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Inventory of the Sponge Fauna of the cemitério Paleolake, Catalão, Goiás, Brazil

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ABSTRACT

The Cemitério Paleolake, Catalão, Goiás, is a lacustrine deposit that is rich in spicules of continental sponges. These spicules, which are present in three sections (1-3), were analyzed for the taxonomic identification of the species in order to reconstruct the late Quaternary palaeoenvironment. An indigenous assemblage of lentic sponges was found, consisting of *Metania spinata* (Carter 1881), *Dosilia pydanieli* Volkmer-Ribeiro (1992), *Radiospongilla amazonensis* Volkmer-Ribeiro and Maciel (1983), *Trochospongilla variabilis* Bonetto and Ezcurra de Drago (1973), *Corvomeyenya thumi* (Traxler 1895), *Heterorotula fistula* Volkmer-Ribeiro and Motta (1995), plus *Corvoheteromeyenya australis* (Bonetto and Ezcurra de Drago 1966), which here has its first record in an assemblage formed by biosiliceous deposits. Furthermore, at the base of the sections, spicules of sponges from lotic environments were detected, including *Corvospongilla seckti* Bonetto and Ezcurra de Drago (1966), *Oncosclera navicella* (Carter 1881) and *Eunapius fragilis* (Leidy 1851), which suggests a contribution from flowing water. We identified 25 spongofacies horizons caused by sponge assemblages typical of a lentic environment, dated from at least 39,700 years BP., and currently occurring in lakes typical of the Cerrado Biome.

Key words: Cerrado Biome, continental sponges, Quaternary paleointerpretations, sediments, spicules.

INTRODUCTION

Continental sponges (Phylum Porifera) are animals that can be found in any, permanent or temporary, body of fresh water under natural conditions, e.g., rivers, lakes and in coastal mixohaline environments. They are sessile and live attached to a submerged or an emergent substrate, such as macrophyte

roots, rocks, branches of riparian vegetation or tree trunks in regions that experience seasonal flooding, such as the floodplains of the major Amazonian rivers (Volkmer-Ribeiro and Pauls 2000). The specific identification of continental sponges is based on the set of spicules of each species. The gemmoscleres, which are the spicules of the gemmules, are the most important morphological character in the characterization of families, genera and species. Likewise important are microscleres

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and megascleres, which are the spicules that make up the body of the animal. The gemmules, which are the asexual reproduction structures, have been crucial in the occupation of continental environments and ensure the survival of the species in seasonal habitats, being also important structures for the dispersion of the animals within aquatic microenvironments (Volkmer-Ribeiro 1981).

The siliceous spicules of continental sponges can be seen in sedimentary rocks due to their amorphous silica composition (opal). Following death, the body of the sponge remains in the water column, and the spongin rapidly decomposes, releasing the siliceous spicules that are deposited in sediments. When the drainage is reduced and the production of the sponge is voluminous, the accumulation of these spicules in sediments can produce biosiliceous mineral deposits known as spongillites (Volkmer-Ribeiro 1992, Volkmer-Ribeiro and Motta 1995).

The taxonomic and ecological study of this fauna has revealed the preference of different species/assemblages for specific environments (Volkmer-Ribeiro and Machado 2007). As these events are repeated, it has been proposed that these species/assemblages be used as indicators of such environments, thus providing tools for paleo-environmental interpretations in the Quaternary.

The first studies involving the use of spicules from continental sponges in environmental paleo-interpretation were carried out as from 1974, and demonstrated the occurrence of spicules of extant species in sedimentary rocks of the Quaternary (Racek 1974, Hall and Herrmann 1980, Harrison et al. 1979, Harrison and Warner 1986, Harrison 1988, Gaiser et al. 2004).

Martin et al. (1992) identified the continental sponge *Corvomeyenya thumi* (Traxler 1895) in a paleolake profile from Eastern Amazonia in the Serra dos Carajás, Pará, Brazil, dated between 7,000 to 4,000 years BP. This species is adapted to episodic drought, which led to the conclusion

that the inferred regression of the forest was not due to ongoing drought, but to successive periods of drought, a result corroborated by geochemical and palynological evidence. Sifeddine et al. (1994) expanded the study to another paleolake profile in Carajás (Southern Amazon) and showed that both lakes may have evolved through different paleohydrological periods. They also identified in the last 8000 years BP. the alternation of charcoal deposits, which indicate paleofires, and amorphous silica in the form of sponge spicules from *C. thumi*. The authors concluded that, during this time period, the weather conditions were probably on average better for the development of forests, but these developments were regularly interrupted by fire since the presence of *C. thumi* gemmoscleres indicated successive periods of drought, with a reduced water column.

Volkmer-Ribeiro and Turcq (1996) presented a scanning electron microscopy (SEM) analysis of spines from *C. thumi* present in two profiles from the Serra dos Carajás, and demonstrated that extremely short periods of immersion, related to the availability of precipitation and runoff in the system, can cause a gradual series of incipient formations preserved at the time of deposition of sediments. They also concluded that the sequence of spicules observed in both profiles indicated a global climate change, with stages of retraction and expansion of forests during the last 30,000 years, which is supported by pollen and geochemical analysis.

