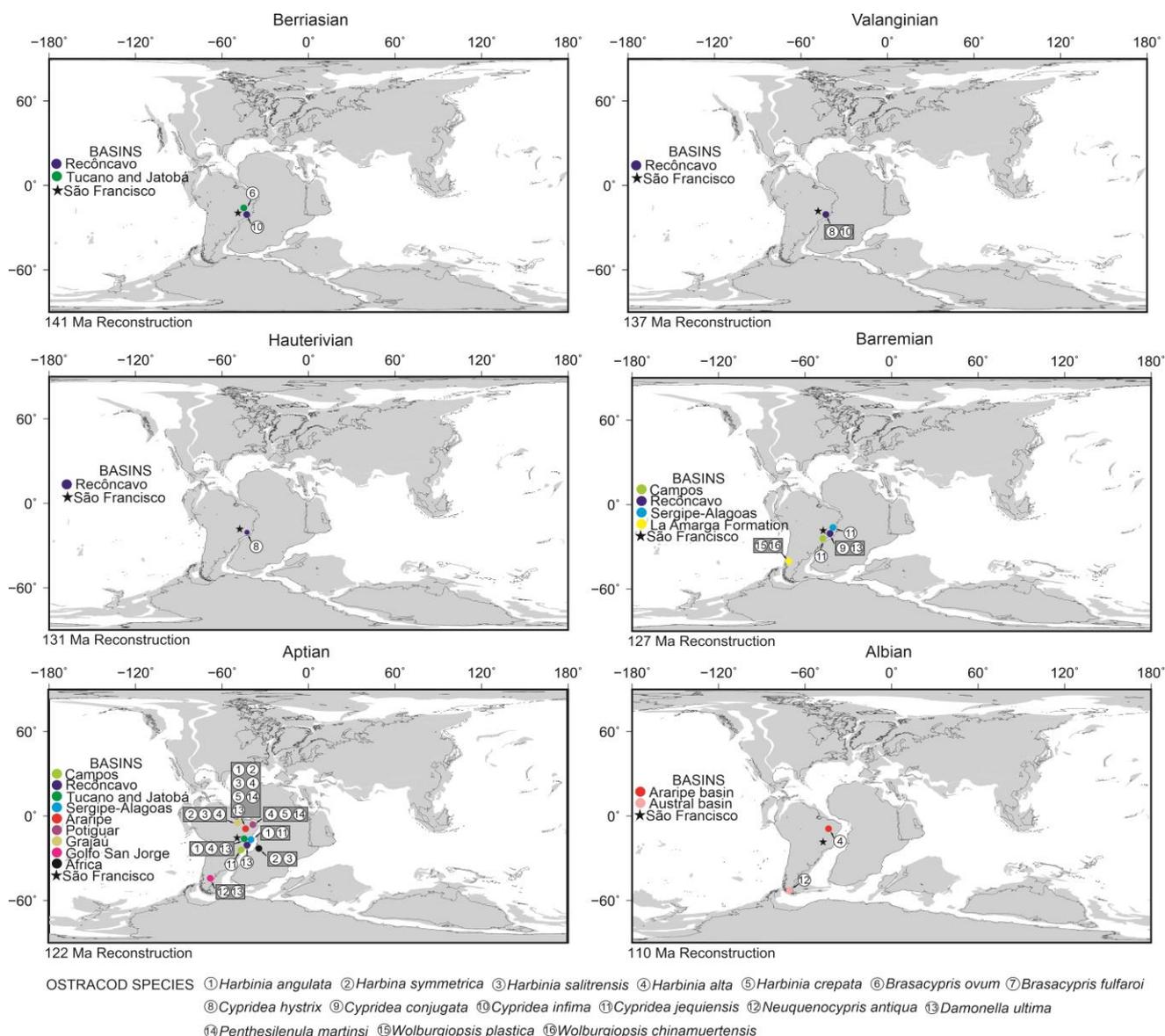


Figure 23. Paleogeography of ostracod species with occurrence in the Quiricó Formation, São Francisco basin, which also occur the other basins from Brazil, Argentina and Africa in the Cretaceous from Gondwana. Obs.: Paleomaps adapted from “Ocean Drilling Stratigraphic Network” (2011) (adapted from Leite et al., to be submitted. Appendix 1).

In the Berriasian, *Brasacypris ovum* was registered in the Tucano basin (Krömmelbein, 1965b). *Cypridea infima* was registered in the Recôncavo basin, Berriasian-Valanginian interval (Silva et al., 2007); (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b). In the Valanginian-Hauterivian interval, *Cypridea hystrix* was registered in the Recôncavo basin (Krömmelbein, 1962). This species also occurs in the *Paracypridea brasiliensis* Zone, NRT-O04, subzones *Paracypridea bicallosa*, NRT-O04.3, and *Paracypridea maacki*, NRT-O04.4 (Viana et al., 1971; Cunha and Moura, 1979; Regali and Viana, 1989).

In the Barremian, *Cypridea conjugata* occurs in the Recôncavo basin (Silva et al., 2007); (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b). *Cypridea jequiensis* occurs in the Sergipe-Alagoas basin (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b; Antonietto, 2015), and in the Campos basin, in the *Petrobrasía diversicostata* Zone, NRT-O09, *Cypridea faveolata* Subzone, NRT-O09.3 (Moura, 1987; Rangel et al., 1994).

Damonella ultima is registered in the upper Barremian-lower Aptian interval (Silva et al., 2007) from the Recôncavo basin (Krömmelbein and Weber, 1971), with occurrence in the *Petrobrasía diversicostata* Zone, NRT-O09, *Bisulcoocypris postangularis* Subzone, NRTO09.1, in the *Cypridea (Sebastianites) fida minor* Zone, NRT-O08, subzones *Cypridea (Sebastianites?) mira*, NRT-O08.3, *Petrobrasía capivarensis*, NRT-O08.2, and *Cypridea (Sebastianites?) sostensis sostensis*, NRT-O08.1 (Tomé et al., 2014), and in the Araripe basin (Antonietto et al., 2016). In Argentina, *Damonella ultima* occurs in the Golfo de San Jorge basin, in the Barremian-Aptian interval (Carignano et al., 2017), and both *Wolburgiopsis plastica* and *Wolburgiopsis chinamuertensis* occur in the La Amarga Formation, Neuquén Province, Barremian (Musacchio, 1970; Do Carmo et al., 2004a).

In the Aptian, *Harbinia angulata* occurs in the Sergipe-Alagoas basin (Krömmelbein and Weber, 1971), in the Araripe basin (Poropat and Colin, 2012b), in the Cedro basin (Tomé, 2007) and in the Jatobá basin (Tomé et al., 2014). *Harbinia symmetrica* and *Harbinia alta* occur in the Araripe basin (Viana et al., 1989; Silva-Telles Jr. and Viana, 1990; Antonietto et al., 2012), in the *Harbinia* spp. 201-218 Zone, NRT-O11 (Do Carmo et al., 2008), *Harbinia symmetrica* in the Aptian (Coimbra et al., 2002) and *Harbinia alta* in the upper Aptian-lower Albian interval (Antonietto et al., 2012). Additionally, *Harbinia symmetrica* occurs in the Grajaú basin (Krömmelbein and Weber, 1971; Ramos et al., 2006) and in the Gabon basin, Gamba Formation, and in Congo and Cabinda basins, Chela Formation, in Africa (Grosdidier et al., 1996; Bate, 1999). *Harbinia alta* occurs in the Grajaú basin (Ramos et al., 2006), Potiguar basin (Do Carmo et al., 2013) and Jatobá basin (Tomé et al., 2014). *Harbinia salitrensis* occurs in the Araripe basin (Krömmelbein and Weber, 1971; Antonietto et al., 2012; Poropat and Colin, 2012b; Tomé et al., 2014) and in the Grajaú basin (Do Carmo et al., 2008). *Harbinia crepata* occurs in the Potiguar basin (Do Carmo et al., 2013) and in the Araripe basin (Silva-Telles Jr. and Viana, 1990).

Still in the Aptian, *Penthesilenula martinsi* occurs in the Araripe basin (Silva, 1978; Silva-Telles Jr. and Viana, 1990; Colin and Dépêche, 1997) and in the Potiguar basin (Do Carmo et al., 2013). *Neuquenocypris (Protoneuquenocypris) antiqua* occurs in the Golfo de San Jorge basin (Musacchio and Simeoni, 1991; Ballent et al., 2011a) and in the Austral basin (Ballent et al., 2011a). At last, in the Upper Cretaceous, *Brasacypris fulfaroi* occurs in the Paraná basin (Dias-Brito et al., 2001).

9.1. Remarks on the biostratigraphy, paleogeography and paleoenvironment

Six biostratigraphic units are recognized on the Quiricó Formation, Zone *Brasacypris ovum* and four zones within the Superzone *Penthesilenula pintoï*: Zone *Timiriasevia sanfranciscanensis*; Zone *Cypridea hystrix*; Zone *Alicenula longiformis*; and Zone *Harbinia* spp. (Fig. 22). Based on the paleoecological approach, especially due to the occurrence of limnic ostracods, it is possible to interpret the deposition under a lacustrine system during the occurrence of Zone *Brasacypris ovum* and Superzone *Penthesilenula pintoï* (Leite et al., to be submitted. Appendix 1).

The hypostratotype section of the Tereza Farm represents the most basal interval of the Quiricó Formation, due to the exclusive occurrence of zones *Brasacypris ovum*, *Timiriasevia sanfranciscanensis* and *Cypridea hystrix*, attributed to the interval Berriasian to Valanginian (Fig. 22). For the lower portion of the Tereza Farm section, it is also possible to interpret a major fluvial influence. The *Alicenula longiformis* Zone, attributed to the Barremian, occurs at the top of the Tereza Farm, and lower portions of the stratotype section and São Bento Farm (Fig. 22). The stratotype section and the São Bento Farm present the upper interval of the Quiricó Formation, due to the occurrence of the *Harbinia* spp. Zone, attributed to the Aptian. Especially the stratotype section presents a paleoenvironmental and sedimentary context indicating water depth often restricted and more saline and arid environmental conditions. This interpretation is based on the abundant occurrence of desert roses, mud cracks and evaporitic levels (Figs 5, 6); also, the abundance of species of *Harbinia*, typical of lakes with hypersalinity (Coimbra et al., 2002; Ramos et al., 2006; Antonietto, 2010), corroborates to the high salinity interpretation for the stratotype section (Leite et al., to be submitted. Appendix 1).

For the Cretaceous paleogeographic context, the existence of interconnected intermittent drainages, at least since the late Barremian, is discussed based on the distribution of several taxa, such as pollen, microcrustaceans and vertebrates, mainly fishes (Maisey, 2000; Amaral et al., 2019). Amaral et al. (2019) discuss the hypothesis that the São Francisco drainage was already established during late Barremian. Also, studies indicate that by Late Jurassic, several lacustrine systems could compose the same paleohydrographic system between several basins from central Gondwana (Assine, 1994; Da Rosa and Garcia, 2000; Garcia et al., 2005; Kuchle et al., 2011).

In terms of paleoenvironmental approach, based precipitation data in the paleogeographic map for the Berriasian-Barremian? (Fig. 24) it is possible to notice that the São Francisco basin was within the wet area with great precipitation. This could explain why species that occur in Recôncavo, Tucano-Jatobá, Campos and Sergipe-Alagoas basins, and in the La Amarga Formation (Argentina) also occur

in the Quiricó Formation. From the great volume of water, a linkage between the São Francisco basin and these other basins could be established. Another possibility is that these basins could be part of the same hydrographic system, corroborating to the hypothesis of Assine (1994), Da Rosa and Garcia (2000), Garcia et al. (2005) and Kuchle et al. (2011).

BERRIASIAN-BARREMIAN?

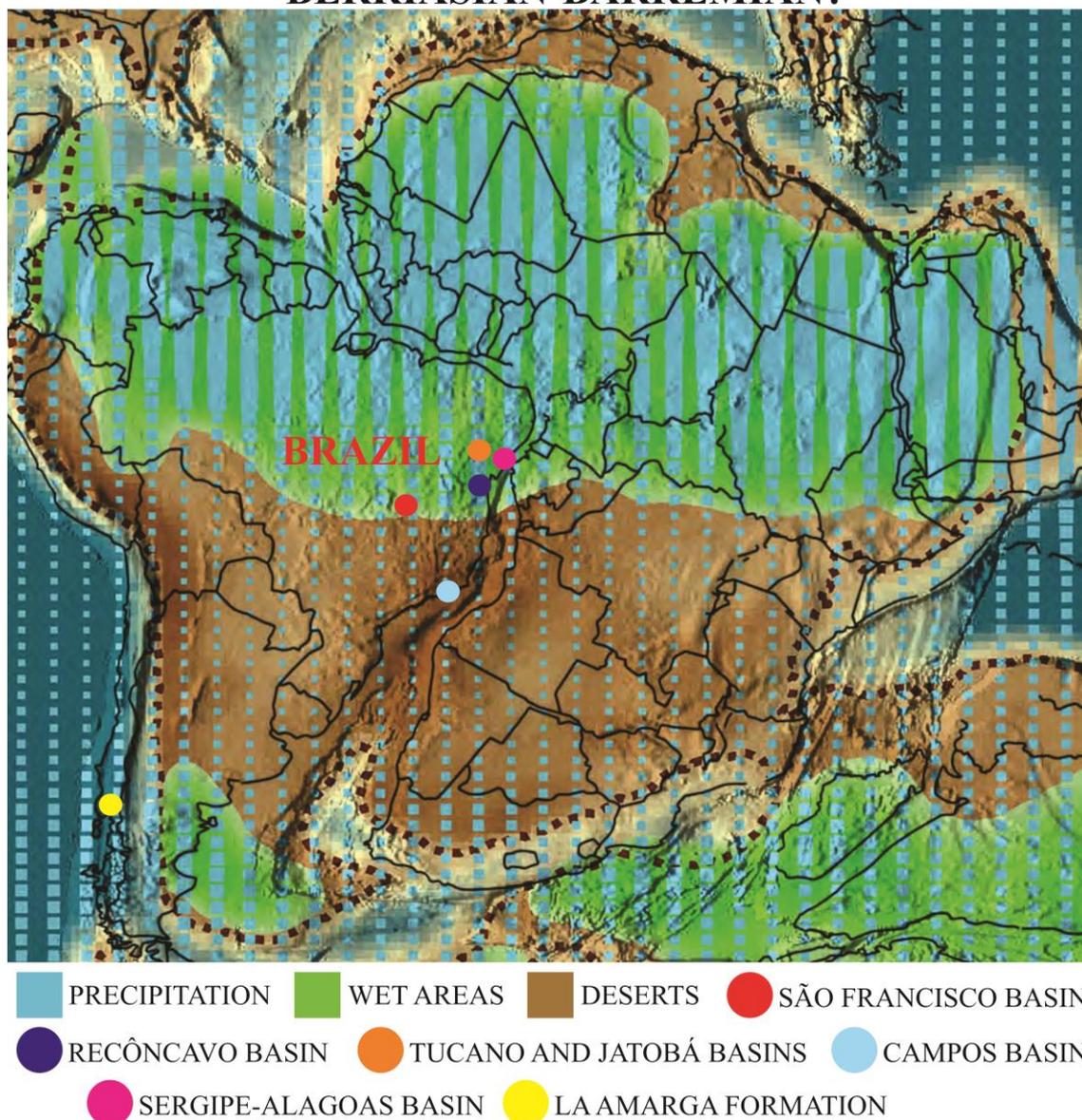


Figure 24. Berriasian to possibly Barremian paleogeography map with rainfall (light blue squares = precipitation, green areas = wet areas where precipitation > evaporation, tan areas = deserts) and basins where limnic ostracod species occur (based on (Scotese, 2013a), from Leite et al., to be submitted. Appendix 1).

On the other hand, from data in the paleogeographic map for the early Aptian (Fig. 25) it is possible to observe that the São Francisco basin is just outside of the wet area, under the desert regime; however, species that occur in the Quiricó Formation also occur in several other basins (Recôncavo,

Tucano-Jatobá, Campos, Sergipe-Alagoas, Potiguar, Grajaú, Araripe – Brazil; Golfo San Jorge, Austral – Argentina; Gamba, Congo, Cabinda – Africa), and since the Quiricó Formation was under arid conditions, it is possible to infer that a São Francisco drainage, linking this basin with others, was already established corroborating to the hypothesis presented by Amaral et al. (2019) (Leite et al., to be submitted. Appendix 1). It is important to point out that, although there are no marine records in the five studied sections from the Quiricó Formation, during the late Aptian, it is possible to interpret that there were connections among the São Francisco basin and marginal basins from Brazil that show evidence of marine ingression (Arai, 2014, 2016; Assine et al., 2014, 2016).

EARLY APTIAN

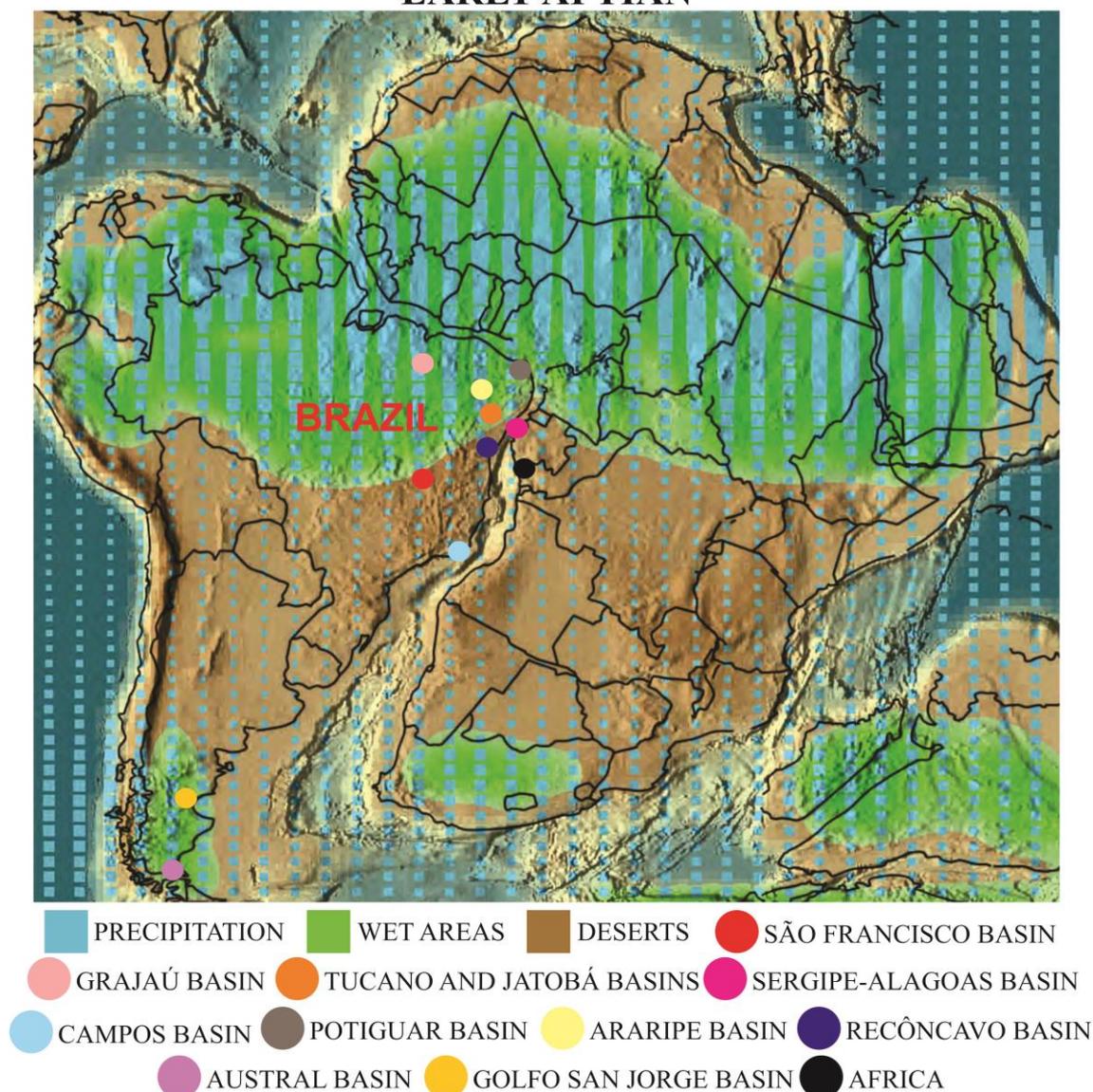


Figure 25. Early Aptian paleogeography map with rainfall (light blue squares = precipitation, green areas = wet areas where precipitation > evaporation, tan areas = deserts) and basins where limnic ostracod species occur (based on (Scotese, 2013b), from Leite et al., to be submitted. Appendix 1).

10. CONCLUSIONS

The present thesis presents the first formal description of the stratotype section of the Quiricó Formation, as well as the proposal of a hypostratotype section, and description of additional sections with important fossil content. All studied sections are located in the Minas Gerais State, southeast Brazil: 1. Stratotype section, Presidente Olegário County; 2. Hypostratotype section from the Tereza Farm, João Pinheiro County; 3. São Bento Farm section, Carmo do Paranaíba County; 4. Sono river section, João Pinheiro County; and 5. São José Farm section, Presidente Olegário County. The detailed description contributes to the definition and characterization of the Quiricó Formation, in addition to posing as an important reference for future studies on the characterization of lithostratigraphic units in Brazil.

Twenty-one species of ostracods occur in the five studied sections from Quiricó Formation: 1. *Harbinia* aff. *Harbinia angulata* (Krömmelbein and Weber, 1971); 2. *Harbinia symmetrica* (Krömmelbein and Weber, 1971); 3. *Harbinia* aff. *Harbinia salitrensis* (Krömmelbein and Weber, 1971); 4. *Harbinia alta* Antonietto et al., 2012; 5. *Harbinia* aff. *Harbinia crepata* Do Carmo et al., 2013; 6. *Brasacypris ovum* Krömmelbein, 1965b; 7. *Brasacypris* aff. *Brasacypris morigerata* Musacchio, 1973; 8. *Brasacypris fulfaroi* Dias-Brito et al., 2001; 9. *Cypridea hystrix* Krömmelbein, 1962; 10. *Cypridea conjugata* Krömmelbein and Weber, 1971; 11. *Cypridea* aff. *Cypridea infima* Krömmelbein and Weber, 1971; 12. *Cypridea* aff. *Cypridea jequiensis* Krömmelbein and Weber, 1971; 13. *Cypridea* sp.; 14. *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni, 1991; 15. *Damonella* aff. *Damonella ultima* (Krömmelbein and Weber, 1971); 16. *Penthesilenula martinsi* (Silva, 1978); 17. *Penthesilenula pintoii* Leite et al., 2018; 18. *Alicenula longiformis* Leite et al., 2018; 19. *Timiriasevia sanfranciscanensis* Leite et al., 2018; 20. *Wolburgiopsis plastica* (Musacchio, 1970); 21. *Wolburgiopsis chinamuertensis* (Musacchio, 1970). The species of *Cypridea* were analyzed, with the objective of reexamining the taxonomy, and the *Cypridea infima* Krömmelbein and Weber, 1971 and the *Cypridea* aff. *Cypridea jequiensis* Krömmelbein and Weber, 1971 recovered from the Quiricó Formation, were better identified as *Cypridea* aff. *Cypridea infima* and *Cypridea* aff. *Cypridea jequiensis*, respectively.

Six biostratigraphic units are currently recognized in the Quiricó Formation, approaching three of the five studied sections: stratotype section, hypostratotype section of the Tereza Farm and São Bento Farm section. One superzone and five zones are described, Zone *Brasacypris ovum*, and four zones within the *Penthesilenula pintoii* Superzone: Zone *Timiriasevia sanfranciscanensis*; Zone *Cypridea hystrix*; Zone *Alicenula longiformis*; and Zone *Harbinia* spp.

Stratigraphic data and ostracod taxonomy indicate that the Quiricó Formation was deposited in a lacustrine environment, with a major fluvial influence during the deposition of the lower portion and arid conditions during the deposition of the upper portion of the formation. The biostratigraphic framework and the paleozoogeography of ostracods enable the correlation with local stages Rio da Serra to Alagoas, and the interpretation of an interval from Berriasian to Aptian/Albian? in Gondwana. From the paleozoogeography, associated with paleoecological interpretations, it is possible to infer that, from the studied interval, the São Francisco basin was correlated with several other interior and marginal basins from central Gondwana, possibly through a paleo São Francisco drainage. Finally, from the taxonomic, sedimentary, biostratigraphic, paleozoogeographic and paleoecological study, it is possible to attribute the Quiricó Formation to the Berriasian-Aptian/Albian? interval. A perspective for future research is the geochemical analysis of ostracod carapace, and from the results carry out paleoecological studies and thus, integrate with the available data from the Quiricó Formation.

11. REFERENCES

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12.APPENDIX 1

BIOSTRATIGRAPHY OF LIMINIC OSTRACODA (CRUSTACEA) FROM THE QUIRICÓ FORMATION, LOWER CRETACEOUS OF THE SÃO FRANCISCO BASIN, MINAS GERAIS STATE, BRAZIL: AN APPROACH ON PALEOZOOGEOGRAPHIC EVOLUTION OF GONDWANA

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ABSTRACT. The present study is the first attempt to establish a biostratigraphic framework based on ostracods for the Quiricó Formation, São Francisco basin, Brazil. Three sections located at Minas Gerais State were approached: 1. stratotype section of the Quiricó Formation, by the banks of the Quiricó and São José creeks, Presidente Olegário County; 2. hypostratotype section of the Tereza Farm, João Pinheiro County; and 3. São Bento Farm section, Carmo do Paranaíba County. After ostracod taxonomic analysis and integration with previous studies, the first biozonation based on limnic ostracods for the Lower Cretaceous of the São Francisco basin is proposed. Six biostratigraphic units are described, one superzone and five zones. The *Brasacypris ovum* Zone is defined by the lowest occurrences of *Brasacypris ovum* and of *Timiriasevia sanfranciscanensis*, and is attributed to the Berriasian. The Superzone *Penthesilenula pinto* is defined by the local range of *Penthesilenula pinto*, attributed to the Berriasian-Aptian/Albian? interval. Within this superzone, four zones are described: 1. Zone *Timiriasevia sanfranciscanensis*, defined by the lowest occurrences of *Timiriasevia sanfranciscanensis* and of *Cypridea hystrix*, attributed to the Berriasian; 2. Zone *Cypridea hystrix*, defined by the local range of *Cypridea hystrix*, attributed to the Valanginian-Hauterivian interval; 3. Zone *Alicenula longiformis*, defined by highest occurrence of *Cypridea hystrix* and of *Alicenula longiformis*, attributed to the Barremian; and 4. Zone *Harbinia* spp., defined by the assemblage of species of *Harbinia*, with the lower limit marked by the highest occurrence of *Alicenula longiformis*, attributed to the Aptian. A paleozoogeographical analysis showed faunal similarities with several sedimentary basins in Brazil, Argentina, Gabon, Gamba, Congo and Cabinda during the late assemblage of Gondwana previous to the complete breakup of the supercontinent.

Key Words. Quiricó Formation, ostracod, biostratigraphy

INTRODUCTION

The present work is a biostratigraphic and paleozoogeographical study of Lower Cretaceous limnic ostracods from the Quiricó Formation, São Francisco basin, southeastern Brazil. This study is the first attempt to establish a biostratigraphic framework based on ostracods for this formation, since biostratigraphy is the main instrument for dating it. And with that, determine the paleozoogeographical significance and contribution of the Lower Cretaceous from the São Francisco basin to the paleogeographic study of Gondwana and the evolution of the rift system related to the opening of the South Atlantic ocean.

Other than ostracods, the Quiricó Formation yields an abundant and diversified fossil record, including charophytes, spinicaudatans, mollusks, fish, theropods and sauropods, plant remains and palynomorphs (Do Carmo et al., 2004a; Campos and Do Carmo, 2005; Bittencourt et al., 2015; Leite et al., 2018). This is the only formation from the Mesozoic of the São Francisco basin that yields occurrences of ostracods (Do Carmo et al., 2004a; Campos and Do Carmo, 2005; Bittencourt et al., 2015; Leite et al., 2018).

Ostracods are crustaceans, with small bivalve carapace, commonly calcitic, and mean size of about 1 mm, and can be found in several aquatic environments, such as deep marine or limnic, even humid terrestrial (Horne et al., 2002). They are among the most diverse group of living crustaceans, and encompass a rich fossil record due to their calcified valves, easily preserved in sediments and rocks (Cohen et al., 1998; Ikeya et al., 2005; Rodriguez-Lazaro and Ruiz-Muñoz, 2012). Limnic ostracods are key elements for biostratigraphic studies on continental sections (Milhomem et al., 2001; Sames and Horne, 2012).

The chronostratigraphic position of the Quiricó Formation was first cited by Scorza and Silva Santos (1955), with the identification of the fish *Dastilbe moraesii* Silva Santos in Scorza and Silva Santos, 1955 in layers of papyraceous shale from the Presidente Olegário region. The *Dastilbe* Genus occurs with an excellent preservation at the Araripe basin, in Aptian layers, which could indicate that the Quiricó Formation, on that location, was attributed to the Aptian as well (Scorza and Silva Santos, 1955).

Ostracods, charophytes and bone remains were recovered in sections of the Areado Group from the Minas Gerais State, by Barbosa et al. (1970), and they determined that the ostracod fauna was similar to that found at the Santana Formation, attributed to the Aptian/Albian interval. Later, Lima (1979) identified the *Transitoripollis crisopolensis* Palynozone (P-230), in the same papyraceous shale where *Dastilbe moraesii* Silva Santos in Scorza and Silva Santos, 1955 was recovered, thus attributing it to the Barremian to possibly lower Aptian, corroborated by Arai et al. (1995). However, several

authors suggest that this palynozone is attributed to the Alagoas Local Stage, Aptian (Arai et al., 1989; Regali, 1989; Arai, 2001; Nascimento, 2013; Antunes et al., 2018). Therefore, the papyraceous shale remains attributed to the Aptian.

In the Tereza Farm section, João Pinheiro County, coelacanth *Mawsonia gigas* Woodward in Mawson and Woodward, 1907 were recovered (Carvalho, 2002; Carvalho and Maisey, 2008). This species is typically attributed to the Upper Jurassic-Berriasian-Valanginian-Hauterivian interval, and is recorded in the Recôncavo, Tucano, Almada, Sergipe-Alagoas, Araripe, Iguatu and São Luís do Grajaú basins (Carvalho, 2002; Carvalho and Maisey, 2008). The material recovered from the Quiricó Formation represents a single population of *Mawsonia gigas*, a species originally described from the Candeias Formation, attributed to the Local Stage Rio da Serra (Caixeta et al., 1994; Carvalho, 2002; Carvalho and Maisey, 2008). It is important to point out that, after a detailed revision on this species, unexpected Cenomanian occurrences were inferred (Carvalho and Maisey, 2008; Barbosa et al., 2019; Batista et al., 2019; Cavin et al., 2021; Toriño et al., 2021).

The first study on limnic ostracods from the Quiricó Formation was conducted by Do Carmo et al. (2004a), which recovered 15 species from the São Bento Farm section (Carmo do Paranaíba County) and from the Sono river section (João Pinheiro County), and determined that the base of the Quiricó Formation in the São Bento Farm was attributed to the Barremian. So, considering the results of Do Carmo et al. (2004a), the Quiricó Formation would comprise the Barremian-Aptian interval. However, a later study on ostracod taxonomy from outcrops of the Quiricó Formation in the Minas Gerais State (Leite et al., 2018), where 16 species were recovered, suggested that the base of the Quiricó Formation, at the Tereza Farm section, could be attributed to the Rio da Serra Local Stage, considered Valanginian. Whereas the top of the Quiricó Formation, at the São José creek could be attributed to the Alagoas Local Stage, considered Aptian. Therefore, the Quiricó Formation would encompass the Valanginian-Aptian interval.

Considering the ostracod biostratigraphic framework established on marginal basins in Brazil, the detailed analysis of biostratigraphy and of paleozoogeography based on ostracods conducted herein approaches the chronostratigraphic positioning of the Quiricó Formation. The stratigraphic positioning of fossiliferous occurrences for the Areado Group contributes to the expansion of knowledge regarding the biodiversity of the continental Cretaceous of Brazil, allowing development of future studies of advanced biostratigraphic correlation with other Cretaceous basins from Gondwana.

A synthesis of the evolution and breakup of Gondwana

The supercontinent of Gondwana lasted for about 500 million years, from when it assembled during the Neoproterozoic, until it fragmented into separate continents during the Early Cretaceous (Scotese et al., 1999; Blakey, 2008; Merdith et al., 2017). The assembly of Gondwana resulted from Brasiliano-Panafrican orogeny caused by the collision of East and West Gondwana. During the Late Paleozoic, Gondwana and Laurussia (comprising the Laurentian, Baltic, Kazakhstan and Siberian cratons) became welded together to form the megacontinent Pangea, extending from far northern, to far southern latitudes. Laurasia was formed during the Permian-Jurassic, from the accretion of additional terranes (North and South China blocks) with the eastern margin of Laurussia. In the Middle Jurassic, due to crustal extension, Laurentia began to separate from Gondwana, thus ending the Pangea (McLoughlin, 2001; Orme, 2007; Blakey, 2008).

Between the latest Jurassic and the earliest Cretaceous there were intense tectonic changes in Gondwana, in which the fragmentation intensified (Scherer and Goldberg, 2007). Three distinct tectonic styles and locations were involved in the breakup of Gondwana. In the north and the central domains, the crustal extension began in the Late Triassic, and sea floor spreading began in the Early Jurassic. In the southern Atlantic domain, the Malvinas plateau began separating from the southern Africa during the Early Jurassic. All three domains show the initial crustal extension accompanied by magmatism, followed by rifting and basin formation along rifted margins, and then transitional-oceanic-sedimentologic regimes. The rupture of the southern Atlantic domain was marked by crustal uplift, extension and volcanism, represented by basaltic rocks of the Paraná basin (Orme, 2007).

The initial North Atlantic ocean crust was formed during the Middle Jurassic, and expanded southwest (Blakey, 2008). By the Aptian, the continental rifting between South America and South Africa had begun and the Tethys ocean occupied both the northern and the southern hemispheres, reaching its maximum extension in the late Albian (Dias-Brito, 2000; Blakey, 2008; Matos et al., 2021). During the early Aptian, the Equatorial Atlantic was developed, and the lithospheric limit between South America and Africa began delineating (Matos et al., 2021). The widening of the South Atlantic can be related with clockwise rotations of South America during the Aptian, and by the end of the Albian, a continuous mid-ocean-ridge was established, and, thus, the complete separation between South America and Africa (Salomon et al., 2017; Matos et al., 2021). Also, the end of the sea pathway between the Tethys sea and the Atlantic, through Northeast Brazil was during the Albian (Matos et al., 2021). Additionally, the final breakup of Gondwana initiated during the Albian, with the separation of Antarctica and Australia, and ended by the late Eocene, when mature oceans existed between the major continents of Gondwana (Blakey, 2008).

LOWER CRETACEOUS GEOLOGICAL SETTINGS

The São Francisco basin is composed by Proterozoic sedimentary rocks, overlapped by Phanerozoic sedimentary rocks (Zalán and Silva, 2007). The Phanerozoic portion is distributed over Distrito Federal, Goiás, Minas Gerais, Bahia, Piauí, Tocantins and Maranhão (Campos and Do Carmo, 2005; Bueno, 2012). The phanerozoic sequence is represented, from base to top, by groups: Santa Fé, Carboniferous-Permian; Areado, Lower Cretaceous; and Mata da Corda and Urucuia, Upper Cretaceous (Campos and Do Carmo, 2005; Zalán and Silva, 2007). The Santa Fé Group consists of glacial records with fluvio-glacial, glacial-lacustrine and periglacial eolic facies. The Areado Group consists of fluvio-deltaic, eolian, lacustrine and alluvial fan sedimentary rocks. Overlying this unit, is the Mata da Corda Group, composed by volcanic pyroclastic alkaline rocks and proximal epiclastic sedimentary rocks, and the Urucuia Group is composed of eolian sandstones, fluvial sandstones, conglomerates and mudstones (Campos and Dardenne, 1997; Campos and Do Carmo, 2005).

The Areado Group presents a broad lateral lithofacies variation, and is composed from base to top, by the Abaeté, Quiricó and Três Barras formations. The Abaeté Formation presents two distinct sedimentary contexts: in the southern portion of the basin, deposited by alluvial fans, with immature matrix-supported conglomerates; in the rest of the basin, deposited by braided river systems, with mature grain-supported conglomerates (Seer et al., 1989; Campos and Dardenne, 1997; Campos and Do Carmo, 2005).

The Quiricó Formation was deposited in a lacustrine system, and it is composed by siltstones, which occur interstratified and predominate at the base of the sequence; fine, medium and coarse sandstones in the intermediate portion; and more frequent in the upper portion of the sequence, shales and micritic limestones. This is the only formation from the Areado Group where ostracods have been recovered to date. Locally, in the Presidente Olegário County, Minas Gerais State, there are intervals with a papyraceous shale, rich in organic matter, in which occurs the fish *Dastilbe moraesii* Silva Santos in Scorza and Silva Santos (1955) and leaves (Campos and Dardenne, 1997; Campos and Do Carmo, 2005). Also, palynomorphs were recovered in the papyraceous shale (Lima, 1979).

The Três Barras Formation presents the largest lithological diversity and the largest volume of rocks; it was deposited in fluvial-deltaic and eolian fluvial systems and presents heterogeneous sandstones (Campos and Dardenne, 1997; Campos and Do Carmo, 2005). This formation also presents an unconformity that separates the sedimentary succession in a lower stratigraphic unit, consisting of a wet eolian system, and an upper stratigraphic unit, consisting of a dry eolian system (Mescolotti et al., 2019). This unconformity is dated as Cenomanian to Coniacian, because the lower unit is

interdigitated with the upper portion of the Quiricó Formation, and the upper unit is overlain by the Mata da Corda Group (Mescolotti et al., 2019).

The Quiricó Formation was first mentioned by Barbosa (1965), when he designated the type locality, but never formally described the stratotype section. The first attempt at describing the stratotype section was performed by Leite et al. (2018). The outcrop identified as the section of the São José Farm, by the banks of the São José creek, was recognized by Leite and Do Carmo (2021) as the stratotype section of the Quiricó Formation, which extends to the banks of the Quiricó creek. In this locality, the outcrop consists of a complete section of the Areado Group, with the three formations from base to top Abaeté, Quiricó and Três Barras. Also, it is remarkable in the lower portion of section, the contact of the Abaeté Formation with the Santa Fé Group. The stratotype section, and a hypostratotype section, located at the Tereza Farm, were described in detail by Leite and Do Carmo (2021).

Biochronostratigraphic framework

The biochronostratigraphic framework of Lower Cretaceous limnic ostracods of the proto-South Atlantic are based on Sergipe-Alagoas and Recôncavo-Tucano basins. Schaller (1969) proposed the first framework based on data from the Sergipe-Alagoas basin. Further on, Viana et al. (1971) considering the exceptional preservation of limnic ostracods from the Recôncavo-Tucano basin, proposed the second framework, which was then updated by Moura (1972) and finally by Cunha and Moura (1979). Further on, the Campos basin had its biochronostratigraphic framework erected and correlated with previous studies (Moura and Praça, 1985; Moura, 1987), and the same was performed for the Araripe basin (Coimbra et al., 2002; Do Carmo et al., 2008). Innumerable publications on taxonomy were conducted in parallel to these biochronostratigraphic frameworks, and will be approached herein later on. It will be presented herein the biochronostratigraphic framework of basins Recôncavo-Tucano, Sergipe-Alagoas, Campos and Araripe, Brazil (Fig. 1).