Volkmer-Ribeiro et al. (2004) statistically evaluated the content of gemmoscleres from the species *Ephydatia facunda* Weltner (1895) in current sediments from seven coastal lagoons in the Taim Hydrological System, Rio Grande do Sul, Brazil. The applied methodology revealed the evolution of this system, with the greatest sponge production related to an enrichment of organic matter, which reaches its culmination in the marsh environment. Volkmer-Ribeiro et al. (2007) again identified the species *E. facunda* in sediments of the

Luján Formation, west of the city of Luján, 63 km from Buenos Aires, Argentina, concluding from the evidence that there had been a period of lacustrine sedimentation in a coastal lagoon environment (from 11,060 to 10,420 years BP.), which is also corroborated by the presence of frustules from the diatom *Hyalodiscus subtilis* (Bailey). They also pointed to a relationship between this deposit and transgressive events prior to the studied formation.

Parolin et al. (2007), through the presence of continental sponge spicules in sediment profiles in the floodplain of the Esperança River, Taquarussu region, Mato Grosso do Sul, Brazil, suggest the occurrence of flood pulse between 4610-4010 years BP. Almeida et al. (2009), after taxonomic and taphonomic analysis of the spicules of continental sponges in spongolite deposits in the region of João Pinheiro, northwest of Minas Gerais, Brazil, pointed to alternating periods of wet and cold weather and drier climate, with torrential rainfall between the Upper Pleistocene and Holocene in this region.

Parolin et al. (2008), after the identification of sponge spicules typical of distinct environments and using a vibro-core sample in sediments at Samambaia Lake, Taquarussu, Mato Grosso do Sul, Brazil, characterized the alternation of lentic and lotic phases from the late Pleistocene to middle Holocene. At that time, the term “spongofacies” was proposed and defined for facies with a predominance of sponge spicules that, when identified, indicate specific paleoenvironmental characteristics.

The Cemitério Paleolake deposit formed over a dome of carbonatite magma rock in the central part of the Catalão I Carbonatite Complex, in Catalão, Goiás. The rocks in the deposit have a large amount of continental sponge spicules, which to date had not been identified. The focus of this paper, regarding a taxonomic study of this paleolake deposit, reveals that sponge assemblages contributed substantially to this deposit. The spongofacies technique of Parolin et al. (2008) was applied in order to identify horizons

and develop a more robust understanding on the evolution of the deposit during the Quaternary. The results presented herein correspond to an unpublished component of the Master's thesis of the senior author.

MATERIALS AND METHODS

The Ultramafic-alkaline-carbonatite complex of Catalão I is located 15 km from the center of the municipality of Catalão, southeast Goiás (18°08'S 47°08'W; Fig. 1). The Cemitério paleolake outcrop includes a lacustrine deposit with a continuous exposure (Fig. 2) caused by the filling of a depression located in the central part of the Catalão I Carbonatite Complex, where the sedimentary rocks lie discordantly on a dome of magmatic carbonatite rock from the Upper Cretaceous (Ribeiro et al. 2001). Data were collected by Dr. Roberto Iannuzzi and Dr. Nelsa Cardoso by removing blocks of rock from each sediment layer, either manually or with the aid of machines provided by the *Fosfertil* mining company. Three stratigraphic columns were recorded in distinct localities along the exposure. Samples were collected from the three sites from top to bottom, with 21, 19 and 13 collected layers at Sites 1, 2 and 3, respectively (Figs. 2, 3).

For the Optical Microscope (OM) identification of the sponge spicules in the sediments, a specific laboratory technique was applied to obtain permanent slides. About 0.35 cm³ parcels of sediments were prepared following the procedure of Volkmer-Ribeiro (1985) for each of the sampled horizons at Sites 1, 2 and 3. Three slides were prepared for each horizon subsample. In addition, specific dissociations were carried out for the release of spicules (Volkmer-Ribeiro and Turcq 1996) in order to produce clear Scanning Electron Microscope (SEM) images, which were obtained at the Microscopy Center of the Lutheran University of Brazil (ULBRA).

The presence of spicules in different rocks was visually evaluated and qualified by OM (permanent slides) and in the rock fragments (Stereoscopic Microscope – magnifying glass) as: (S) spongofacies (abundant spicules, according to the definition proposed by Parolin et al. 2008); (F) few spicules; and (A) absence of spicules.

All sediments related to the layers and/or levels from the three Sections, as well as permanent slides and prepared SEM supports, have been cataloged in the Porifera collection of the Museum of Natural Science (MCN-POR), Zoobotanic Foundation of Rio Grande do Sul (FZB), with the reference MCN-POR nr 8147 to 8200.