Corresponding to the uppermost Jurassic, there is one local chronostratigraphic unit: Dom João Stage. Corresponding to the Lower Cretaceous, there are five local chronostratigraphic units, from base to top: Rio da Serra Stage, Aratu Stage, Buracica Stage, Jiquiá Stage and Alagoas Stage (Schaller, 1969; Viana et al., 1971; Cunha and Moura, 1979; Moura and Praça, 1985; Moura, 1987).

Originally, the Local Stage Dom João comprises the *Bisulcocypris pricei* Zone, coded as O01 - "O" from Ostracoda, and zone numbers from uppermost Jurassic to Lower Cretaceous from 1 to 11 - (Viana et al., 1971; Cunha and Moura, 1979), renamed herein as *Theriosynoecum pricei* Zone, which will be discussed later on Taxonomic remarks. The Local Stage Rio da Serra comprises 12

biochronostratigraphic units: Zone *Theriosynoecum verietuberatum*, coded as O02, subzones *Cypridea kegei*, coded as O02.1, and *Cypridea* cf. *C. primaria*, coded as O02.2; Zone *Cypridea (Morininoides) candeiensis*, coded as O03, subzones *Cypridea sellata*, coded as O03.1, and *Cypridea (Morininoides) hidronodosa*, coded as O03.2; and Zone *Paracypridea brasiliensis*, coded as O04, subzones *Cypridea salvadorensis nodifer*, coded as O04.1, *Reconcavona? polita*, coded as O04.2, *Paracypridea bicalloso*, coded as O04.3, *Paracypridea maacki*, coded as O04.4 and *Cypridea ventronodata*, coded as O04.5 (Viana et al., 1971; Cunha and Moura, 1979).

The Local Stage Aratu comprises nine biostratigraphic units: Zone *Paracypridea obovata obovata*, coded as O05, subzones *Ilhosina remanei cuneiformes*, coded as O05.1, *Paracypridea elegans elegans*, coded as O05.2, *Reconcavona uncinata*, coded as O05.3, *Reconcavona uniacantha*, coded as O05.4, and *Reconcavona gastrocantha*, coded as O05.5; and Zone *Cypridea (Morinina?) bibullata bibullata*, coded as O06, subzones *Reconcavona triebeli*, coded as O06.1, and *Cypridea (Morinina?) bibullata tribullata*, coded as O06.2 (Viana et al., 1971; Cunha and Moura, 1979).

The Local Stage Buracica comprises nine biostratigraphic units: Zone *Coriacina coriacea*, coded as O07, subzones *Cypridea eminens*, coded as O07.1, *Petrobrasia marfinensis*, coded as O07.2, *Metacypris* sp. 6, coded as O07.3, herein renamed *Theriosynoecum* sp. 6 (discussion on Taxonomic remarks) and *Paracypridea quadrirugosa weberi*, coded as O07.4; and Zone *Cypridea (Sebastianites) fida minor*, coded as O08, subzones *Cypridea (Sebastianites?) sostensis sostensis*, coded as O08.1, *Petrobrasia capivarensis*, coded as O08.2, and *Cypridea (Sebastianites?) mira*, coded as O08.3 (Viana et al., 1971; Cunha and Moura, 1979). The Local Stage Jiquiá comprises five biostratigraphic units: Zone *Petrobrasia diversicostata*, coded as O09, subzones *Bisulcocypris postangularis*, coded as O09.1, herein renamed *Theriosynoecum postangularis* (discussion on Taxonomic remarks), *Cypridea (Sebastianites) devexa*, coded as O09.2, and *Cypridea (Pseudocypridina) faveolata*, coded as O09.3; and Zone *Limnocythere? troelseni*, coded as O10 (Viana et al., 1971; Cunha and Moura, 1979; Moura, 1987).

The Local Stage Alagoas is herein considered as comprising the *Harbinia* spp. Zone, coded as O11. The *Harbinia* spp. Zone was first assigned by Schaller (1969) as *Cytheridea?* spp. 201-218 Zone, an assemblage zone characterized by the occurrence of species of *Cytheridea*, morphotypes recognized as 201 to 218. It was later renamed by Do Carmo et al. (2008) as *Harbinia* spp. 201-218. In this zone, the group of species composed by *Harbinia micropapillosa* (Bate, 1972), *Harbinia angulata* (Krömmelbein and Weber, 1971), *Harbinia sinuata* (Krömmelbein and Weber, 1971), *Harbinia salitrensis* (Krömmelbein and Weber, 1971) and *Harbinia symmetrica* (Krömmelbein and Weber, 1971) are index species of Zone O11. In the present work, this zone is renamed as *Harbinia* spp. Zone,



once the abbreviation spp. is used to indicate the occurrence of more than one species of the same genus (Sigovini et al., 2016).

Taxonomic remarks

It is presented herein an update for species on the chronobiostratigraphic framework erected by Cunha and Moura (1979) modified accordingly to Moura and Praça (1985) and Moura (1987). The *Bisulcoypris pricei* Zone (O01) as well as the *Bisulcoypris postangularis postangularis* Subzone (O09.1), are herein renamed as *Theriosynoecum pricei* Zone and *Theriosynoecum postangularis postangularis* Subzone, respectively. At first, Pinto and Sanguinetti (1984), while discussing both genera, concluded that *Theriosynoecum* Branson, 1936 would differ from *Bisulcoypris* Pinto and Sanguinetti, 1958 by presenting a nodule in the posterodorsal region and accommodation groove. However, according to Do Carmo et al. (1999), there is a species of *Theriosynoecum* with a great variability of nodules, and considering this variability, the nodule criteria on limnocytherids is not recommended as a diagnostic characteristic. Therefore, *Bisulcoypris* was considered as a junior synonym of *Theriosynoecum*, thus invalidating the *Bisulcoypris* Genus (Colin and Danielopol, 1978; Do Carmo et al., 2004b; Sames, 2011). *Bisulcoypris postangularis postangularis* (Swain, 1946), *Bisulcoypris pricei* Pinto and Sanguinetti, 1958, *Bisulcoypris ventrostriata* Moura, 1972 and *Bisulcoypris uninodosa* Pinto and Sanguinetti, 1958 are reassigned to the *Theriosynoecum* Genus. Such generic attribution is adopted herein and by Poropat and Colin (2012a).

The *Metacypris* sp. 6 Subzone (O07-3), is renamed as *Theriosynoecum* sp. 6 Subzone. According to Sames (2011), Middle Jurassic to Early Cretaceous species that formally were attributed to *Metacypris* Brady and Robertson, 1870, that are bisulcate and large, should be assigned to the *Theriosynoecum* Genus, while weakly monosulcate species, that are restricted to an Aptian to Recent lineage, would remain in the *Metacypris* Genus. Therefore, *Metacypris* sp. 6 Krömmelbein, 1962, *Metacypris* sp. 2 Krömmelbein, 1962 and *Metacypris* sp. 5 Krömmelbein, 1962 are reassigned to the *Theriosynoecum* Genus. Such generic attribution is adopted herein and by Poropat and Colin (2012a).

Poropat and Colin (2012a) renamed the *Limnocythere? troelseni* Zone (O10) to *Ilyocypris troelseni*, however, without presenting a taxonomic remarks that justifies this new generic attribution. Krömmelbein and Weber (1971) tentatively attributed this species to *Limnocythere* Brady, 1868, expressing doubt regarding this attribution due to the lack of internal details of the carapace. Although there is an external morphological similarity between *Limnocythere* Brady, 1868 and *Ilyocypris* Brady and Norman, 1889, only internal characteristics should provide important information for the conclusion of this matter, therefore, it was chosen in the present work to follow the original position by Krömmelbein and Weber (1971).

The Genus *Harbinia* Tsao, 1959 is widely discussed by Do Carmo et al. (2013, 2008) due to similarities to *Pattersoncypris* Bate, 1972. The subspecies described by Krömmelbein and Weber (1971) belonging to *Hourcqia* Krömmelbein, 1965a (i.e. *Hourcqia angulata angulata* Krömmelbein and Weber, 1971; *Hourcqia angulata salitrensis* Krömmelbein and Weber, 1971; *Hourcqia angulata sinuata* Krömmelbein and Weber, 1971; and *Hourcqia angulata symmetrica* Krömmelbein and Weber, 1971) were reassigned to *Harbinia* and elevated to the level of species.

A revision of *Hourcqia*, *Pattersoncypris* and *Harbinia* by Poropat and Colin (2012a) led to the revalidations of *Pattersoncypris*, encompassing species *Harbinia micropapillosa*, *Harbinia salitrensis* and *Harbinia sinuata*. They also proposed the Genus *Kroemmelbeincypris* Poropat and Colin, 2012a, including in it *Harbinia angulata* and *Harbinia symmetrica*. The proposal of *Kroemmelbeincypris* was based on the inclined posterior margin, which would differentiate those species from *Harbinia*. Several characteristics described from *Kroemmelbeincypris*, such as valve overlap, outline and ornamentation, are also present in the revised diagnosis of *Harbinia* Tsao, 1959 emend. Hou, 1984, and, therefore, in the present work, authors adopt the classification by Do Carmo et al. (2008, 2013, 2018) in which the afore mentioned species are within the Genus *Harbinia*.

The other six species that were originally attributed to other genera previously studied are well consolidated within their taxonomic status. These species are: *Petrobrasia marfinenses* (Krömmelbein, 1962); *Salvadoriella redunca redunca* (Krömmelbein, 1962); *Paracypridea obovata obovata* (Swain, 1946); *Paracypridea rhomboidalis* (Wicher, 1959); *Theriosynoecum laciniatum* (Krömmelbein, 1965b); and *Darwinula* cf. *D. oblonga* (Roemer, 1839).

STUDIED AREA

The present study encompasses three sections of the Quiricó Formation, from Minas Gerais State, southeastern Brazil: stratotype section of the Quiricó Formation, by the banks of the Quiricó and São José creeks, Presidente Olegário County; hypostratotype section of the Quiricó Formation from the Tereza Farm, João Pinheiro County; and the São Bento Farm section, Carmo do Paranaíba County (Fig. 2).

The stratotype section of the Quiricó Formation, Presidente Olegário County, begins in the banks of the Quiricó creek, where the base of the section is, and extends to the banks of the São José creek, where the top of the section is. In this section, the Areado Group is in contact with the Santa Fé Group, from the Permian-Carboniferous. Also, all three formations of the Areado Group are present – Abaeté, Quiricó and Três Barras. The hypostratotype section of the Tereza Farm, João Pinheiro County, is composed of four lithostratigraphic units, from base to top: Serra da Saudade Formation,

BambuÍ Group; Abaeté, Quiricó and Três Barras formations, Areado Group. The São Bento Farm section, Carmo do Paranaíba County, is composed of three lithostratigraphic units, from base to top: JequitaÍ Formation; Quiricó and Três Barras formations, Areado Group.

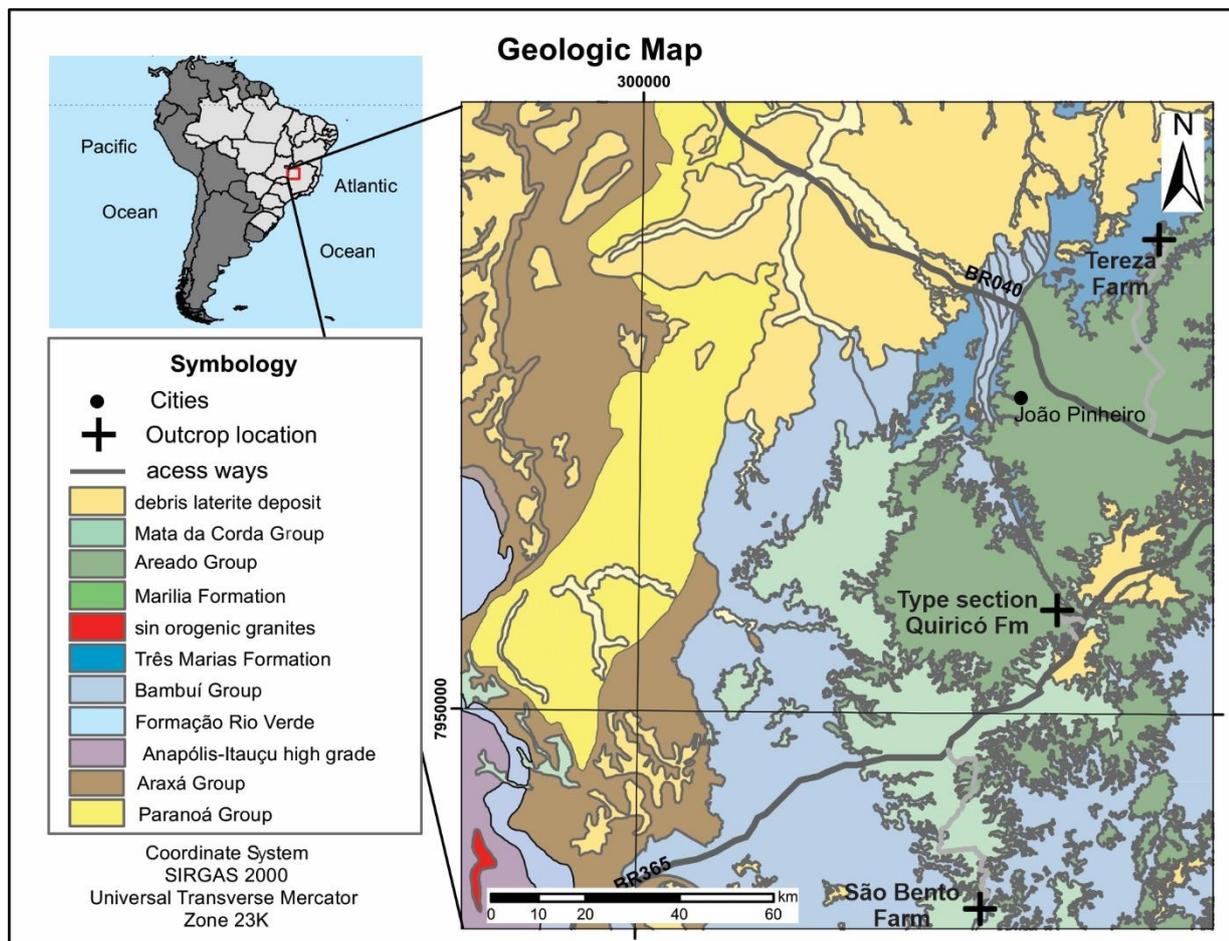


Figure 2. Geologic map with the locality of the three studied sections: 1. stratotype section of the Quiricó Formation, Presidente Olegário County; 2. hypostratotype section of the Quiricó Formation, Tereza Farm, João Pinheiro County; 3. São Bento Farm, Carmo do Paranaíba County, Minas Gerais State, southeastern Brazil.

MATERIAL AND METHODS

The material approached by the present work was first studied from the perspective of ostracod taxonomy by Do Carmo et al. (2004a). Data from Leite et al. (2018), which approached the upper portion of the stratotype section of the Quiricó Formation and the hypostratotype section of the Tereza Farm, was combined with data obtained from samples collected during other fieldworks conducted in

the stratotype section of the Quiricó Formation (intermediate and lower portions) and the São Bento Farm section.

The samples were processed in the Micropaleontology Laboratory, following the standard protocol (Leite et al., 2018), and are housed in the Micropaleontology Collection (MP) under the curatorship of the Geosciences Museum of the University of Brasília. Additionally, the specimens illustrated are part of the Research Collection (CP) of the Geosciences Museum of the University of Brasília.

After the ostracod taxonomic analysis and integration of data on ostracods, vertebrates and palynomorphs, it is presented herein the first biostratigraphic framework for the Lower Cretaceous of the Quiricó Formation. The biostratigraphic method utilized by the present study follows the International Stratigraphic Code (Murphy and Salvador, 1999). All biozones were coded as OSF, which stands for Ostracod São Francisco. The studied ostracod species were also used to revise the paleogeographical affinities of the São Francisco basin with other basins during the Early Cretaceous of Gondwana, by comparing data from the published data on this topic.

OSTRACOD ASSEMBLAGES FROM THE STUDIED SECTIONS

A total of 20 species of ostracods were recovered in the three studied sections at São Francisco basin by Leite (2017) and Leite et al. (2018): 1. *Penthesilenula pintoi* Leite et al., 2018; 2. *Brasacypris ovum* Krömmelbein, 1965b; 3. *Harbinia* aff. *Harbinia salitrensis* (Krömmelbein and Weber, 1971); 4. *Harbinia* aff. *Harbinia angulata* (Krömmelbein and Weber, 1971); 5. *Harbinia alta* Antonietto et al., 2012; 6. *Harbinia* aff. *Harbinia crepata* Do Carmo et al., 2013; 7. *Harbinia symmetrica* (Krömmelbein and Weber, 1971); 8. *Penthesilenula martinsi* (Silva, 1978); 9. *Alicenula longiformis* Leite et al., 2018; 10. *Damonella* aff. *Damonella ultima* (Krömmelbein and Weber, 1971); 11. *Brasacypris fulfaroi* Dias-Brito et al., 2001; 12. *Wolburgiopsis plastica* (Musacchio, 1970); 13. *Wolburgiopsis chinamuertensis* (Musacchio, 1970); 14. *Cypridea* aff. *C. infima* Krömmelbein and Weber, 1971; 15. *Cypridea hystrix* Krömmelbein, 1962; 16. *Cypridea* aff. *C. conjugata* Krömmelbein and Weber, 1971; 17. *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni, 1991; 18. *Cypridea jequiensis* Krömmelbein and Weber, 1971; 19. *Timiriasevia sanfranciscanensis* Leite et al., 2018; and 20. *Cypridea* sp.

At the stratotype section of the Quiricó Formation, 11 species were recovered: 1. *Penthesilenula pintoi* Leite et al., 2018; 2. *Brasacypris ovum* Krömmelbein, 1965b; 3. *Harbinia* aff. *Harbinia salitrensis* (Krömmelbein and Weber, 1971); 4. *Harbinia* aff. *Harbinia angulata* (Krömmelbein and Weber, 1971); 5. *Harbinia alta* Antonietto et al., 2012; 6. *Harbinia* aff. *Harbinia*

crepata Do Carmo *et al.*, 2013; 7. *Harbinia symmetrica* (Krömmelbein and Weber, 1971); 8. *Penthesilenula martinsi* (Silva, 1978); 9. *Alicenula longiformis* Leite *et al.*, 2018; 10. *Damonella* aff. *Damonella ultima* (Krömmelbein and Weber, 1971); and 11. *Brasacypris fulfaroi* Dias-Brito *et al.*, 2001. Ostracods were not recovered at base of the Quiricó Formation in the stratotype section. The intermediate portion of the section encompasses intervals with the greatest number of species, eight of the total: *Penthesilenula pintoi*, *Brasacypris ovum*, *Harbinia alta*, *Harbinia* aff. *H. crepata*, *Penthesilenula martinsi*, *Alicenula longiformis*, *Damonella* aff. *Damonella ultima* and *Brasacypris fulfaroi*. The upper portion of the section, studied by Leite *et al.* (2018), is marked by the occurrence of *Penthesilenula pintoi*, *Harbinia* aff. *H. salitrensis*, *Harbinia* aff. *H. angulata*, *Harbinia* aff. *H. crepata* and *Harbinia symmetrica*. *Harbinia* Tsao, 1959 emend. Hou, 1984 is the most diverse genus, with five species. Both *Penthesilenula pintoi* and *Brasacypris ovum* occur all through the fossiliferous interval. Also, *Penthesilenula pintoi* is the most abundant species (Fig. 3).