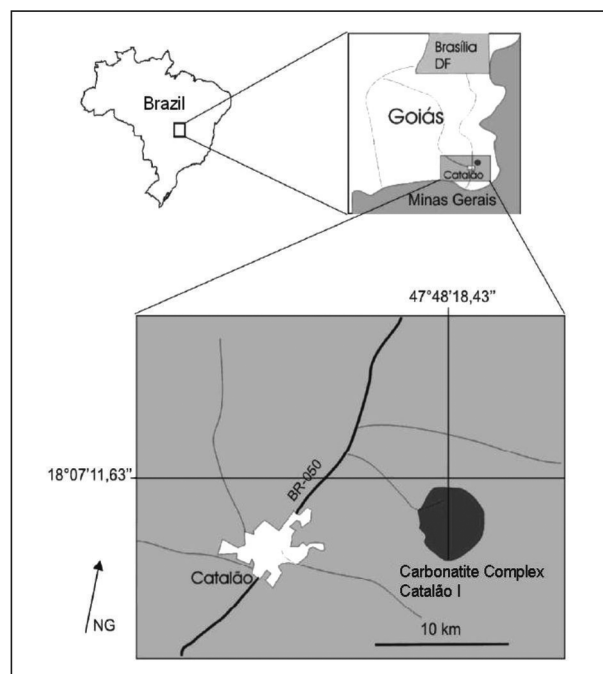


Fig. 1. Location map of the Carbonatitic Complex of Catalão I, which is the depositional site of the Cemitério Paleolake. Modified from Cardoso and Iannuzzi (2006).

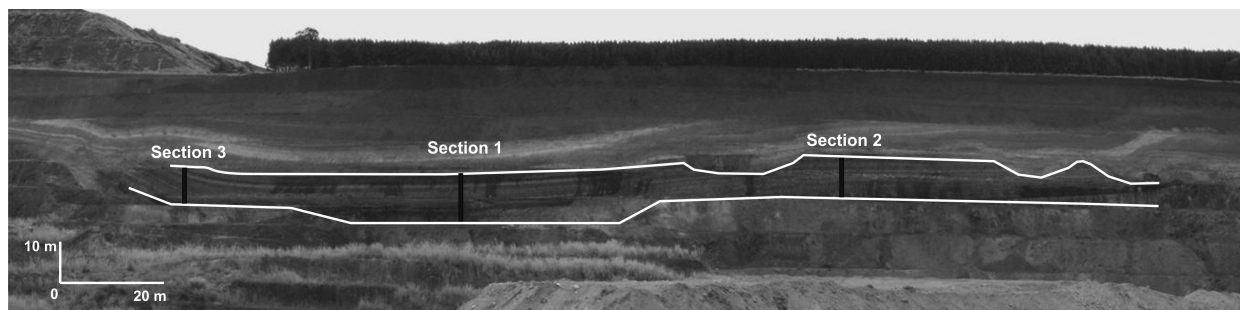


Fig. 2. Photograph of the Cemitério Paleolake. The white line traces the limits of the deposit. The black bars indicate the position of the three sampled sections.