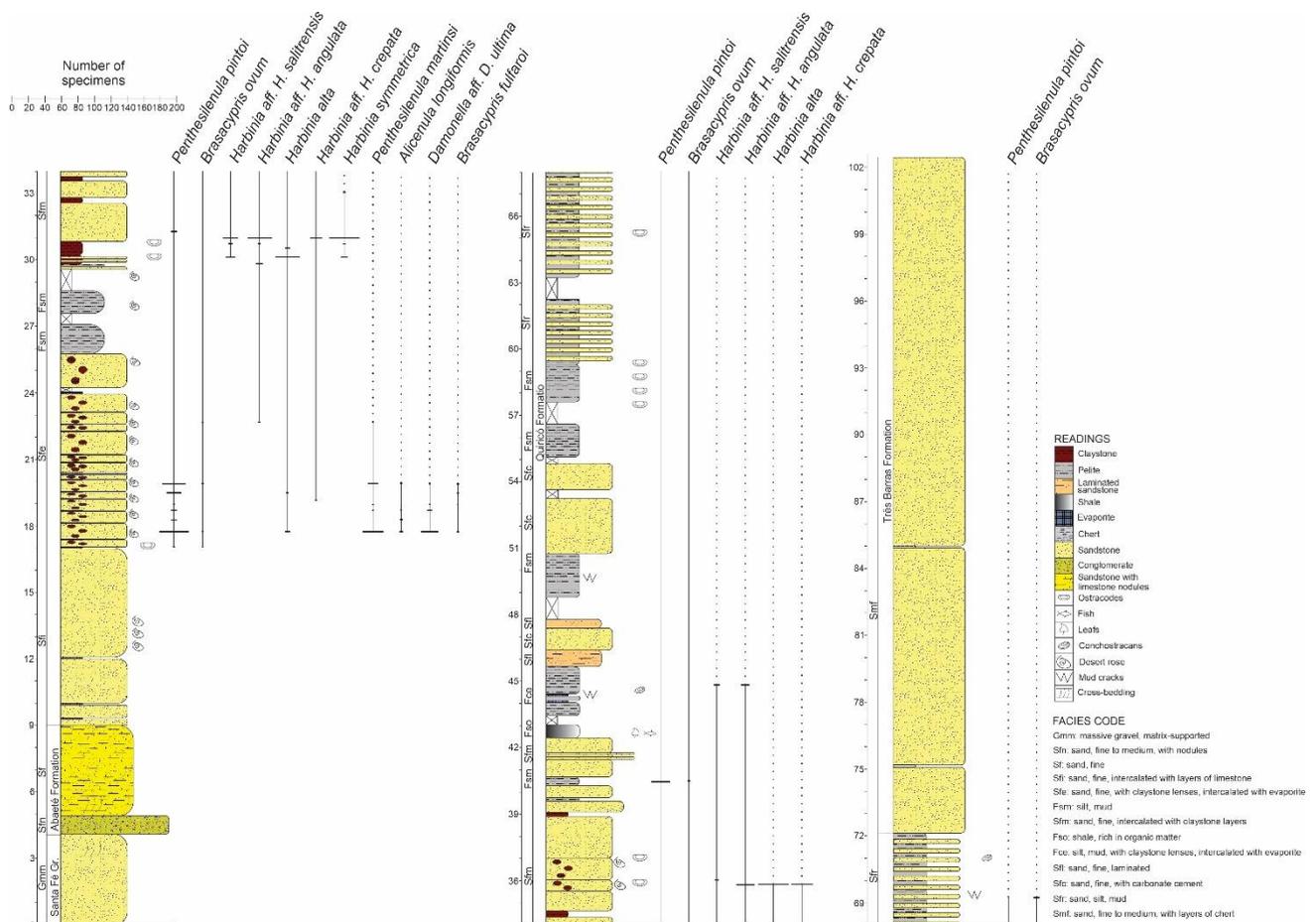


Figure 3. Lithostratigraphic log of the stratotype section of the Quiricó Formation, with ostracod stratigraphic distribution, occurrence and abundance of each species, Presidente Olegário County, Minas Gerais State, Brazil.

At the São Bento Farm section, eight species were recovered: 1. *Brasacypris ovum* Krömmelbein, 1965b; 2. *Brasacypris fulfaroi* Dias-Brito *et al.*, 2001; 3. *Penthesilenula martinsi* (Silva, 1978); 4. *Penthesilenula pintoi* Leite *et al.*, 2018; 5. *Wolburgiopsis plastica* (Musacchio, 1970); 6. *Wolburgiopsis chinamuertensis* (Musacchio, 1970); 7. *Alicenula longiformis* Leite *et al.*, 2018; and 8. *Damonella* aff. *Damonella ultima* (Krömmelbein and Weber, 1971). The *Harbinia* spp. is not one species, but assemblages of specimens of *Harbinia* that were not identified at species level. The intermediate portion of the section encompasses intervals with the greatest number of species, six of the total: *Brasacypris ovum*, *Penthesilenula martinsi*, *Penthesilenula pintoi*, *Wolburgiopsis plastica*, *Wolburgiopsis chinamuertensis* and *Damonella* aff. *D. ultima*. Also, in the intermediate portion, the assemblage *Harbinia* spp. occurs along with the other species. *Brasacypris fulfaroi* occurs only in one layer, at the top of the section, in assemblage with *Brasacypris ovum* (Fig. 4).

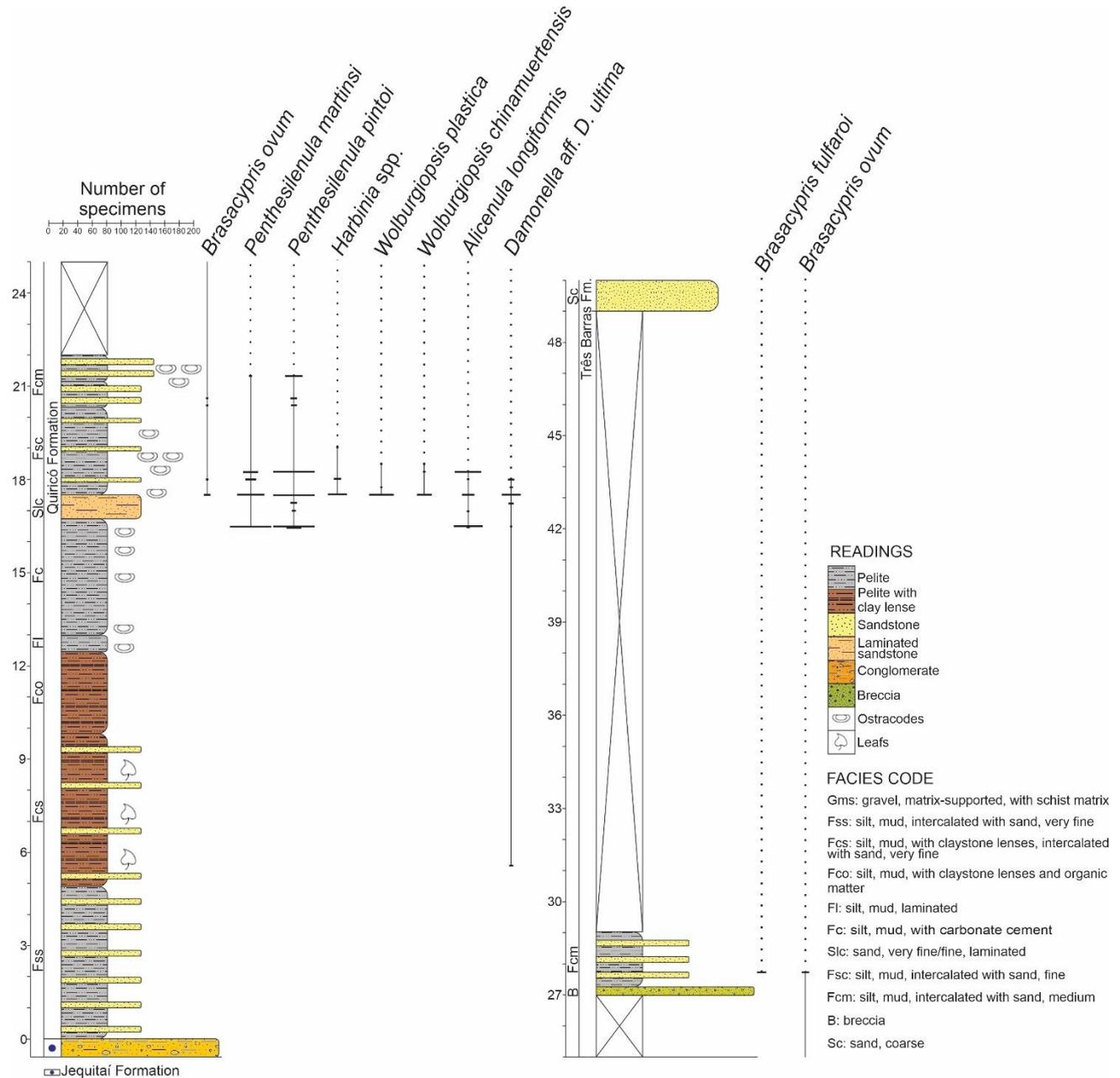


Figure 4. Lithostratigraphic log of the São Bento Farm section, with ostracod occurrence and abundance of each species, Carmo do Paranaíba County, Minas Gerais State, Brazil.

The hypostratotype section of the Tereza Farm was detailed by Leite et al. (2018), and 12 species were recovered: 1. *Penthesilenula pintoii* Leite et al., 2018; 2. *Alicenula longiformis* Leite et al., 2018; 3. *Cypridea* aff. *C. infima* Krömmelbein and Weber, 1971; 4. *Brasacypris fulfaroi* Dias-Brito et al., 2001; 5. *Brasacypris ovum* Krömmelbein, 1965b; 6. *Cypridea hystrix* Krömmelbein, 1962; 7. *Penthesilenula martinsi* (Silva, 1978); 8. *Cypridea* aff. *C. conjugata* Krömmelbein and Weber, 1971; 9. *Neuquenocypris (Protoneuquenocypris) antiqua* Musacchio and Simeoni, 1991; 10. *Cypridea*

jequiensis Krömmelbein and Weber, 1971; 11. *Timiriasevia sanfranciscanensis* Leite et al., 2018; 12. *Cypridea* sp. The basal and intermediate portions of the section encompass intervals with all the species occurring in assemblage. *Penthesilenula pintoi* occurs all through the section, and in the greatest number of specimens. The genus with the greatest variety of species in the hypostratotype section of the Tereza Farm is *Cypridea* Bosquet, 1852, with four species (Fig. 5). It is important to point out that Coimbra (2020), from the analysis of figures and descriptions from Leite et al. (2018), interpreted that all *Cypridea* species were erroneously identified, and would be new taxa. In the present study, the authors follow the position adopted by Leite et al. (2018), and a taxonomic discussion on the matter should follow through the “*Revista Brasileira de Paleontologia*” as a reply.

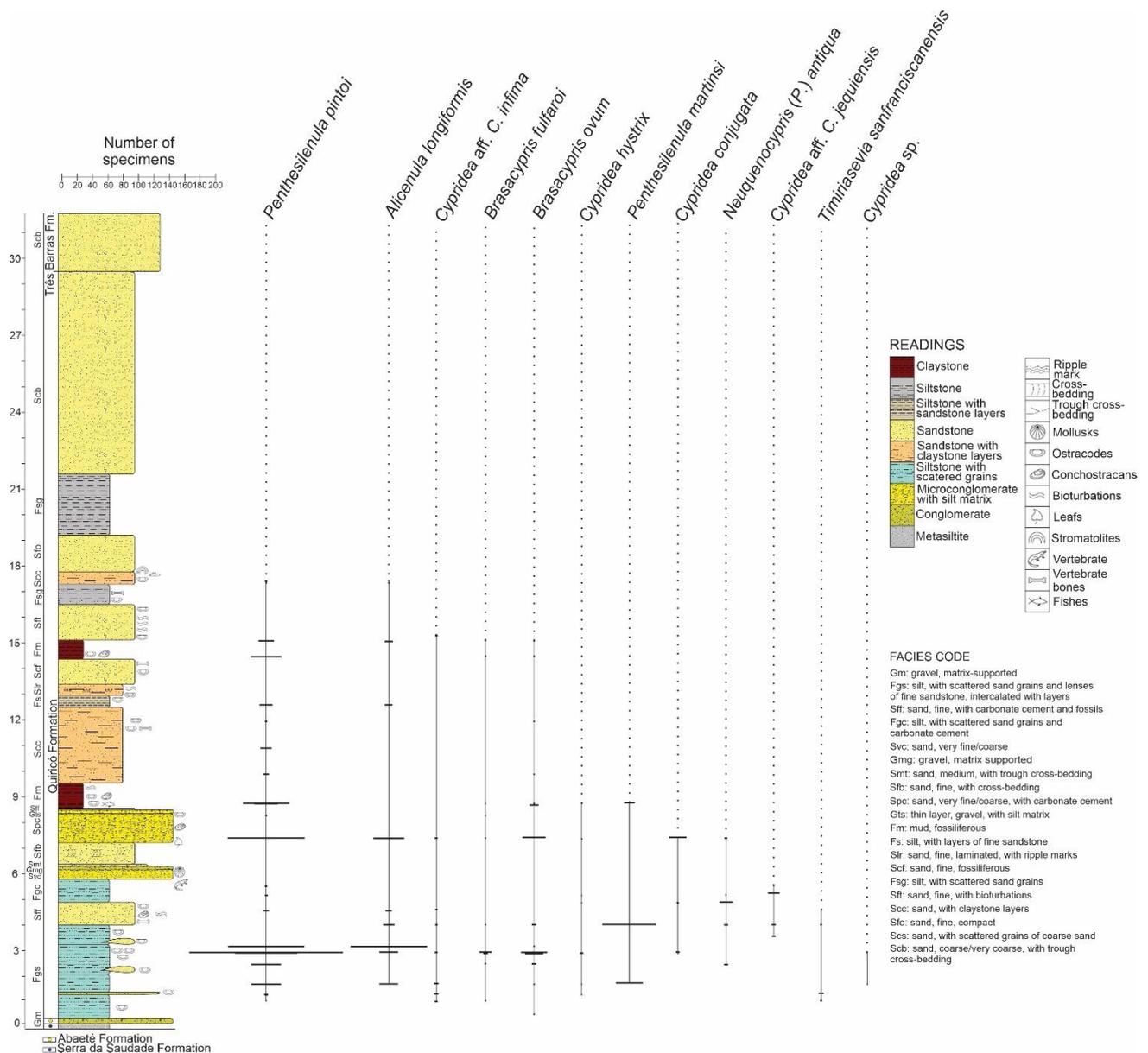


Figure 5. Lithostratigraphic log of the hypostratotype section of the Tereza Farm, with ostracod occurrence and abundance of each species, João Pinheiro County, Minas Gerais State, Brazil.

BIOSTRATIGRAPHY

Six biostratigraphic units are currently proposed: Zone *Brasacypris ovum*, OSF-0 Superzone *Penthesilenula pintoi*, OSF-1; *Timiriasevia sanfranciscanensis*, OSF-1.1; Zone *Cypridea hystrix*, OSF-1.2; Zone *Alicenula longiformis*, OSF-1.3; and Zone *Harbinia* spp., OSF-1.4. The *Brasacypris ovum* Zone, lowest occurrence interval, encompasses the Berriasian. The *Penthesilenula pintoi* Superzone, range interval, encompasses the other four zones and its chronostratigraphic attribution is defined by them, from Berriasian to Aptian/Albian?. The *Timiriasevia sanfranciscanensis* Zone, lowest-occurrence interval, encompasses the Berriasian. The *Cypridea hystrix* Zone, range interval, encompasses the Valanginian-Hauterivian interval. The *Alicenula longiformis* Zone, highest-occurrence interval, encompasses the Barremian. The *Harbinia* spp. Zone, assemblage interval, encompasses the Aptian (Fig. 6).

The *Penthesilenula pintoi* Superzone occurs in all three sections approached in the present study. The stratotype section of the Quiricó Formation and the São Bento Farm section encompass zones *Alicenula longiformis* and *Harbinia* spp., attributed to the Barremian and Aptian respectively. The hypostratotype section of the Tereza Farm encompasses zones *Brasacypris ovum*, *Timiriasevia sanfranciscanensis*, *Cypridea hystrix* and *Alicenula longiformis*, the first two attributed to the Berriasian and the others to Valanginian-Hauterivian and Barremian, respectively.

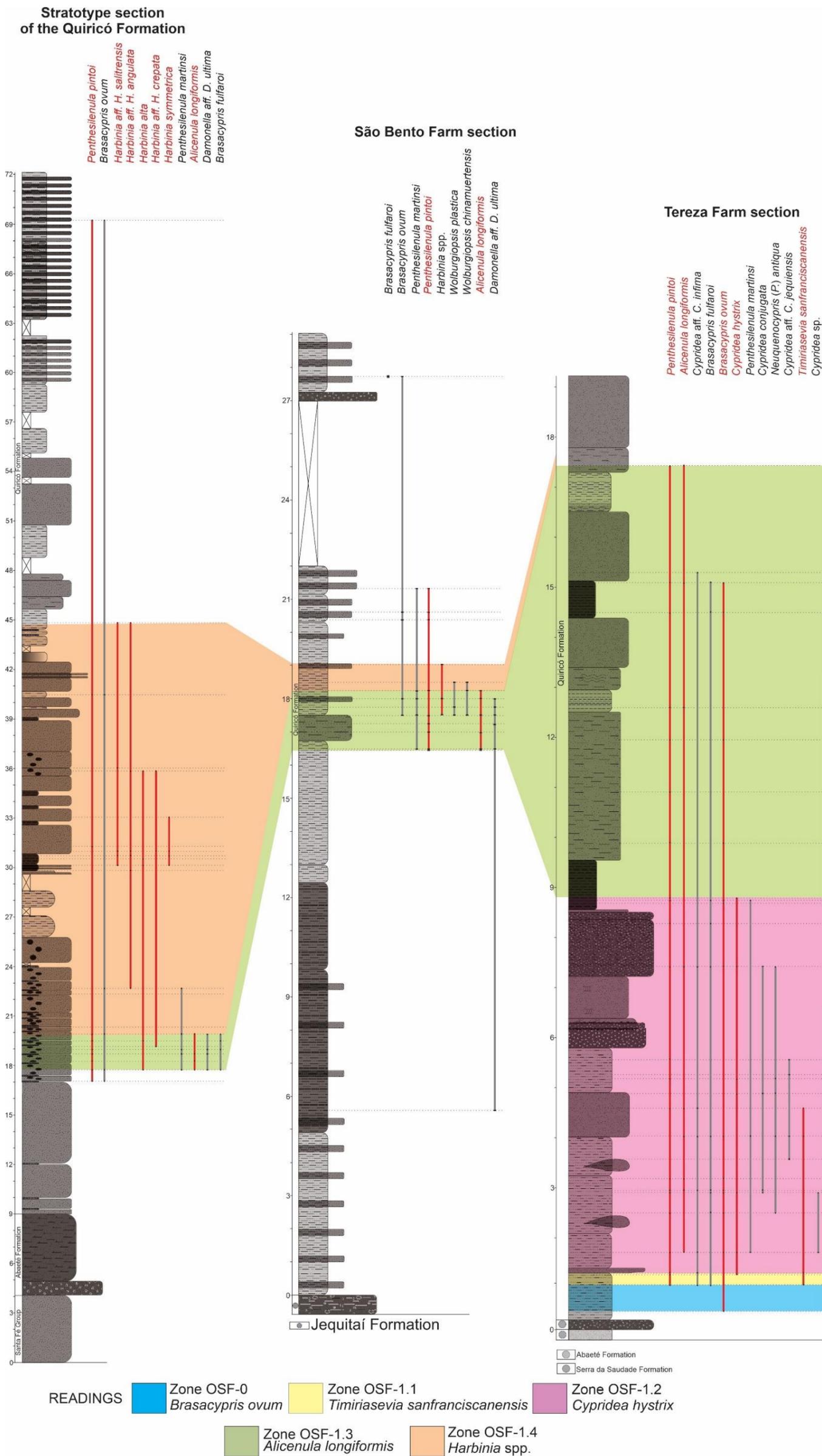


Figure 6. Lithostratigraphic logs for the stratotype section of the Quiricó Formation, the São Bento Farm section and the hypostratotype section of the Tereza Farm, with ostracod occurrences, and proposed biostratigraphic zones.

***Brasacypris ovum* Zone, OSF-0, lowest-occurrence interval**

Definition. Lower and upper boundaries of the zone defined by the lowest occurrences of *Brasacypris ovum* Krömmelbein, 1965b and *Timiriasevia sanfranciscanensis* Leite et al., 2018 respectively (Figs 6, 7).

Characterization. The only species that occurs in this zone is *Brasacypris ovum* Krömmelbein, 1965b.

Stage. Berriasian (see remarks) (Fig. 7).

Local Stage. Rio da Serra O02 (see remarks) (Figs 7, 8).

Stratotype section. Hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, Brazil (Fig. 6).

Remarks. This zone was established using *Brasacypris ovum* Krömmelbein, 1965b and it occurs exclusively in the Tereza Farm section (Fig. 6). It is the only zone not included in the *Penthesilenula pintoï* Superzone. The lowest occurrence of *Brasacypris ovum* marks the beginning of this zone. *Brasacypris ovum* occurs in the Berriasian (Caixeta et al., 1994; Costa et al., 2007; Silva et al., 2007), of the Tucano basin, Itaparica and Candeias formations, attributed to the Local Stage Rio da Serra O02 (Krömmelbein, 1965b, 1966; Costa et al., 2007). Therefore, the attribution of this zone to the Berriasian and to the Local Stage Rio da Serra O02. This zone does not occur in the stratotype section of the Quiricó Formation, nor in the São Bento Farm section (Fig. 7).

***Penthesilenula pintoï* Superzone, OSF-1, range interval**

Definition. Stratigraphic interval corresponding to the local range of *Penthesilenula pintoï* Leite et al., 2018 (Figs 6, 7).

Characterization. From base to top, the following zones are recognized: *Timiriasevia sanfranciscanensis*, *Cypridea hystrix*, *Alicenula longiformis* and *Harbinia* spp.

Stage. Berriasian-Aptian/Albian? (see remarks) (Fig. 7).

Local Stage. Rio da Serra O02, O03 and O04; Aratu O05; Buracica O08; Jiquiá O09; and Alagoas O11 (see remarks) (Figs 7, 8).

Stratotype section. Stratotype section of the Quiricó Formation, by the banks of the Quiricó and São José creeks, Presidente Olegário County, Minas Gerais State, Brazil (Fig. 6).

Remarks. *Penthesilenula pintoï* Leite et al., 2018, which defines this superzone, occurs all through the fossiliferous interval of the Quiricó Formation, indicating a deposition continuity between all the studied sections. *Penthesilenula pintoï* is the most abundant species, reaching more than 200 specimens

in some intervals and was described from the Quiricó Formation. This superzone occurs in all studied sections; however, it is not entirely represented in its stratotype section, in the São Bento Farm section and in the hypostratotype section of the Tereza Farm. The stratotype section and the São Bento Farm section encompass zones *Alicenula longiformis*, attributed to the Barremian and *Harbinia* spp., attributed to the Aptian. The hypostratotype section of the Tereza Farm encompasses zones *Timiriasevia sanfranciscanensis*, attributed to the Berriasian, *Cypridea hystrix*, attributed to the Valanginian-Hauterivian and *Alicenula longiformis*. Especially in the stratotype section of the Quiricó Formation, the upper portion of sequence, marked by only one layer with the occurrence of *Penthesilenula pinto*i and *Brasacypris ovum*, does not correspond to the *Harbinia* spp. Zone. Although the *Harbinia* spp. zone is attributed to the Aptian, the attribution of the upper portion of the *Penthesilenula pinto*i Superzone to the Aptian or post-Aptian is uncertain, that is why the top of this superzone is positioned in the Aptian/Albian?. The attribution of the *Penthesilenula pinto*i Superzone to the Berriasian-Aptian/Albian? interval and to local stages Rio da Serra (O02, O03 and O04), Aratu (O05), Buracica (O08), Jiquiá (O09) and Alagoas (O11), is based on the attribution of zones *Timiriasevia sanfranciscanensis*, *Cypridea hystrix*, *Alicenula longiformis* and *Harbinia* spp. (Fig. 7).

***Timiriasevia sanfranciscanensis* Zone, OSF-1.1, lowest-occurrence interval**

Definition. Lower and upper boundaries of the zone defined by the lowest occurrences of *Timiriasevia sanfranciscanensis* Leite et al., 2018 and *Cypridea hystrix* Krömmelbein, 1962, respectively (Figs 6, 7).

Characterization. Species that occur in this zone are *Penthesilenula pinto*i Leite et al., 2018, *Cypridea* aff. *C. infima* Krömmelbein and Weber, 1971, *Brasacypris fulfaroi* Dias-Brito et al., 2001, and *Brasacypris ovum* Krömmelbein, 1965b.

Stage. Berriasian (see remarks) (Fig. 7).

Local Stage. Rio da Serra O02 and O03 (see remarks) (Figs 7, 8).

Stratotype section. Hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, Brazil (Fig. 6).

Remarks. This zone was established using *Timiriasevia sanfranciscanensis* as its index species, and it occurs exclusively in the Tereza Farm section (Fig. 6). The lowest occurrence of *Cypridea* aff. *C. infima* is within this zone. *Cypridea infima* occurs in the Berriasian (Caixeta et al., 1994; Costa et al., 2007; Silva et al., 2007) of the Recôncavo basin, Candeias Formation, lower and middle portions, attributed to local stages Rio da Serra O02 and O03 (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b). Therefore, the attribution of this zone to the Berriasian and to local stages Rio da Serra

O02 and O03, is based on the lowest occurrence of *Cypridea* aff. *C. infima*. It is important to point out that the niche occupied by species of the Subfamily Timiriaseviinae Mandelstam, 1947, to which the Genus *Timiriasevia* Mandelstam, 1947 belongs to had a notable contraction that could be attributed to the explosion of the Superfamily Cypridoidea Baird, 1845 in the Upper Jurassic-Lower Cretaceous (Collin and Danielopol, 1979). In the stratotype of this zone, there is only one species of Timiriaseviinae, and the lowest occurrence of *Timiriasevia sanfranciscanensis* is before the *Cypridea* species variation, which could be associated with this phenomenon described by Collin and Danielopol (1979) during the latest Jurassic-earliest Cretaceous. This zone does not occur in the stratotype section of the Quiricó Formation, nor in the São Bento Farm section (Fig. 7).

***Cypridea hystrix* Zone, OSF-1.2, range interval**

Definition. Stratigraphic interval corresponding to the local range of *Cypridea hystrix* Krömmelbein, 1962 emend. Leite et al., 2018 (Figs 6, 7).

Characterization. Species that occur in this zone are *Penthesilenula pinto* Leite et al., 2018, *Alicenula longiformis* Leite et al., 2018, *Cypridea* aff. *C. infima* Krömmelbein and Weber, 1971, *Brasacypris fulfaroi* Dias-Brito et al., 2001, *Brasacypris ovum* Krömmelbein, 1965b, *Penthesilenula martinsi* (Silva, 1978), *Cypridea* aff. *C. conjugata* Krömmelbein and Weber, 1971, *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni, 1991, *Cypridea jequiensis* Krömmelbein and Weber, 1971, *Timiriasevia sanfranciscanensis* Leite et al., 2018 and *Cypridea* sp.

Stage. Valanginian-Hauterivian (see remarks) (Fig. 7).

Local Stage. Rio da Serra O04 and Aratu O05 (see remarks) (Figs 7, 8).

Stratotype section. Hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, Brazil (Fig. 6).

Remarks. This zone was established using *Cypridea hystrix* Krömmelbein, 1962 as its index species and it occurs exclusively in the Tereza Farm section (Fig. 6). *Cypridea hystrix* occurs in the Recôncavo basin, Ilhas Formation, attributed to the Valanginian-Hauterivian interval, and the Aratu O05 Local Stage (Krömmelbein, 1962; Poropat and Colin, 2012b). It also occurs in the *Paracypridea brasiliensis* Zone (NRT-O04), with occurrence marked in subzones *Paracypridea bicallosa* (NRT-O04.3) and *Paracypridea maacki* (NRT-O04.4) (Viana et al., 1971; Cunha and Moura, 1979; Regali and Viana, 1989), attributed to the Rio da Serra Local Stage, Valanginian (Caixeta et al., 1994). The fossil fish *Mawsonia gigas* Mawson and Woodward, 1907 recovered and studied by Carvalho and Maisey (2008) from the Tereza Farm section, occurs in layers which are encompassed by the *Cypridea hystrix* zone, and possibly by the lower portion of the *Alicenula longiformis*. Although this is a different fossil group,

the material is abundant and according to Carvalho and Maisey (2008), presents little post-mortem disturbance. *Mawsonia gigas* is typical of the Candeias Formation, attributed to the Rio da Serra Local Stage, Berriasian-Valanginian interval (Caixeta et al., 1994; Carvalho and Maisey, 2008). Therefore, the positioning of the *Cypridea hystrix* zone in the Valanginian-Hauterivian interval and in local stages Rio da Serra O04 and Aratu O05 is based on local occurrences, mainly on the occurrence of *Cypridea hystrix*, but can be corroborated by the abundant occurrence of *Mawsonia gigas* (Fig. 7). This zone does not occur in the stratotype section of the Quiricó Formation, nor in the São Bento Farm section.

***Alicenula longiformis* Zone, OSF-1.3, highest-occurrence interval**

Definition. Lower and upper boundaries of the zone defined by the highest occurrences of *Cypridea hystrix* Krömmelbein, 1962 and *Alicenula longiformis* Leite et al., 2018, respectively (Figs 6, 7).

Characterization. Species that occur in this zone are *Cypridea* aff. *C. infima* Krömmelbein and Weber, 1971, *Penthesilenula pintoii* Leite et al., 2018, *Damonella* aff. *Damonella ultima* (Krömmelbein and Weber, 1971), *Wolburgiopsis plastica* (Musacchio, 1970), *Wolburgiopsis chinamuertensis* (Musacchio, 1970), *Penthesilenula martinsi* (Silva, 1978), *Brasacypris ovum* Krömmelbein, 1965b, *Brasacypris fulfaroi* Dias-Brito et al., 2001, *Harbinia* aff. *Harbinia crepata* Do Carmo et al., 2013, *Harbinia alta* Antonietto et al., 2012 and the assemblage *Harbinia* spp.

Stage. Barremian (see remarks) (Fig. 7).

Local Stage. Buracica O08 and Jiquiá O09 (see remarks) (Figs 7, 8).

Stratotype section. Hypostratotype section of the Tereza Farm, João Pinheiro County, Minas Gerais State, Brazil (Fig. 6).

Remarks. This is the only zone that occurs in all the studied section, and was established using *Alicenula longiformis* as its index species (Fig. 6). It occurs in the upper portion of the Tereza Farm section, the lower portion of the stratotype section of the Quiricó Formation and the lower portion of the São Bento Farm section. In the stratotype section, species that occur in this zone are *Brasacypris fulfaroi*, *Damonella* aff. *Damonella ultima*, *Penthesilenula martinsi*, *Harbinia* aff. *Harbinia crepata*, *Harbinia alta*, *Brasacypris ovum* and *Penthesilenula pintoii*. In the São Bento Farm section, species that occur in this zone are *Damonella* aff. *Damonella ultima*, *Wolburgiopsis chinamuertensis*, *Wolburgiopsis plastica*, *Penthesilenula pintoii*, *Penthesilenula martinsi*, *Brasacypris ovum* and the assemblagem *Harbinia* spp. In the hypostratotype section of the Tereza Farm, species that occur in this zone are *Brasacypris ovum*, *Brasacypris fulfaroi*, *Cypridea* aff. *C. infima* and *Penthesilenula pintoii*. *Alicenula longiformis* was described from the Quiricó Formation by Leite et al. (2018), and has only been recovered in this formation so far. Thus, the positioning of this zone in the Barremian is due

to the local occurrence of other species. In the São Bento Farm section, both *Wolburgiopsis chinamuertensis* and *Wolburgiopsis plastica*, typical species of the Barremian in Argentina (Musacchio, 1970; Do Carmo et al., 2004a), occur mainly in this zone, with only one simultaneous occurrence in one level within the *Harbinia* spp. Zone, corroborating with the age attribution of Do Carmo et al. (2004a) for this section. Also, *Damonella ultima*, which was identified in the studied sections as *Damonella* aff. *Damonella ultima*, is restricted to this zone both in the stratotype section and the São Bento Farm section. This species occurs in the *Petrobrasia diversicostata* Zone (NRT-O09), with occurrence well marked in the *Bisulcocypris postangularis* Subzone (BRT-O09.1), and in the *Cypridea (Sebastianites) fida minor* Zone (NRT-O08), with occurrences well marked in the *Cypridea (Sebastianites?) mira* (NRT-O08.3), *Petrobrasia capivarensis* (NRT-O08.2) and *Cypridea (Sebastianites?) sostensis sostensis* (NRT-O08.1) subzones (Viana et al., 1971; Cunha and Moura, 1979), attributed to the upper Barremian (Caixeta et al., 1994), corroborating with the positioning of the *Alicenula Longiformis* Zone in the Barremian and attribution to local stages Buracica O08 and Jiquiá O09 (Fig. 7).

***Harbinia* spp. Zone, OSF-1.4, assemblage interval**

Definition. Stratigraphic interval corresponding to the assemblage of *Harbinia* aff. *Harbinia salitrensis* (Krömmelbein and Weber, 1971), *Harbinia* aff. *Harbinia angulata* (Krömmelbein and Weber, 1971), *Harbinia alta* Antonietto et al., 2012, *Harbinia* aff. *Harbinia crepata* Do Carmo et al., 2013 and *Harbinia symmetrica* (Krömmelbein and Weber, 1971). The lower limit is defined by the highest occurrence of *Alicenula longiformis* Leite et al., 2018 and the upper limit by the highest occurrence of species of *Harbinia* (Figs 6, 7).

Characterization. Species that occur in this zone are *Penthesilenula pintoii* Leite et al., 2018, *Brasacypris ovum* Krömmelbein, 1965b, *Penthesilenula martinsi* (Silva, 1978), *Wolburgiopsis plastica* (Musacchio, 1970) and *Wolburgiopsis chinamuertensis* (Musacchio, 1970).

Stage. Aptian (see remarks) (Fig. 7).

Local Stage. Alagoas O11 (see remarks) (Figs 7, 8).

Stratotype section. Stratotype section of the Quiricó Formation, by the banks of the Quiricó and São José creeks, Presidente Olegário County, Minas Gerais State, Brazil (Fig. 6).

Remarks. This zone was established using *Harbinia* aff. *Harbinia salitrensis*, *Harbinia* aff. *Harbinia angulata*, *Harbinia alta*, *Harbinia* aff. *Harbinia crepata* and *Harbinia symmetrica* as its index species. It extends to the São Bento Farm section (Carmo do Paranaíba County), corresponding to the occurrence of *Harbinia* spp., assemblages of specimens of *Harbinia* that were not defined in species

level due to poor preservation and deformation of carapace. *Harbinia* aff. *Harbinia salitrensis*, *Harbinia* aff. *Harbinia angulata* and *Harbinia symmetrica* occur exclusively within this zone, while the lowest occurrence of *Harbinia alta* and *Harbinia* aff. *Harbinia crepata* is within the *Alicenula longiformis* Zone (Fig. 5). Especially *Harbinia symmetrica*, *Harbinia angulata*, *Harbinia alta* and *Harbinia salitrensis* belong to the *Harbinia* spp. 201-208 Zone, coded as NRT-O11 (Do Carmo et al., 2008), attributed to the Alagoas Local Stage (Schaller, 1969; Moura, 1987), dated as upper Aptian-lower Albian (Antonietto et al., 2012), corroborating with the positioning of the *Harbinia* spp. Zone in the Aptian and in the Alagoas O11 Local Stage. It is important to point out that this zone does not occur in the Tereza Farm section (Fig. 7).

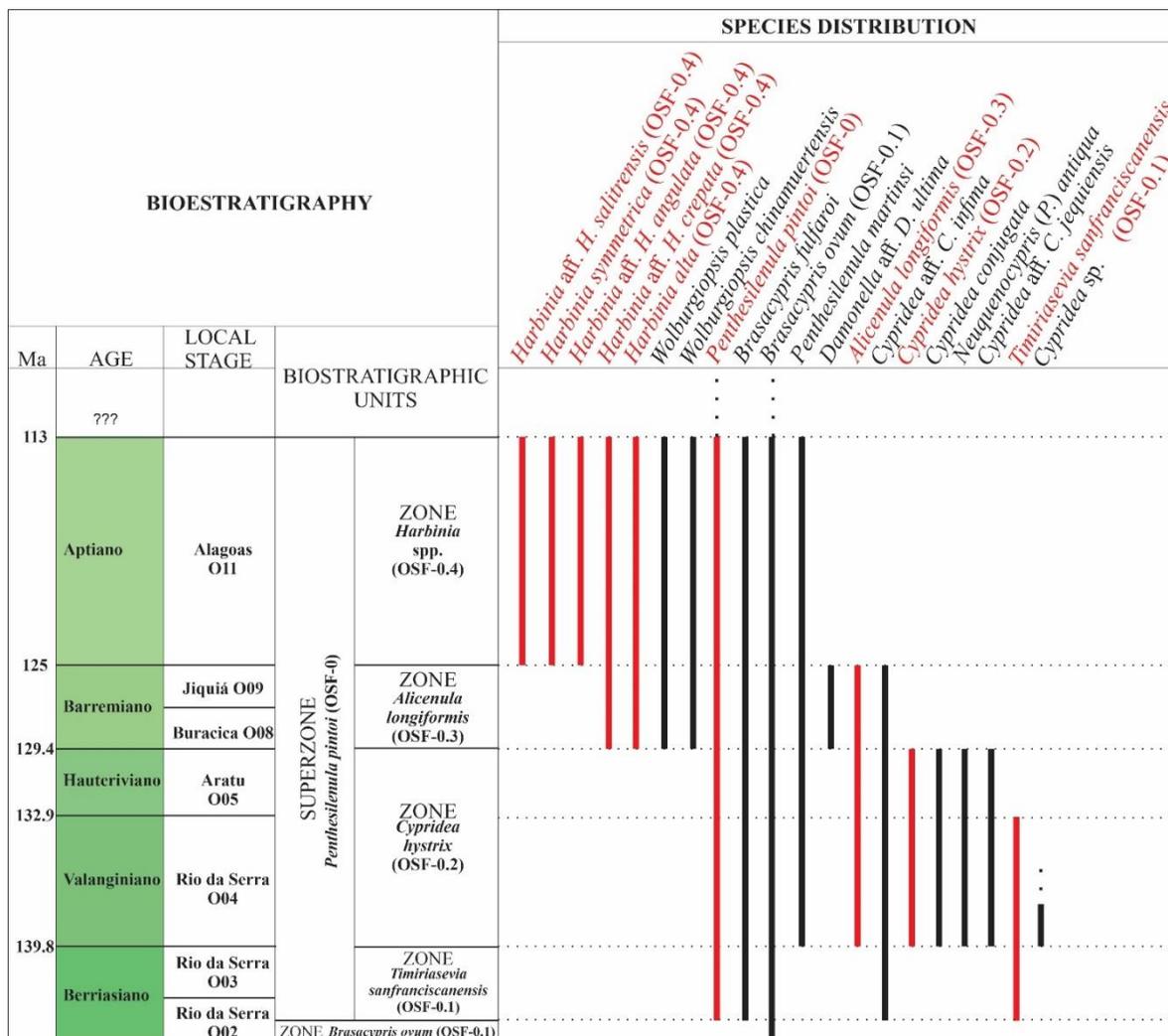


Figure 7. Biostratigraphic units proposed based on limnic ostracod species of the Quiricó Formation, Lower Cretaceous, São Francisco basin (based on the International Chronostratigraphic Chart, 2021). Obs.: The upper age attribution of *Penthesilenula pintoi*, *Brasacypris ovum* and *Cypridea* sp. is uncertain, represented by the dotted line.

Remarks on the chronobiostratigraphic framework based on Ostracoda

The lithostratigraphic interval – Berriasian-Aptian/Albian? – interpreted for the Quiricó Formation is based on ostracod biostratigraphy and differs from previous studies on the chronostratigraphy of the Quiricó Formation. With the exception of formations Alter do Chão and Solimões, which are fluvio-lacustrine (Cunha, 2007; Cunha et al., 2007; Wanderley Filho et al., 2007), it is uncommon for a sedimentary formation to be deposited in a lacustrine system, continuously, during such a wide interval. The local stages to which the Quiricó Formation is attributed to, can be correlated to those of Viana et al. (1971), Moura and Praça (1985), Moura (1987) and Do Carmo et al. (2008) (Fig. 8).