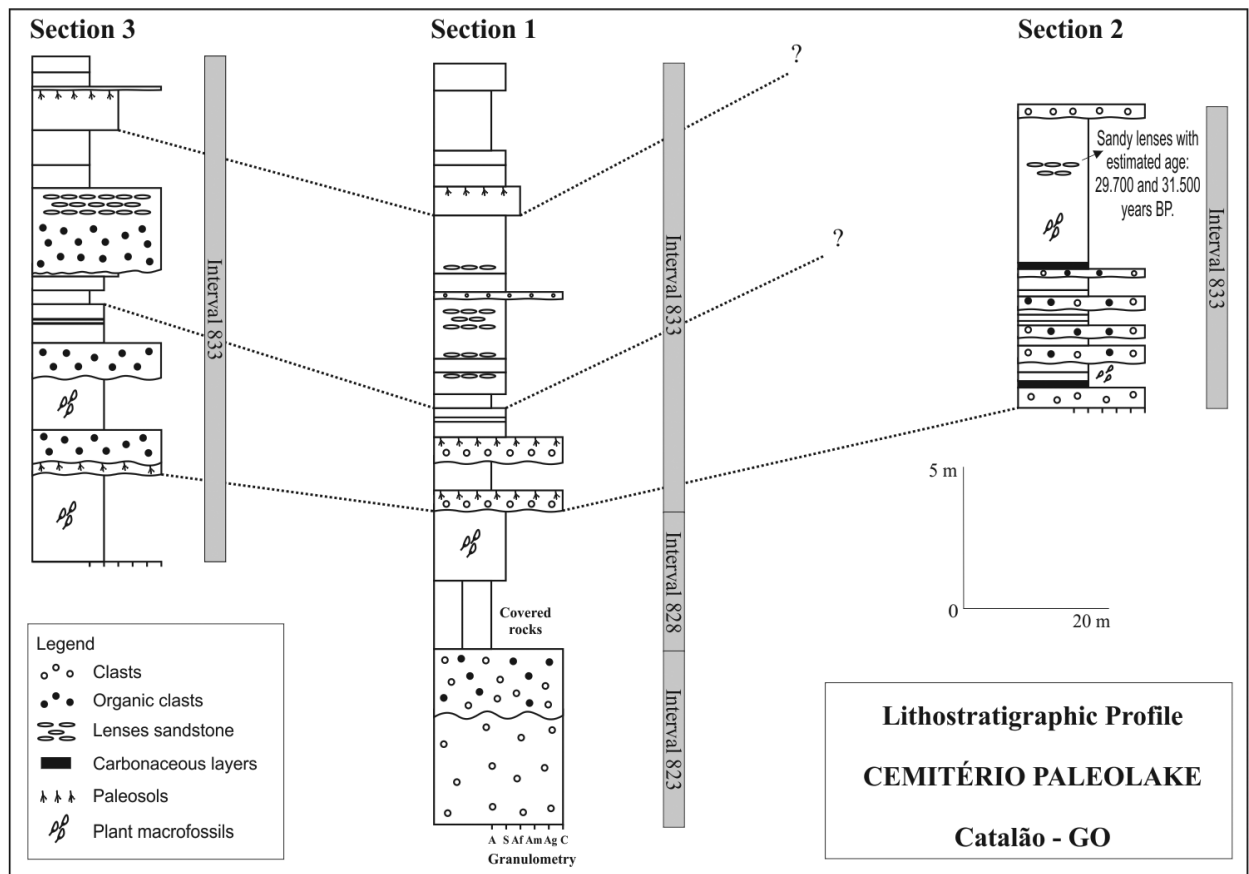


Fig. 3. Lithostratigraphic profile of the Cemitério Paleolake, Catalão, Goiás, showing the correlation among the three sections analyzed. From N.C., unpublished data. (A, argillite; S, siltstone; Af, fine sandstone; Am, medium sandstone; Ag, coarse sandstone; C, conglomerate).

RESULTS

TAXONOMIC STUDY

Dosilia pydanieli Volkmer-Ribeiro (1992)

Fig. 4a; Table I

Dosilia pydanieli Volkmer-Ribeiro (1992): 329, Fig. 2e; Volkmer-Ribeiro and Motta (1995): 149; Volkmer-Ribeiro et al. (1998a): 274; (1998b): 411; Volkmer-Ribeiro (1999): 4; Cândido et al. (2000): 88, Figs. 3-11; Parolin et al. (2003): 17; (2008): 191, Figs. 6B, C, 7D, E; Almeida et al. (2009): 126, Figs. 2A, B; Cândido et al. (2010): 443-444, Figs. 56-62.

TABLE I

Category and measures (μm) of spicules of *D. pydanieli* detected in the three studied sections. All categories are frequent.

Spicule Categories	Measures	Average length	Average width
Gemmoscleres		79	2.8
Microscleres Fig. 4a		38	1.9
Megascleres		550	8.6

Radiospongilla amazonensis
Volkmer-Ribeiro and Maciel (1983)

Figs. 4b, c; Table II

Radiospongilla amazonensis Volkmer-Ribeiro and Maciel (1983): 255, Fig. 5; Volkmer-Ribeiro (1992): 323, Figs. 2D, 4B, C; Volkmer-Ribeiro and Motta (1995): 149; Volkmer-Ribeiro et al. (1998a): 274; (1998b): 411; Parolin et al. (2003): 17; Batista et al. (2003): 530; Tavares et al. (2003): 172, Fig. 8; Batista et al. (2007): 621, Fig. 34; Parolin et al. (2007): 21, Figs. 4B, B1; (2008): 191, Fig. 7H; Almeida et al. (2009): 126, Fig. 2G.

TABLE II

Category and measures (μm) of spicules of *R. amazonensis* detected in the three studied sections. All categories are frequent. Gemmoscleres are smaller than in the original description.

Spicule Categories	Measures	Average length	Average width
Megascleres Fig. 4b		240	14
Gemmoscleres Fig. 4c		58	4.5

Trochospongilla variabilis
Bonetto and Ezcurra de Drago (1973)

Fig. 4d; Table III

Trochospongilla variabilis Bonetto and Ezcurra de Drago (1973): 15, Fig. 11; Volkmer-Ribeiro (1992): 323, Figs. 2C, 3; Volkmer-Ribeiro and Motta (1995): 149; Volkmer-Ribeiro et al. (1998b): 410; Volkmer-Ribeiro (1999): 4; Cândido et al. (2000): 79; Tavares et al. (2003): 176, Fig. 11; Batista et al. (2007): 620, Fig. 31; Volkmer-Ribeiro and Machado (2009): 338, Fig. 4; 340, Figs. 14-19; Almeida et al. (2009): 126, Fig. 2E.

TABLE III

Category and measures (μm) of spicules of *T. variabilis* detected in the three studied sections.

Spicule Categories	Measures	Average length	Average width
Gemmoscleres Fig. 4d - scarce		16	1.5
Megascleres		205	11.5

Corvoheteromeyenya australis
(Bonetto and Ezcurra de Drago 1966)

Figs. 4e, f, g; Table IV

Corvomeyenya australis Bonetto and Ezcurra de Drago (1966): 137, Lam. III.

Corvoheteromeyenya australis Ezcurra de Drago (1979): 110, Figs. 7-9, 19-22; Tavares et al. (2003): 177, Fig. 16.

TABLE IV

Category and measures (μm) of spicules of *C. australis* detected in the three studied sections. The longer slim and spiny birrotulate microsccleres of the species present in sediments are quite thin and as such reduced to spiny oxaeas.

Spicule Categories	Measures	Average length	Average width
Birrotulate microsccleres - Fig. 4e		45	1.4
Isoquela microsccleres Fig. 4f - scarce		12	0.6
Long gemmoscleres Fig. 4g		88	4.5
Short gemmoscleres Fig. 4g - scarce		48	2.6
Megascleres		510	7.1

Heterorotula fistula

Volkmer-Ribeiro and Motta (1995)

Fig. 5a; Table V

Heterorotula fistula Volkmer-Ribeiro and Motta (1995): 151, Figs. 1-23; Volkmer-Ribeiro et al. (1998b): 273; Parolin et al. (2007): 20, Figs. 4C, C1, E, E1; (2008): 191, Fig. 6E; Almeida et al. (2009): 126, Fig. 2F.

TABLE V

Category and measures (μm) of spicules of *H. fistula* detected in the three studied sections. Spicules are scarce, and only the long category of gemmoscleres is seen.

Spicule Categories	Measures	Average length	Average width
Long gemmoscleres Fig. 5a - scarce		128	2.8

Corvospongilla seckti

Bonetto and Ezcurra de Drago (1966)

Fig. 5b; Table VI

Corvospongilla seckti Bonetto and Ezcurra de Drago (1966): 133, Lam. II; (1969): 352; (1970): 52; Batista and Volkmer-Ribeiro (2002): 129; Batista et al. (2003): 530; Tavares et al. (2003): 177, Fig. 14; Batista et al. (2007): 611, Fig. 33; Parolin et al. (2007): 21, Figs. 4A, 5.

Corvospongilla böhmii Volkmer-Ribeiro et al. (1975): 38, Fig. 7; non *Corvospongilla böhmii* (Hilgendorf 1883), Volkmer-Ribeiro et al. (1981): 16, Figs. 6-9; De Rosa-Barbosa (1984): 130.

TABLE VI

Category and measures (μm) of spicules of *C. seckti* detected in the studied sections. Spicules are scarce.

Spicule Categories	Measures	Average length	Average width
Gemmoscleres		45	6.2
Quela microscleres		18	1.2
Megascleres Fig. 5b		129	11

Eunapius fragilis

(Leidy 1851)

Fig. 5c; Table VII

Spongilla fragilis Leidy (1851): 278.

Eunapius fragilis Penney and Racek (1968): 25, Fig. 1; Volkmer-Ribeiro (1999): 4; Tavares et al. (2003): 172, Fig. 7; Batista and Volkmer-Ribeiro (2002): 129.

TABLE VII

Category and measures (μm) of spicules of *E. fragilis* detected in the studied sections. Spicules are scarce.

Spicule Categories	Measures	Average length	Average width
Gemmoscleres Fig. 5c		75	8

Oncosclera navicella

(Carter 1881)

Fig. 5d; Table VIII

Spongilla navicella Carter (1881): 87, Figs. 4a-g.

Oncosclera navicella Volkmer-Ribeiro (1970): 437, Fig. 4; Tavares and Volkmer-Ribeiro (1997):

103, Figs. 11-14, 16; Batista and Volkmer-Ribeiro (2002): 132; Batista et al. (2003): 531; Pinheiro et al. (2003): 3, Figs. 2a, c; Tavares et al. (2003): 177, Fig. 9; Parolin and Volkmer-Ribeiro (2005): 1009, Figs. 23-28; Batista et al. (2007): 623, Fig. 36.

TABLE VIII

Category and measures (μm) of spicules of *O. navicella* detected in the studied sections. Spicules are scarce; however, the gemmoscleres are more robust than reported in the original description.

Spicule Categories	Measures	Average length	Average width
Gemmoscleres Fig. 5d		174	18
Megascleres scarce		287	22

Metania spinata
(Carter 1881)

Fig. 5e; Table IX

Tubella spinata Carter (1881): 96, Figs. 2B, 4D, E; Traxler (1895): 64, Figs. 1-3, 8, 9, 12, 14, 15, 20, 21.

Metania spinata Volkmer-Ribeiro (1984): 544, Figs. 5-7; (1986): 498, Figs. 3A, 5; (1990): 325, Figs. 2a, 3a; (1992): 322, Figs. 2B, 4D, E; Volkmer-Ribeiro and Costa (1992): 8, Figs. 1E, 4; Volkmer-Ribeiro and Motta (1995): 149; Volkmer-Ribeiro et al. (1998a): 274, (1998b): 411; Volkmer-Ribeiro (1999): 5; Parolin et al. (2003): 17; Parolin et al. (2008): 191, Figs. 6D, 7C, G; Almeida et al. (2009): 126, Figs. 2C, D.