The *Brasacypris ovum* Zone is correlated to the *Theriosynoecum verietuberatum* (O02) Zone, attributed to the Rio da Serra Local Stage (Viana et al., 1971; Moura and Praça, 1985; Moura, 1987) (Fig. 8). This correlation is based on the first occurrence of *Brasacypris ovum*. *Brasacypris ovum* occurs in the Itaparica and Candeias formations, Tucano basin, attributed to the Rio da Serra O02 Local Stage (Krömmelbein, 1966; Costa et al., 2007). The *Timiriasevia sanfranciscanensis* Zone is correlated to zones *Theriosynoecum verietuberatum* (O02) and *Cypridea morininoides candeiensis* (O03), attributed to the Rio da Serra Local Stage (Moura, 1987; Moura and Praça, 1985; Viana et al., 1971) (Fig. 8). This correlation is based on the occurrences of *Brasacypris ovum* and *Cypridea* aff. *C. infima*. The occurrence of *Brasacypris ovum* is discussed above. *Cypridea infima* occurs in the lower and middle portions of the Candeias Formation, Recôncavo basin, attributed to local stages Rio da Serra O02 and O03 (Caixeta et al., 1994; Poropat and Colin, 2012b).

The *Cypridea hystrix* Zone is correlated to zones *Paracypridea brasiliensis* (O04) and *Paracypridea obovata obovata* (O05), attributed to the upper Rio da Serra Local Stage and lower Aratu Local Stage, respectively (Viana et al., 1971; Moura and Praça, 1985; Moura, 1987; Do Carmo et al., 2008) (Fig. 8). This correlation is based on the stratigraphic distribution of *Cypridea hystrix*. This species occurs in the *Paracypridea brasiliensis* Zone (O04), with occurrence marked in subzones *Paracypridea bicallosa* (O04.3) and *Paracypridea maacki* (O04.4) (Viana et al., 1971; Cunha and Moura, 1979; Regali and Viana, 1989). Also, *Cypridea hystrix* occurs in the lower portion of the Ilhas Formation, attributed to the Aratu Local Stage, Zone *Paracypridea obovata obovata* (O05) (Poropat and Colin, 2012b). The *Cypridea (Morinina?) bibullata bibullata* Zone (O06), from the Aratu Local Stage, and the *Coriacina coriacea* Zone (O07), from the Buracica Local Stage were not recorded at the Quiricó Formation during the present study, due to an absence of index species to establish these zones.

The *Alicenula longiformis* Zone is correlated to zones *Cypridea (Sebastianites) fida minor* (O08) and *Petrobrasia diversicostata* (O09), attributed to the lower Jiquiá Local Stage and upper Buracica Local Stage, respectively (Viana et al., 1971; Moura and Praça, 1985; Moura, 1987) (Fig. 8). This correlation is based on the occurrences of *Damonella ultima*, restricted to the *Alicenula longiformis* Zone. *Damonella ultima* occurs in subzones *Cypridea (Sebastianites?) mira* (NRT-O08.3), *Petrobrasia capivarensis* (O08.2) and *Cypridea (Sebastianites?) sostensis sostensis* (O08.1) of the *Cypridea (Sebastianites?) fida minor* Zone (O08), attributed to the Buracica Local Stage, and in the *Bisulcocypris postangularis* Subzone (O09.1) of the *Petrobrasia diversicostata* Zone (NRT-O09), attributed to the Jiquiá Local Stage (Viana et al., 1971; Moura and Praça, 1985; Moura, 1987). Also, *Damonella ultima* occurs in the middle and upper portions of the São Sebastião Formation, interval correlated to the upper Buracica and lower Jiquiá local stages (Poropat and Colin, 2012b). The *Limnocythere? troelseni* Zone (O10), from the Jiquiá Local Stage, was not recorded at the Quiricó Formation during the present study, due to an absence of index species.

The *Harbinia* spp. Zone is correlated to the *Harbinia* spp. 201-218 Zone (O11), attributed to the Alagoas Local Stage (Do Carmo et al., 2008) (Fig. 8). This correlation is based on the occurrences of *Harbinia angulata*, *Harbinia salitrensis*, *Harbinia symmetrica* and *Harbinia crepata*. The *Harbinia* spp. 201-218 Zone (O11) was originally named *Cytheridea? spp. 201-218* (Moura and Praça, 1985; Moura, 1987), but due to the occurrence of species of *Harbinia*, specially *Harbinia angulata*, *Harbinia sinuata*, *Harbinia salitrensis* and *Harbinia symmetrica*, which are index species for Zone O11, (Do Carmo et al., 2008) renamed it to *Harbinia* spp. 201-218. This zone was attributed to the upper Aptian-Aptian/Albian interval by Do Carmo et al. (2008). However, Antonietto (2015) due to the occurrence of *Harbinia crepata* in the Sergipe-Alagoas basin, a typical Aptian species (Do Carmo et al., 2013), beyond the Alagoas Local Stage, repositioned the upper limit of this local stage in the Aptian, with the overlapping biostratigraphic zone attributed to the Aptian-Albian interval. In the Quiricó Formation, the interval in which species of *Harbinia* marks the Alagoas Local Stage.

Lastly, based on the previous chronostratigraphic attributions of the afore mentioned zones, the *Penthesilenula pintoi* Subzone (OSF-0), which comprises zones *Timiriasevia sanfranciscanensis*, *Cypridea hystrix*, *Alicenula longiformis* and *Harbinia* spp. is correlated to local stages Rio da Serra, Aratu, Buracica, Jiquiá and Alagoas of Viana et al. (1971), Moura and Praça (1985), Moura (1987) and Do Carmo et al. (2008) (Fig. 8). However, the upper portion of this superzone, due to one interval with the occurrence of *Penthesilenula pintoi* and *Brasacypris ovum*, has its attribution uncertain whether in the Aptian or post-Aptian, following the discussion above about the Alagoas Local Stage.

Local	Recôncavo-Tucano basin Campos basin			Araripe basin		São Francisco basin		
	Viana et al. (1971) modified by Moura & Praça (1985) and Moura (1987)			Do Carmo et al. (2008)		Current local correlation		
???								
Alagoas	<i>Cytheridea?</i> spp. GR. 201- 218	O11		<i>Harbinia</i> spp. 201-218	O11			<i>Harbinia</i> spp. (OSF-1.4) Zone
Jiquiá	<i>Limnocythere?</i> <i>troelseni</i> Krommelbein & Weber, 1971	O10				MISSING INDEX FOSSIL		MISSING INDEX FOSSIL
			<i>Petrobrasia</i> <i>diversicostata</i> Krommelbein, 1965	O09	O09.3			<i>Alicenula longiformis</i> (OSF-1.3) Zone
					O09.2			
			O09.1					
Buracica	<i>Cypridea</i> (<i>Sebastianites</i>) <i>fida minor</i> Moura, 1972	O08	O08.3			MISSING INDEX FOSSIL		
			O08.2					
			O08.1					
	<i>Coriacina</i> <i>coriacea</i> Krommelbein, 1962	O07	O07.4				MISSING INDEX FOSSIL	
			O07.3					
			O07.2					
			O07.1					
Aratu	<i>Cypridea</i> (<i>Morinina?</i>) <i>bibullata</i> <i>bibullata</i> (Wicher, 1959)	O06	O06.2			MISSING INDEX FOSSIL		
			O06.1					
	<i>Paracypridea</i> <i>obovata</i> <i>obovata</i> (Swain, 1946)	O05	O05.5	<i>Paracypridea</i> <i>obovata</i> <i>obovata</i> (Swain, 1946)	O05		MISSING INDEX FOSSIL	<i>Penthesilenula pintoii</i> (OSF-1) Superzone
			O05.4					
			O05.3					
			O05.2					
			O05.1					
Rio da Serra	<i>Paracypridea</i> <i>brasiliensis</i> Krommelbein, 1961	O04	O04.5	<i>Paracypridea</i> <i>brasiliensis</i> Krommelbein, 1961	O04	MISSING INDEX FOSSIL	<i>Cypridea hystrix</i> (OSF-1.2) Zone	
			O04.4					
			O04.3					
			O04.2					
	<i>Cypridea</i> <i>morininooides</i> <i>candeiensis</i> Krommelbein, 1962	O03	O03.2	<i>Cypridea</i> <i>morininooides</i> <i>candeiensis</i> Krommelbein, 1962	O03		MISSING INDEX FOSSIL	<i>Timiriasevia</i> <i>sanfranciscanensis</i> (OSF-1.1) Zone
			O03.1					
<i>Theriosynoecum</i> <i>varietuberatum</i> Grekkof & Krommelbein, 1967	O02	O02.2			MISSING INDEX FOSSIL	<i>Brasacypris ovum</i> (OSF-0) Zone		
		O02.1						

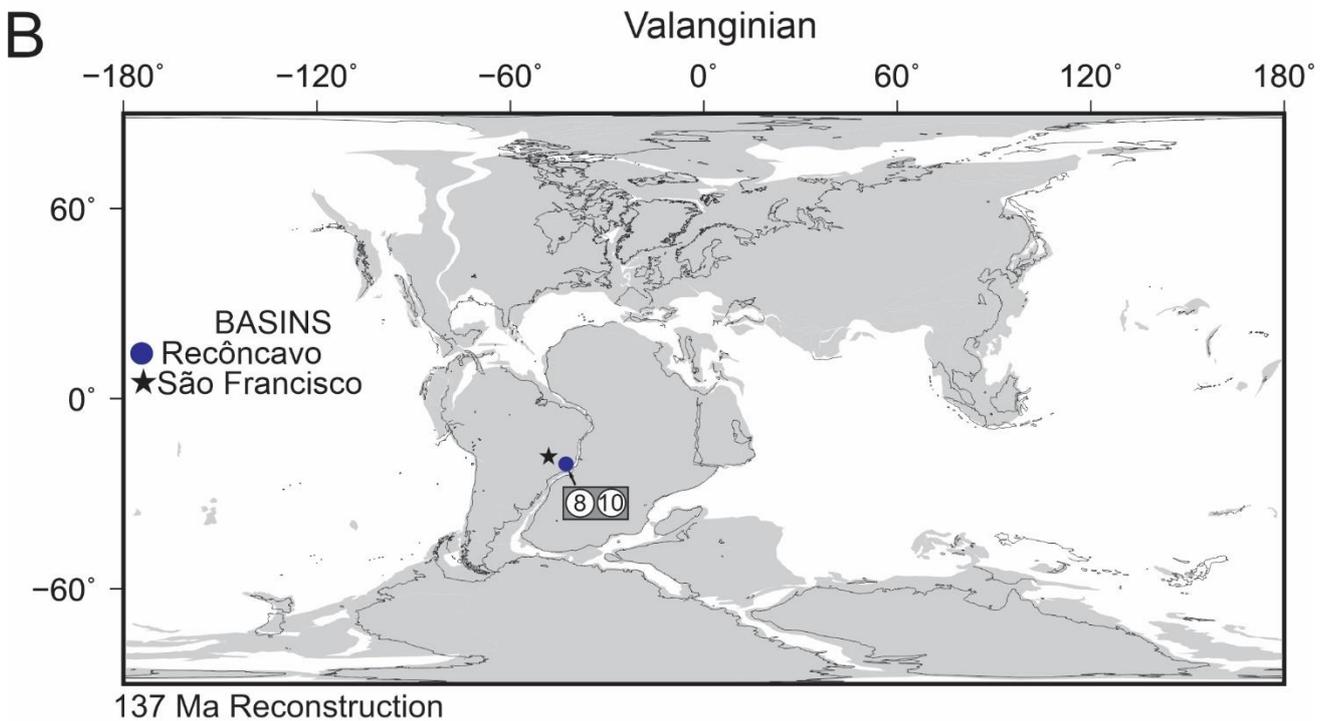
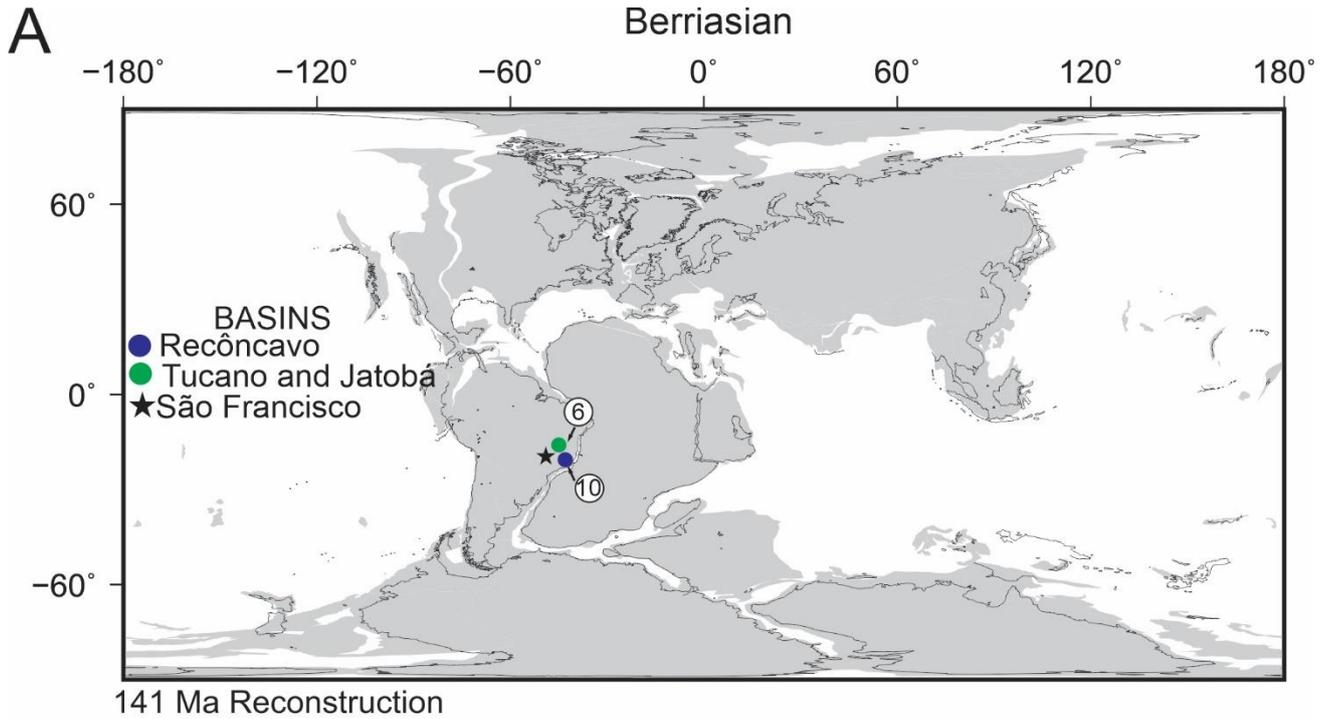
Figure 8. Biostratigraphic units based on limnic ostracod species of the Lower Cretaceous from the São Francisco basin: correlation synthesis with previous chronobiostratigraphic frameworks. **OBS:** The chronobiostratigraphic framework of Viana et al. (1971) is presented with modifications on biostratigraphic units by Moura and Praça (1985), Moura (1987) and Do Carmo et al. (2008).

ANALYSIS ON PALEOZOOGEOGRAPHIC DISTRIBUTION

The paleozoogeographical context of the present study consists of six geochronologic settings: Berriasian, Hauterivian, Valanginian, Barremian, Aptian, Albian (Figs 9, 10, 11). Three of the 20 species recovered, *Penthesilenula pintoi* Leite et al., 2018, *Alicenula longiformis* Leite et al., 2018 and *Timiriasevia sanfranciscanensis* Leite et al., 2018 were described from the Quiricó Formation, restricted to São Francisco basin. Thirteen species, *Harbinia salitrensis* (Krömmelbein and Weber, 1971), *Harbinia angulata* (Krömmelbein and Weber, 1971), *Harbinia alta* Antonietto et al., 2012, *Harbinia crepata* Do Carmo et al., 2013, *Harbinia symmetrica* (Krömmelbein and Weber, 1971), *Brasacypris ovum* Krömmelbein, 1965b, *Brasacypris fulfaroi* Dias-Brito et al., 2001, *Penthesilenula martinsi* (Silva, 1978), *Damonella ultima* (Krömmelbein and Weber, 1971), *Cypridea infima* Krömmelbein and Weber, 1971, *Cypridea hystrix* Krömmelbein, 1962, *Cypridea conjugata* Krömmelbein and Weber, 1971 and *Cypridea jequiensis* Krömmelbein and Weber, 1971, were described from other basins from Brazil. Three species, *Wolburgiopsis plastica* (Musacchio, 1970), *Wolburgiopsis chinamuertensis* (Musacchio, 1970) and *Neuquenocypris (Protoneuquenocypris) antiqua* Musacchio and Simeoni, 1991, were described in basins from Argentina. *Harbinia symmetrica* occurs in basins from Gabon, Congo and Angola, Africa.

Brasacypris ovum Krömmelbein, 1965b was recorded in the Rio da Serra Local Stage, Berriasian (Caixeta et al., 1994; Costa et al., 2007; Poropat and Colin, 2012b), at the Tucano basin, Itaparica and Candeias formations (Krömmelbein, 1965b) (Fig. 9 A). *Cypridea infima* Krömmelbein and Weber, 1971 was first recorded in the Berriasian-Valanginian interval (Silva et al., 2007), Recôncavo basin, Candeias Formation, middle and upper portions (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b) (Fig. 9 A, B).

Cypridea hystrix Krömmelbein, 1962 was recorded in the Rio da Serra Local Stage, Valanginian-Hauterivian interval (Caixeta et al., 1994; Costa et al., 2007; Poropat and Colin, 2012b), at the Recôncavo basin, lower Ilhas Formation (Krömmelbein, 1962) (Figs 9 B, 10 A). *Cypridea hystrix* also occurs in the Valanginian of the Recôncavo basin (Caixeta et al., 1994), in the *Paracypridea brasiliensis* Zone (NRT-O04), with occurrences well marked in subzones *Paracypridea bicallosa* (NRT-O04.3) and *Paracypridea maacki* (NRT-O04.4) (Viana et al., 1971; Cunha and Moura, 1979; Regali and Viana, 1989) (Fig. 9 A).



OSTRACOD SPECIES ⑥ *Brasacypris ovum* ⑧ *Cypridea hystrix* ⑩ *Cypridea infima*

Figure 9. Paleozoogeographic distribution of ostracod species from the Quiricó Formation: **A.** Berriasian; **B.** Valanginian. Obs.: Paleomaps were adapted from Ocean Drilling Stratigraphic Network, 2011 (accessed on April of 2021).

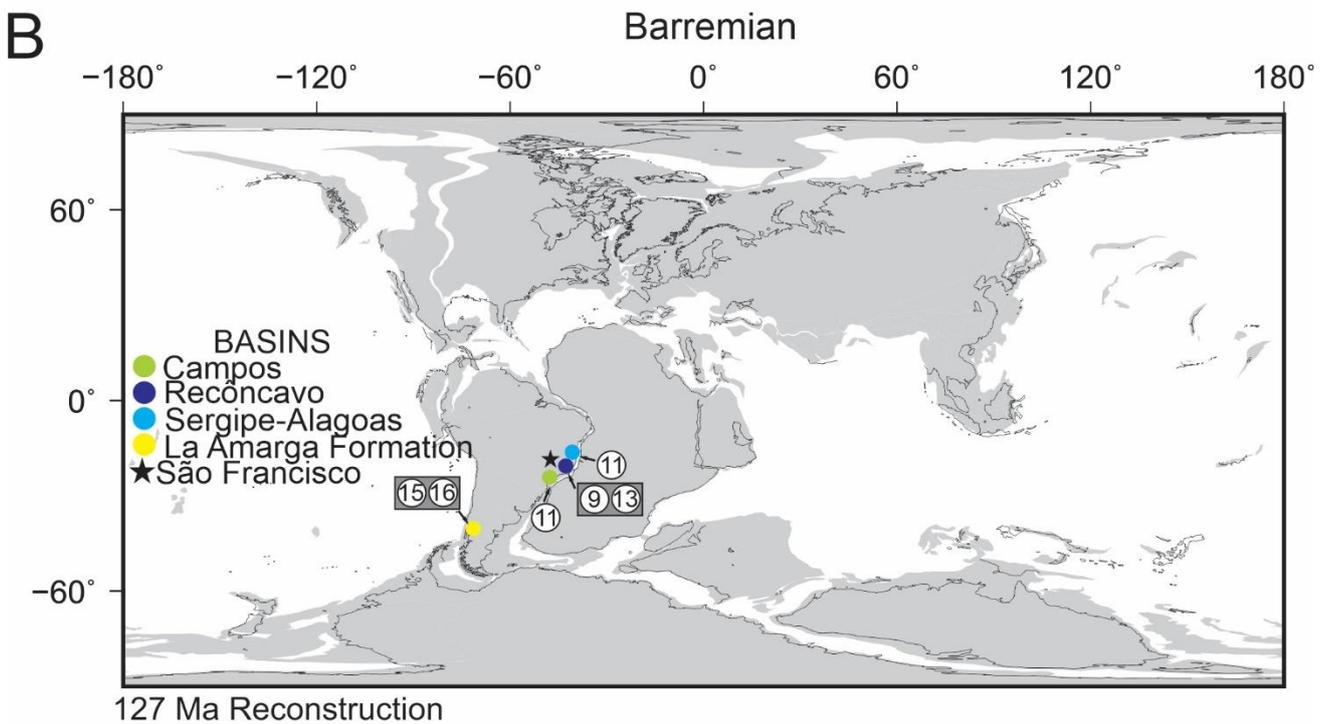
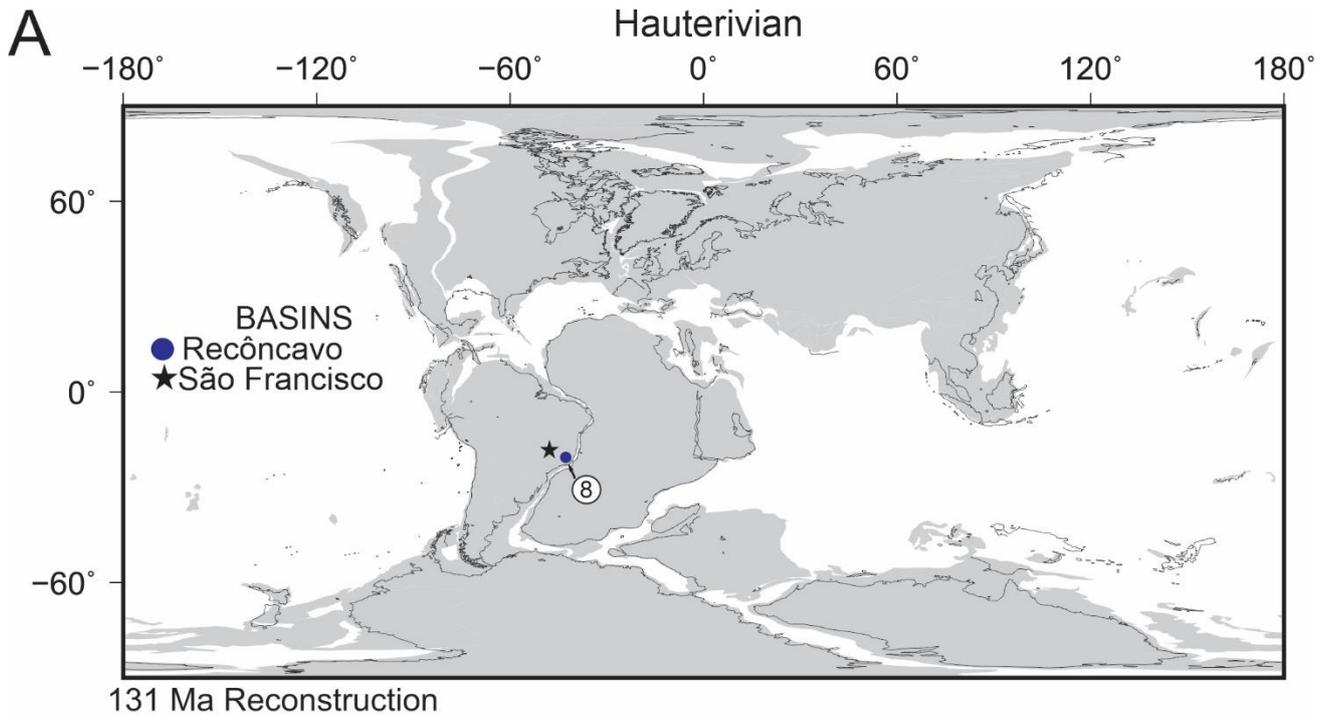
Cypridea conjugata Krömmelbein and Weber, 1971 was first recorded in the Barremian (Silva et al., 2007) from the Recôncavo basin, São Sebastião Formation (Krömmelbein and Weber, 1971; Poropat and Colin, 2012b) (Fig. 10 B). *Cypridea jequiensis* Krömmelbein and Weber, 1971 was recorded in the Barremian, Jiquiá Local Stage, Post-Bahia Series of the Sergipe-Alagoas basin (Antonietto, 2015; Krömmelbein and Weber, 1971; Poropat and Colin, 2012b) and in the Barremian-Aptian interval, Jiquiá Local Stage of the Campos basin, Lagoa Feia Formation, with occurrences at the *Cypridea faveolata* Subzone (NRT-O09.3), upper portion of the *Petrobrasias diversicostata* Zone (NRT-O09) (Moura, 1987; Rangel et al., 1994) (Figs 10 B, 11 A).

As for *Damonella ultima* (Krömmelbein and Weber, 1971), it was first recorded in the upper Barremian-lower Aptian interval (Silva et al., 2007), Jiquiá Local Stage (Tomé et al., 2014), Recôncavo basin, mid-upper sections of the São Sebastião Formation (Krömmelbein and Weber, 1971), with occurrence in the *Bisulcocypris postangularis* Subzone (NRTO09.1) of the *Petrobrasias diversicostata* Zone (NRT-O09), and subzones *Cypridea (Sebastianites?) mira* (NRT-O08.3), *Petrobrasias capivarensis* (NRT-O08.2) and *Cypridea (Sebastianites?) sostensis sostensis* (NRT-O08.1) of the *Cypridea (Sebastianites) fida minor* Zone (NRT-O08) (Figs 10 B, 11 A). *Damonella ultima* also occurs in the upper Aptian of the Jatobá basin (Tomé et al., 2014) and in the upper Aptian of the Araripe basin (Antonietto et al., 2016) (Fig. 11 A). In the Golfo San Jorge basin, Pozo D-129 Formation, Argentina, *Damonella ultima* was recorded in the upper Barremian-Aptian interval (Carignano et al., 2017) (Figs 10 B, 11 A). Both *Wolburgiopsis plastica* (Musacchio, 1970) and *Wolburgiopsis chinamuertensis* (Musacchio, 1970) were recorded in the Barremian of the La Amarga Formation, Neuquén Province, Argentina (Musacchio, 1970; Do Carmo et al., 2004a) (Fig. 10 B).

Harbinia angulata (Krömmelbein and Weber, 1971) was first recorded in the upper Aptian of the Sergipe-Alagoas basin, Riachuelo Formation (Krömmelbein and Weber, 1971), and also of the Araripe basin (Poropat and Colin, 2012b), Cedro basin (Tomé, 2007) and Jatobá basin (Tomé et al., 2014) (Fig. 11 A). *Harbinia symmetrica* (Krömmelbein and Weber, 1971) and *Harbinia alta* Antonietto et al., 2012 were recorded in the Alagoas Local Stage (Schaller, 1969; Moura, 1987) of the Araripe basin (Viana et al., 1989; Silva-Telles Jr. and Viana, 1990; Antonietto et al., 2012) in the *Harbinia* spp. 201-218 Zone (NRT-O11) (Do Carmo et al., 2008), *Harbinia symmetrica* in the Aptian (Coimbra et al., 2002) and *Harbinia alta* in the upper Aptian-lower Albian interval (Antonietto et al., 2012) (Fig. 11 A, B). *Harbinia symmetrica* was also recorded in the Aptian of the Grajaú basin, Codó Formation (Krömmelbein and Weber, 1971; Ramos et al., 2006) and it was also recorded in the Aptian of basins of Gabon, Gamba Formation, and Congo and Cabinda, Chela Formation, Africa (Grosdidier et al., 1996; Bate, 1999) (Fig. 11 A).

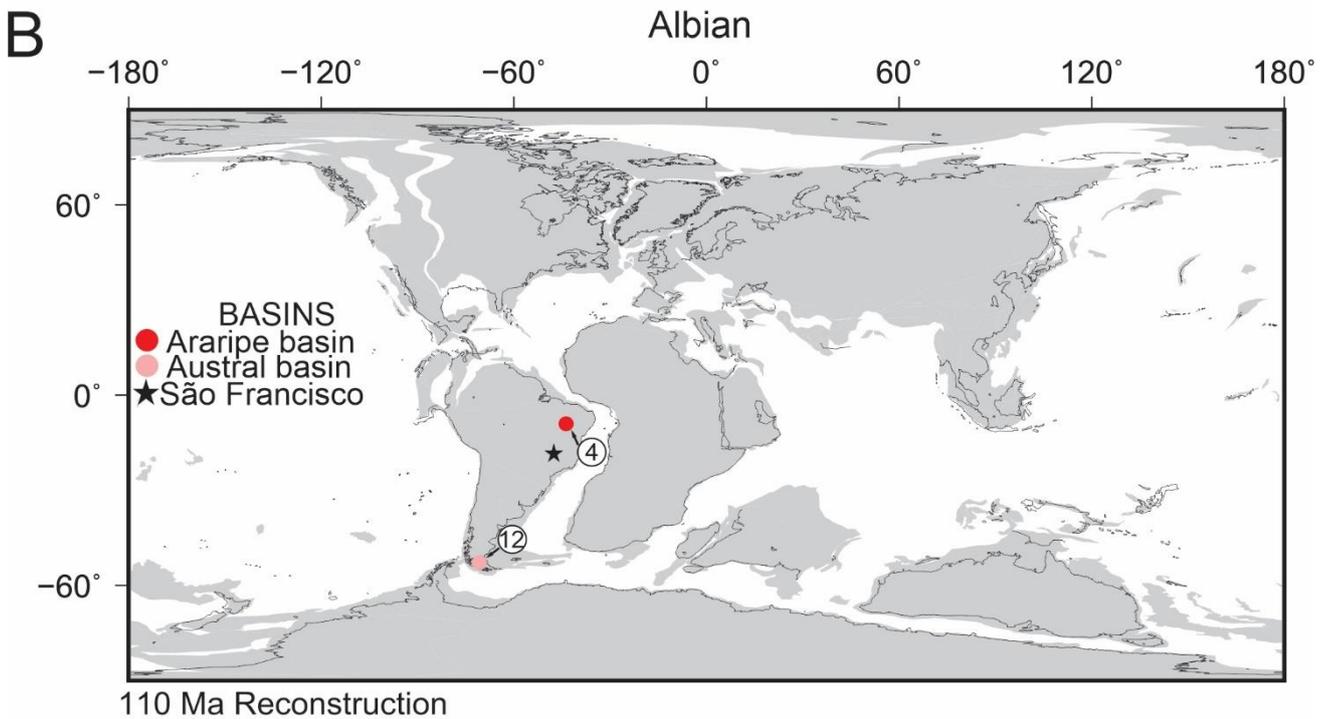
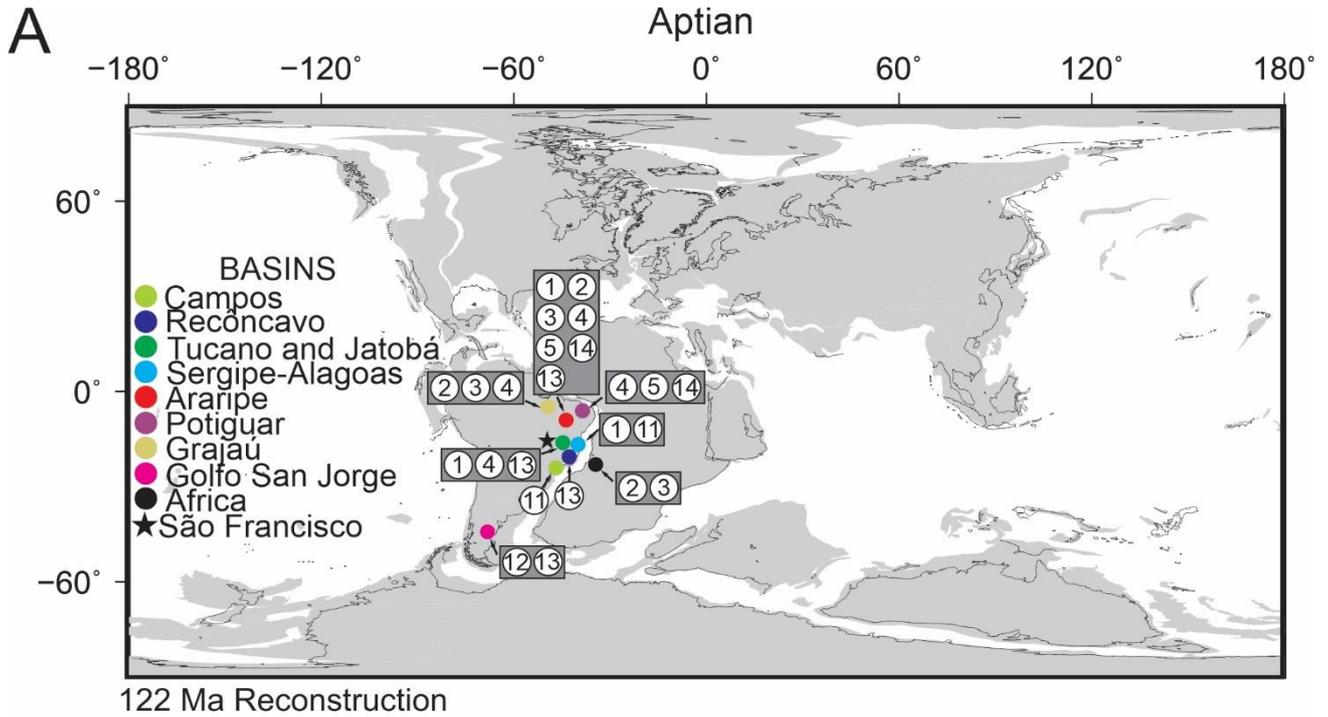
As for *Harbinia alta*, it occurs in the upper Aptian of the Grajaú basin (Ramos et al., 2006), the middle-upper Aptian interval of the Potiguar basin (Do Carmo et al., 2013) and in the upper Aptian of the Jatobá basin (Tomé et al., 2014) (Fig. 11 A). *Harbinia salitrensis* (Krömmelbein and Weber, 1971) was first recorded in the Aptian of the Araripe basin, Santana Formation (Krömmelbein and Weber, 1971; Antonietto et al., 2012; Poropat and Colin, 2012b; Tomé et al., 2014), and of the Grajaú basin (Do Carmo et al., 2008) (Fig. 11 A). *Harbinia crepata* Do Carmo et al., 2013 was first recorded in the middle-upper Aptian interval of the Potiguar basin, Alagamar Formation (Do Carmo et al., 2013) and also in the Aptian of the Araripe basin (Silva-Telles Jr. and Viana, 1990) (Fig. 11 A).

Penthesilenula martinsi (Silva, 1978) was first recovered in the Aptian (Coimbra et al., 2002) of the Araripe basin, Santana Formation (Silva, 1978; Silva-Telles Jr. and Viana, 1990; Colin and Dépêche, 1997), and in the middle-upper Aptian interval of the Potiguar basin (Do Carmo et al., 2013) (Fig. 11 A). *Neuquenocypris* (*Protoneuquenocypris*) *antiqua* Musacchio and Simeoni, 1991 was recovered in the Aptian of the Golfo San Jorge basin, D-129 Formation (Musacchio and Simeoni, 1991; Ballent et al., 2011), and also in the Albian from the Austral basin (Ballent et al., 2011) (Fig. 11 A, B). *Brasacypris fulfaroi* Dias-Brito et al., 2001 was first recovered in the Paraná basin, Bauru Group, Adamantina Formation, Turonian-Santonian interval (Dias-Brito et al., 2001). Therefore, occurrences recorded herein are considered the earliest of *Brasacypris fulfaroi*: Berriasian to Aptian.



OSTRACOD SPECIES ⑧ *Cypridea hystrix* ⑨ *Cypridea conjugata* ⑪ *Cypridea jequiensis*
 ⑬ *Damonella ultima* ⑮ *Wolburgiopsis plastica* ⑯ *Wolburgiopsis chinamuertensis*

Figure 10. Paleozoogeographic distribution of ostracod species from the Quiricó Formation: **A.** Hauterivian; **B.** Barremian. Obs.: Paleomaps were adapted from Ocean Drilling Stratigraphic Network, 2011 (accessed on April of 2021).



OSTRACOD SPECIES ① *Harbinia angulata* ② *Harbinia symmetrica* ③ *Harbinia salitrensis*
 ④ *Harbinia alta* ⑤ *Harbinia crepata* ⑥ *Brasacypris ovum* ⑪ *Cypridea jequiensis*
 ⑫ *Neuquenocypris (P.) antiqua* ⑬ *Damonella ultima* ⑭ *Penthesilenula martinsi*

Figure 11. Paleozoogeographic distribution from ostracod species of the Quiricó Formation: **A.** Aptian; **B.** Albian. Obs.: Paleomaps were adapted from Ocean Drilling Stratigraphic Network, 2011 (accessed on April of 2021).

Remarks on the biostratigraphy, paleogeography and paleoenvironment

In synthesis, six biostratigraphic units are recognized on the Quiricó Formation, Zone *Brasacypris ovum* and four zones within the Superzone *Penthesilenula pintoii*: Zone *Timiriasevia sanfranciscanensis*; Zone *Cypridea hystrix*; Zone *Alicenula longiformis*; and Zone *Harbinia* spp. The hypostratotype section of the Tereza Farm presents the most basal interval of the Quiricó Formation, due to the exclusive occurrence of zones *Brasacypris ovum*, *Timiriasevia sanfranciscanensis* and *Cypridea hystrix*, attributed to the interval Berriasian to Valanginian. The *Alicenula longiformis* Zone, attributed to the Barremian, occurs at the top of the Tereza Farm, and lower portions of the stratotype section and São Bento Farm. The stratotype section and the São Bento Farm present the upper interval of the Quiricó Formation, due to the occurrence of the *Harbinia* spp. Zone, attributed to the Aptian.

Based on the paleoecological approach, especially due to the occurrence of limnic ostracods, it is possible to interpret a deposition under a lacustrine system during the occurrence of Zone *Brasacypris ovum* and Superzone *Penthesilenula pintoii*; nevertheless, the sedimentary context of the most basal Quiricó Formation (Fig. 5), indicates major fluvial influence. The sedimentary context of the upper portion of the Quiricó Formation, indicates drier paleoclimatic conditions and an increase in salinity, especially at the stratotype section, corroborated by sedimentary characteristics (desert roses and mud cracks) (Fig. 3), and the dominance of species of *Harbinia*. A remarks on depositional, biostratigraphic and paleogeographic settings is presented below.