TABLE IX

Category and measures (μm) of spicules of *M. spinata* detected in the three studied sections.

Spicule Categories	Measures	Average length	Average width
Gemmoscleres scarce and broken - Fig. 5e		-	-
Microscleres - Fig. 5e		47	1.4
Alpha megascleres		280	29
Beta megascleres scarce		220	21

Corvomeyenya thumi
(Traxler 1895)

Fig. 5f; Table X

Tubella thumi Traxler (1895): 64, Figs. 6, 7, 10, 11, 18.

Metania thumi Penney and Racek (1968): 148.

Corvomeyenya thumi Volkmer-Ribeiro (1992): 320, Figs. 2A, 6, 8A; Martin et al. (1992): 190; Sifeddine et al. (1994): 1647; Volkmer-Ribeiro and Motta (1995): 155; Volkmer-Ribeiro and Turcq (1996): 186, Figs. 1-4; Cordeiro et al. (1997): 815; Turcq et al. (1998): 140; Volkmer-Ribeiro et al. (1998a): 273, (1998b): 410; Volkmer-Ribeiro (1999): 5; Sifeddine et al. (2001): 231; Cordeiro et al. (2008): 51; Almeida et al. (2009): 126.

TABLE X

Category and measures (μm) of spicules of *C. thumi* detected in the studied sections.

Spicule Categories	Measures	Average length	Average width
Gemmoscleres scarce and broken - Fig. 5f		-	-
Microscleres - scarce		3.9	0.2
Megascleres		490	12

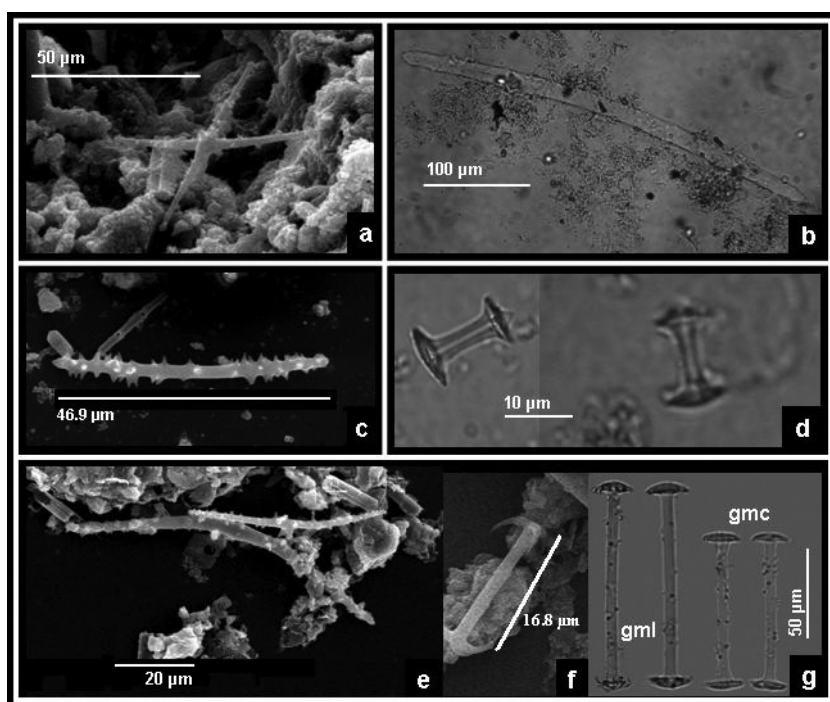


Fig. 4. Scanning Electron Microscope images (a, c, e, f) and Optical Microscope picture (b, d, g) of the sponge spicules found in the rocks of the Cemitério paleolake. a. *Dosilia pydanieli* Volkmer-Ribeiro (1992): a. microsclere; b, c. *Radiospongilla amazonensis* Volkmer-Ribeiro and Maciel (1983): b. megasclere, c. gemmosclere; d. *Trochospongilla variabilis* Bonetto and Ezcurra de Drago (1973): gemmoscleres; e, f, g. *Corvoheteromeyenia australis* (Bonetto and Ezcurra de Drago 1966): e. spiny oxea microscleres, f. chela microsclere, g. long (gml) and short (gmc) gemmoscleres.