The hypostratotype of the Tereza Farm presents three different settings: lower, intermediate and upper. The lower setting shows that the zones *Brasacypris ovum* and *Timiriasevia sanfranciscanensis* are within the same sedimentary context, with the deposition of siltstones with scattered sand grains (facies Fgs) (Fig. 5); and the same biological context, with a low diversity of species (Figs 6, 7). The intermediate setting shows a significant increase in ostracod diversity, from five species of the lower setting to 12 species (Figs 6, 7), composing the *Cypridea hystrix* Zone. The sedimentary context of this setting indicates a greater water inlet and sedimentary input, corroborated by the increasing in granulometry, with the deposition of coarse sandstones, microconglomerates and conglomerates, and structures such as cross-bedding and trough cross-bedding (facies Svc, Gmg, Sfb, Smt, Spc, Gts) (Fig. 5). The upper setting shows a decrease in ostracod diversity, from 12 species of the intermediate setting to five species (Figs 6, 7), composing the *Alicenula longiformis* Zone. The sedimentary context of this setting indicates a decrease in energy of the depositional tract, when compared to the intermediate portion, with claystones, siltstones and very fine sandstones (facies Fm, Scc, Fs, Slr, Scf, Sft, Fsg, Sfo) (Fig. 5).

The correlation between the three sections is based on the *Alicenula longiformis* Zone, which is the only zone that occurs in all sections. Both the stratotype section and the São Bento Farm section present lithotypes with finer granulometry, when compared to the Tereza Farm section, indicating not only another sedimentary context, but due to the absence of the most basal zones, another chronostratigraphic interval of deposition in a wider lacustrine paleoenvironment. The São Bento Farm section presents three different biological settings: lower, intermediate and upper. The lower setting encompasses a large interval, where no biozones were recognized, and there is only one layer with the occurrence of ostracod; exclusively *Damonella* aff. *D. ultima* (Figs 6, 7). The intermediate setting encompasses the interval with the most diversity of ostracods, from one species on the lower setting, to eight species, and comprises zones *Alicenula longiformis* and *Harbinia* spp. (Figs 6, 7). The upper setting shows a decrease in ostracod diversity, from eight species to three in assemblage, and at the top of the section, there is a layer with the only occurrence of *Brasacypris fulfaroi* (Figs 6, 7). The sedimentary context of the São Bento Farm is quite homogeneous, with claystones, pelites and fine sandstones (facies Fss, Fcs, Fco, Fl, Fc, Slc, Fcm) (Fig. 4).

The stratotype section presents two different settings: lower and upper. The lower context encompasses zones *Alicenula longiformis* and *Harbinia* spp., with the greatest diversity of species, 11 species (Figs 6, 7). The sedimentary context of this setting, in both zones, indicates water depth often restricted and more saline and arid environmental conditions, reflected by the abundant occurrence of desert roses, mud cracks and evaporitic levels; with claystones, pelites and fine sandstones (facies Sfe, Fsm, Sfm, Fso, Fce) (Fig. 3). It is important to point out that this setting is marked by the abundance of species of *Harbinia*, which are typical of lakes with hypersalinity (Coimbra et al., 2002; Ramos et al., 2006; Antonietto, 2010). Especially *Harbinia crepata* is considered holoeuryhaline, i.e., adapted to almost every type of salinity, while *Harbinia alta* is freshwater euryhaline, i.e., is a freshwater species capable of penetrating extensively in to brackish water (Do Carmo et al., 2018). The upper context encompasses the uppermost portion of Superzone *Penthesilenula pintoii*, with a noteworthy decrease in ostracod diversity, from 11 species to two (Figs 6, 7). The sedimentary context of this setting is very similar with the lower setting, with pelites and fine sandstones; however, indicators of restricted water depth and salinity are mostly absent, with the occasional presence of mud cracks (facies Sfl, Sfc, Fsm, Sfr) (Fig. 3).

As result of tectono-sedimentary evolution of the rift succession, by the Late Jurassic there were several lacustrine systems that could compose the same hydrographic paleo-system between several basins from central Gondwana (Assine, 1994; Da Rosa and Garcia, 2000; Garcia et al., 2005;

Kuchle et al., 2011). These lowland areas received fluvial sedimentary contribution from surrounding structural highs (Kuchle et al., 2011).

On this Cretaceous paleogeographic context, it is possible to discuss the existence of interconnected intermittent drainages, at least since the late Barremian, among the basins of Sergipe-Alagoas, São Francisco, Araripe, Parnaíba and Tucano-Jatobá, due to the distribution of several taxa, such as pollen, microcrustaceans and vertebrates, mainly fishes (Maisey, 2000; Amaral et al., 2019). The study based on fish remains indicates that these basins could present intermittent connections with faunal exchange all through the Late Jurassic-Early Cretaceous (Maisey, 2000; Carvalho, 2002; Carvalho and Maisey, 2008). It is also presented and evaluated the hypothesis that the São Francisco drainage is very ancient and already established during the late Barremian, acting as a link for several aquatic taxa, connecting highland areas of the western Congo-São Francisco craton and marginal regions of the Brazilian Northeast (Amaral et al., 2019).

On Early Cretaceous, the São Francisco basin was an area of structural highs, and, more specifically during the deposition of the sequence in the hypostratotype section of the Tereza Farm, from Berriasian to possibly Barremian, there were high rates of precipitation and wet areas (Fig. 12). For this interval, at the São Francisco basin, there are indicators of a fluvial contribution on a lacustrine paleoenvironment, probably product of a major drainage related to the paleo São Francisco river, suggesting a possible link between the São Francisco basin and basins in the marginal rift system in central Gondwana.

Considering the possibility of paleohydrographic systems and precipitation data in the paleogeographic map for the Berriasian-Barremian? interval (Fig. 12), it is possible to observe that the São Francisco basin was within the wet area with great precipitation, which could explain why species that occur in Recôncavo, Tucano-Jatobá, Campos and Sergipe-Alagoas basins, and in the La Amarga Formation (Argentina) also occur in the Quiricó Formation. From the great volume of water, a linkage between the São Francisco basin and these other basins could be established, or at least these basins could be part of the same hydrographic system, corroborating to the hypothesis of Assine (1994), Da Rosa and Garcia (2000), Garcia et al. (2005) and Kuchle et al. (2011).

As for paleohydrographic systems and precipitation data in the paleogeographic map for the early Aptian (Fig. 13), it is possible to notice that the São Francisco basin is just outside of the wet area, under the desert regime; however, species that occur in the Quiricó Formation also occur in several other basins (Recôncavo, Tucano-Jatobá, Campos, Sergipe-Alagoas, Potiguar, Grajaú, Araripe – Brazil; Golfo San Jorge, Austral – Argentina; Gamba, Congo, Cabinda – Africa), and since the Quiricó Formation was under arid conditions, it is possible to infer that a São Francisco drainage,

linking this basin with others, was already established, corroborating to the hypothesis presented by (Amaral et al., 2019). It is important to point out that, although there are no marine records in the five studied sections from the Quiricó Formation, during the late Aptian, it is possible to interpret that there were connections among the São Francisco basin and marginal basins that show evidence of marine ingression (Arai, 2014, 2016; Assine et al., 2014, 2016).

Possibly towards the end of the Barremian, and especially during the Aptian, ostracod distribution shows a notable increase in species distribution, with occurrences in several basins (Fig. 11, A). This distribution pattern seems to be related to biological dispersal strategy, related to desiccation resistant eggs of the Superfamily Cypridoidea (Whatley, 1992; Do Carmo et al., 2013) (Fig. 11, A). However, the dispersal of *Penthesilenula martinsi*, associated with these cypridoideans – *Harbinia angulata*, *Harbinia symmetrica*, *Harbinia salitrensis*, *Harbinia alta*, *Harbinia crepata*, *Brasacypris ovum*, *Damonella ultima*, *Cypridea jequiensis* and *Neuquenocypris (Protoneuquenocypris) antiqua* – (Fig. 11, A), would require a perennial fluvial drainage linking the São Francisco basin and marginal basins during this interval (Barremian-Aptian), even under semi-arid conditions and major eolian contribution of the studied area (Fig. 13). So, the hypothesis of the Early Cretaceous origin of the São Francisco drainage, is based on stratigraphic and paleogeographic analysis of ostracod and fish species. Additionally, paleoenvironmental interpretation based stratigraphic distribution of species related to the sedimentary-evolution record in the Lower Cretaceous interval of São Francisco basin also corroborates paleogeographic data on precipitation for the Berriasian and early Aptian proposed by (Scotese, 2013a, 2013b) (Figs 12, 13).

BERRIASIAN-BARREMIAN?

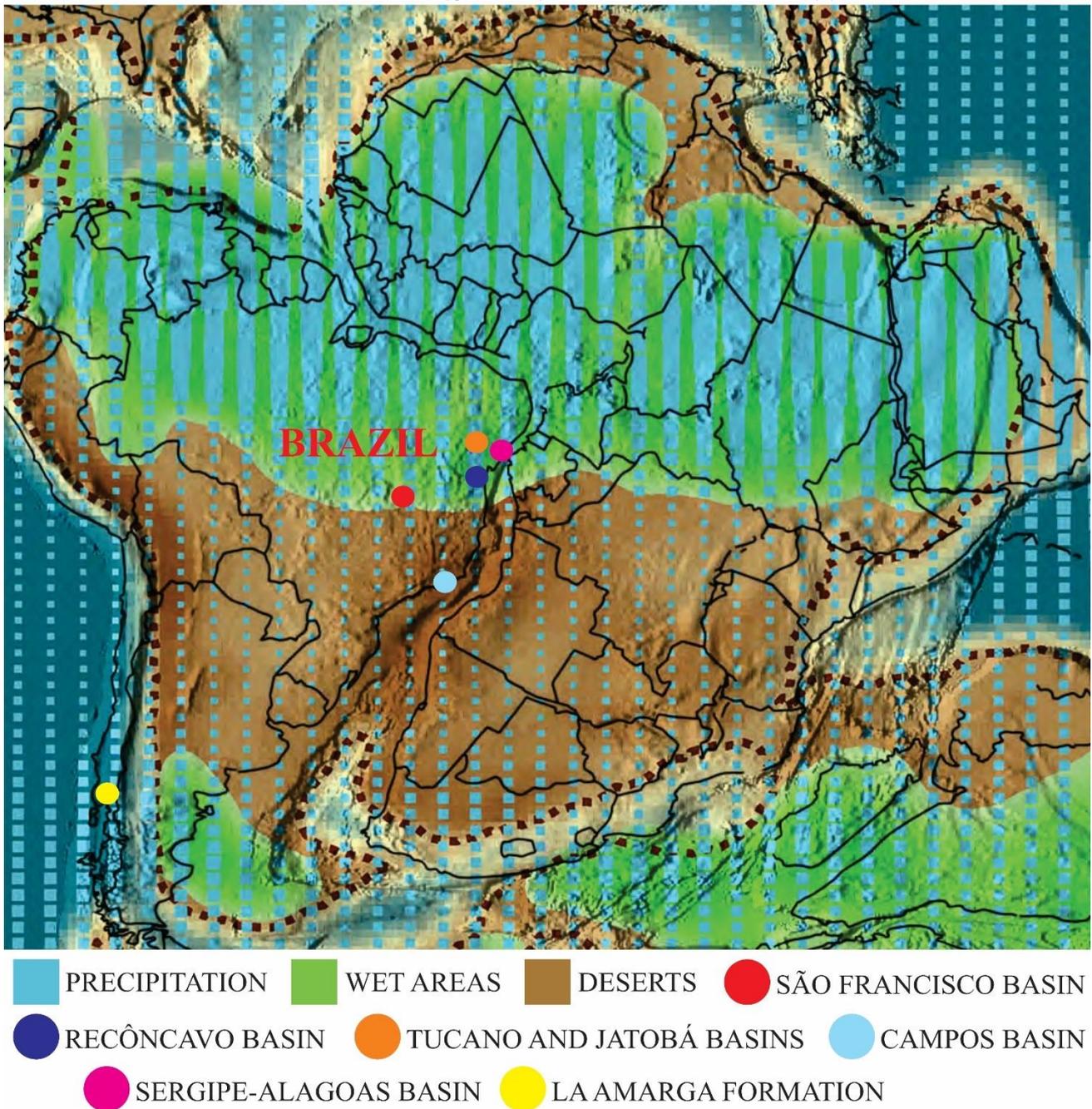


Figure 12. Berriasian paleogeography map with rainfall (light blue squares = precipitation, green areas = wet areas where precipitation > evaporation, tan areas = deserts; red circle = São Francisco basin) (based on (Scotese, 2013a).

EARLY APTIAN

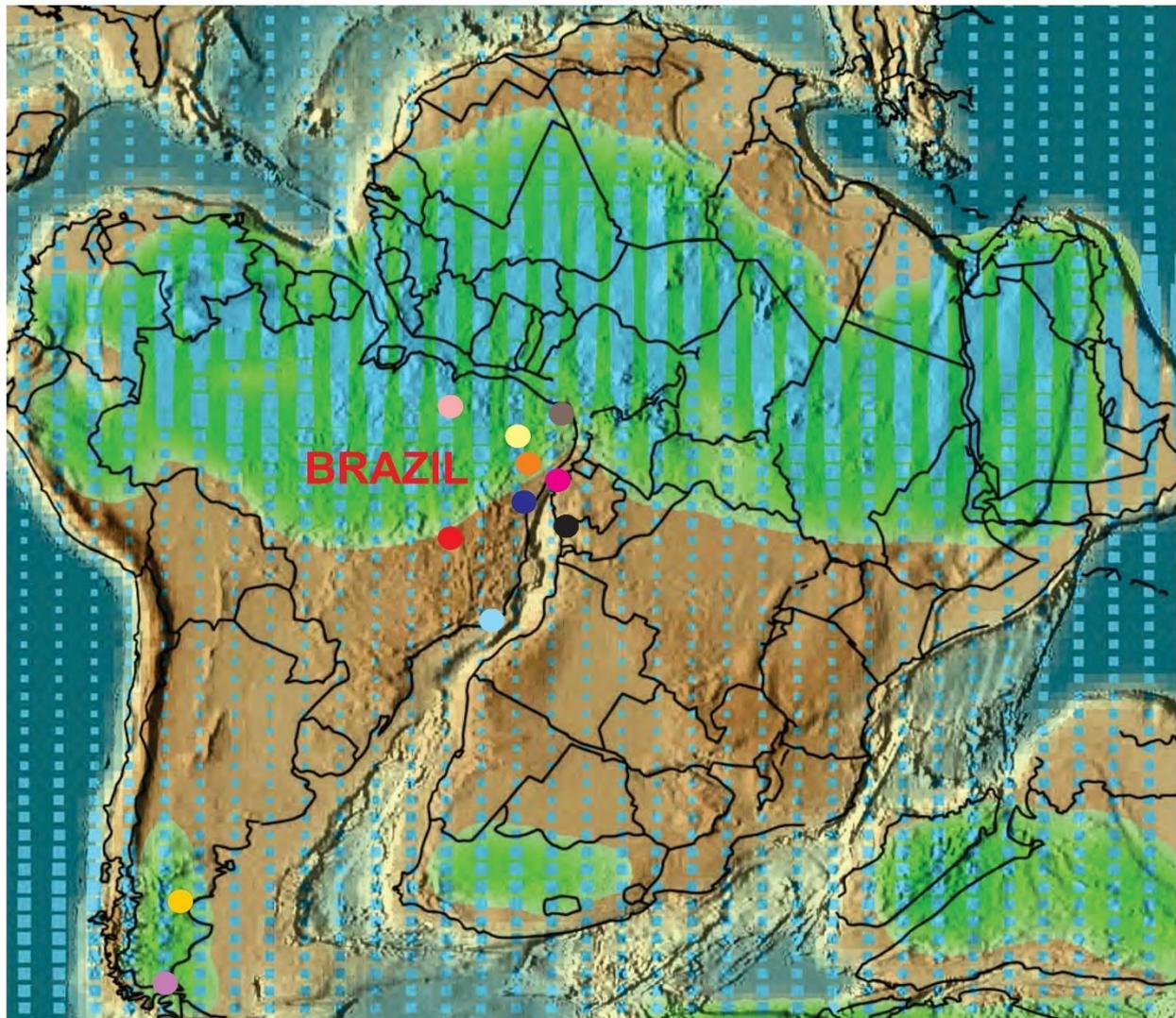


Figure 13. Early Aptian paleogeography map with rainfall (light blue squares = precipitation, green areas = wet areas where precipitation > evaporation, tan areas = deserts; red circle = São Francisco basin) (based on (Scotese, 2013b)).

CONCLUSIONS

The present study on the biostratigraphy and paleozoogeography of limnic ostracod species from Lower Cretaceous of the São Francisco basin, resulted in the first attempt to establish ostracod based biozones for the Quiricó Formation. Six biostratigraphic units are proposed: 1. *Brasacypris ovum*

Zone, OSF-0; 2. *Penthesilenula pintoi* Superzone, OSF-1; 3. *Timiriasevia sanfranciscanensis* Zone, OSF-1.1; 4. *Cypridea hystrix* Zone, OSF-1.2; 5. *Alicenula longiformis* Zone, OSF-1.3; and 6. *Harbinia* spp. Zone, OSF-1.4. The *Brasacypris ovum* Zone, lowest-occurrence interval, is outside of Superzone *Penthesilenula pintoi* and it is the most basal zone of the Quiricó Formation. The *Penthesilenula pintoi* Superzone, range interval, encompasses all four subzones and is determined by their range: Zone *Timiriasevia sanfranciscanensis*, lowest-occurrence interval; Zone *Cypridea hystrix*, range interval; Zone *Alicenula longiformis*, highest-occurrence interval; and Zone *Harbinia* spp., assemblage interval.

The *Brasacypris ovum* Zone is attributed to the Berriasian and correlated to the Rio da Serra Local Stage O02. The *Penthesilenula pintoi* Superzone is attributed to the Berriasian-Aptian/Albian? interval and correlated to local stages Rio da Serra O02, O03 and O04; Aratu O05; Buracica O08; Jiquiá O09; and Alagoas O11. The upper portion of the *Brasacypris ovum* Zone, marked by one interval with the occurrence of species *Penthesilenula pintoi* and *Brasacypris ovum*, has an uncertain attribution, if Aptian or post-Aptian. The *Timiriasevia sanfranciscanensis* Zone is correlated to the Rio da Serra Local Stage O02 and O03, attributed to the Berriasian. The *Cypridea hystrix* Zone is correlated to the Rio da Serra Local Stage O04 and Aratu Local Stage O05, attributed to the Valanginian-Hauterivian interval. The *Alicenula longiformis* Zone is correlated to the Buracica Local Stage O08 and Jiquiá Local Stage O09, attributed to the Barremian. The *Harbinia* spp. Zone (OSF-0.4) is correlated to the Alagoas Local Stage O11, attributed to the Aptian. The Aratu Local Stage O06, Buracica Local Stage O07 and Jiquiá Local Stage O10 were not recognized in the Quiricó Formation so far, due to absence of index species in the studied sections.

The Quiricó Formation, formally attributed to the Barremian-Aptian interval, is interpreted as Berriasian-Aptian/Albian?, according to data herein. The deposition of this formation in a lacustrine system presents two well marked distinct contexts, supported by lithostratigraphy, biostratigraphy and paleogeography: an older context corresponding to the hypostratotype section of the Tereza Farm, a younger context corresponding to the stratotype section and the São Bento Farm section. At the lower portion of the Tereza Farm section, there is a major fluvial influence, and along with precipitation data and paleogeographic maps, it is possible to interpret the possibility of paleohydrogeographic system between the São Francisco basin and other interior and marginal rift basins already present during the Berriasian-Valanginian interval. On the stratotype section and São Bento Farm section, precipitation and paleogeographic maps, along with sedimentary characteristics and ostracod species, indicate drier paleoclimatic conditions, corroborating the hypothesis of establishment the São Francisco drainage in the Early Cretaceous.

Although there are two identifiable contexts for the deposition of the Quiricó Formation, the deposition appears continuous throughout the Berriasian-Aptian/Albian? interval, according to the occurrence of *Penthesilenula pintoi* Leite et al., 2018, and of *Zone Alicenula longiformis*, which links all studied sections. Therefore, the context of the Quiricó Formation consists of an unprecedented setting for sedimentary deposition in a lacustrine environment. The present work also allows a major expansion of the paleozoogeographical correlation between the São Francisco basin and other basins from Brazil, South America and Africa. It is noteworthy that a more detailed study on the occurrence of fishes from the Quiricó Formation, specially at the Tereza Farm section, associated with the occurrence of ostracods, would improve the chronobiostratigraphic understanding of the São Francisco basin.

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