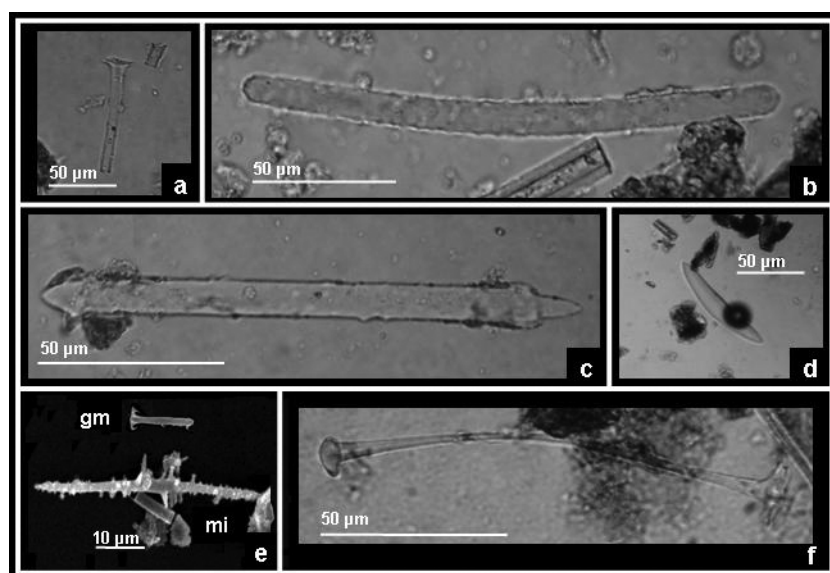


Fig. 5. Scanning Electron Microscope images (a, b, c, f) and Optical Microscope picture (e) of the sponge spicules found in the rocks of the Cemitério paleolake. a. *Heterorotula fistula* Volkmer-Ribeiro and Motta (1995): fragment of long gemmosclere; b. *Corvospongilla seckti* Bonetto and Ezcurra de Drago (1966): megasclere; c. *Eunapius fragilis* (Leidy 1851): gemmosclere; d. *Oncosclera navicella* (Carter 1881): gemmosclere; e. *Metania spinata* (Carter 1881): microsclere (mi) and fragment of gemmosclere (gm); f. *Corvomeyenia thumi* (Traxler 1895): gemmosclere.

SPECIFIC SPONGE COMPOSITION AT THE BIOFACIES

Section 1 (Fig. 6)

Layer 1: Few spicules of *C. seckti*, *M. spinata*, *D. pydanieli* and *C. australis*.

Layer 2: Few spicules of *C. seckti* and *O. navicella*.

Layer 3: Spicules absent.

Layer 4: Few spicules of *M. spinata*, *D. pydanieli*, *C. australis*, *R. amazonensis* and *T. variabilis*.

Layer 5: Spongofacies with spicules of *M. spinata*, *D. pydanieli*, *C. australis*, *R. amazonensis* and *T. variabilis*.

Layer 6: Spongofacies as in Layer 5.

Layer 7: Few spicules, as in Layer 4.

Layer 8: Spicules absent.

Layer 9: Spongofacies as in Layer 5.

Layer 10: Spongofacies as in Layer 5.

Layer 11: Spongofacies as in Layer 5.

Layer 12: Few spicules, as in Layer 4.

Layer 13: Few spicules, as in Layer 4.

Layer 14: Spongofacies as in Layer 5.

Layer 15: Few spicules of *M. spinata*, *D. pydanieli* and *C. australis*.

Layer 16: Few spicules, as in Layer 15.

Layer 17: Spicules absent.

Layer 18: Spicules absent.

Section 2 (Fig. 7)

Layer 1: Few spicules of *E. fragilis*, *M. spinata*, *D. pydanieli*, *R. amazonensis*, *T. variabilis*, *C. australis*, *H. fistula*, *C. seckti* and *O. navicella*.

Layer 2: Few spicules, differing from that of Layer 1 by the absence of *E. fragilis* and *O. navicella*.

Layer 3: Spongofacies of *M. spinata*, *D. pydanieli*, *R. amazonensis*, *C. australis*, *H. fistula* and *C. seckti*.

Layer 4: Spongofacies differing from that of Layer 3 by the absence of *C. seckti*.

Layer 5: Few spicules of *C. seckti*.

Layer 6: Few spicules of *H. fistula*.

Layer 7: Few spicules of *H. fistula* and *C. seckti*.

Layer 8: Spicules absent.

Layer 9: Spicules absent.

Layer 10: Spicules absent.

Layer 11: Spongofacies with spicules of *M. spinata*, *D. pydanieli*, *R. amazonensis*, *T. variabilis*, *C. australis*, *H. fistula* and *C. thumi*.

Layer 12: Spongofacies differing from that of Layer 11 by the presence of *O. navicella*.

Layer 13: Spongofacies differing from that of Layer 11 by the absence of *R. amazonensis* and *C. thumi*.

Layer 14: Spongofacies differing from that of Layer 11 by the absence of *R. amazonensis*, *T. variabilis* and *C. thumi*.

Layer 15: Spongofacies differing from that of Layer 11 by the absence of *C. seckti* and *O. navicella*.

Layer 16: Spongofacies differing from that of Layer 11 by the absence of *C. thumi*.

Section 3 (Fig. 8)

Layer 1: Few spicules of *D. pydanieli*, *R. amazonensis*, *T. variabilis* and *C. australis*.

Layer 2: Spongofacies with spicules of *D. pydanieli*, *R. amazonensis*, *T. variabilis*, *C. australis*, *C. thumi* and *M. spinata*.

Layer 3: Spongofacies with spicules of *D. pydanieli*, *R. amazonensis*, *T. variabilis*, *C. australis* and *M. spinata*.

Layer 4: Spongofacies as in Layer 3.

Layer 5: Few spicules of *D. pydanieli*, *R. amazonensis*, *T. variabilis*, *C. australis* and *M. spinata*.

Layer 6: Spongofacies as in Layer 3.

Layer 7: Spongofacies as in Layer 3.

Layer 8: Spongofacies as in Layer 3.

Layer 9: Spongofacies as in Layer 3.

Layer 10: Spongofacies as in Layer 3.

Layer 11: Spongofacies as in Layer 3.

Layer 12: Spongofacies as in Layer 3.

Layer 13: Spongofacies as in Layer 3.

STRATIGRAPHIC RANGES

Spicules of *M. spinata*, *D. pydanieli* and *C. australis* were present throughout Section 1 (from Layer 1 to 16); the ones of *R. amazonensis* and *T. variabilis* were present from Layer 4 to 16. *C. seckti* and *O. navicella* appeared with rare spicules in Layers 1 and 2 (Fig. 6).

Spicules of *D. pydanieli*, *R. amazonensis*, *T. variabilis*, *C. australis* and *H. fistula* were present throughout Section 2 (from Layer 1 to 16); the ones

of *C. seckti* and *O. navicella* from Layer 1 to 13, and those of *C. thumi* from Layer 11 to 15. Rare spicules of *E. fragilis* were seen in Layer 1 (Fig. 7).

Spicules of *D. pydanieli*, *R. amazonensis*, *T. variabilis* and *C. australis* were present throughout Section 3 (from Layer 1 to 13), and the ones of *M. spinata* from Layer 2 to 13. Rare spicules of *C. thumi* were seen in Layer 2 (Fig. 8).

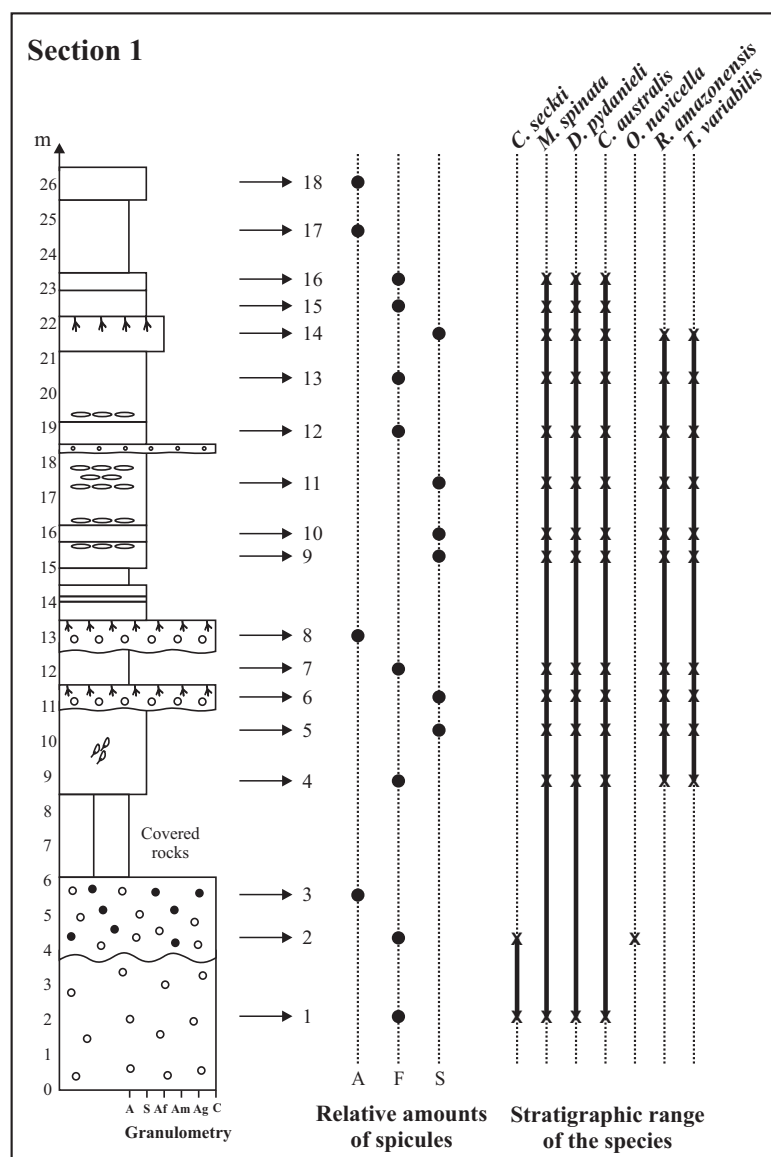


Fig. 6. Profile of Section 1 (meters) vis-a-vis the corresponding relative amounts of sponge spicules (A, absent; F, few; S, spongofacies) and stratigraphic range of the identified species. (X, occurrence of a particular species; A, argillite; S, siltstone; Af, fine sandstone; Am, medium sandstone; Ag, coarse sandstone; C, conglomerate). Legend of rocks as Figure 3. From V.S.M., unpublished data.

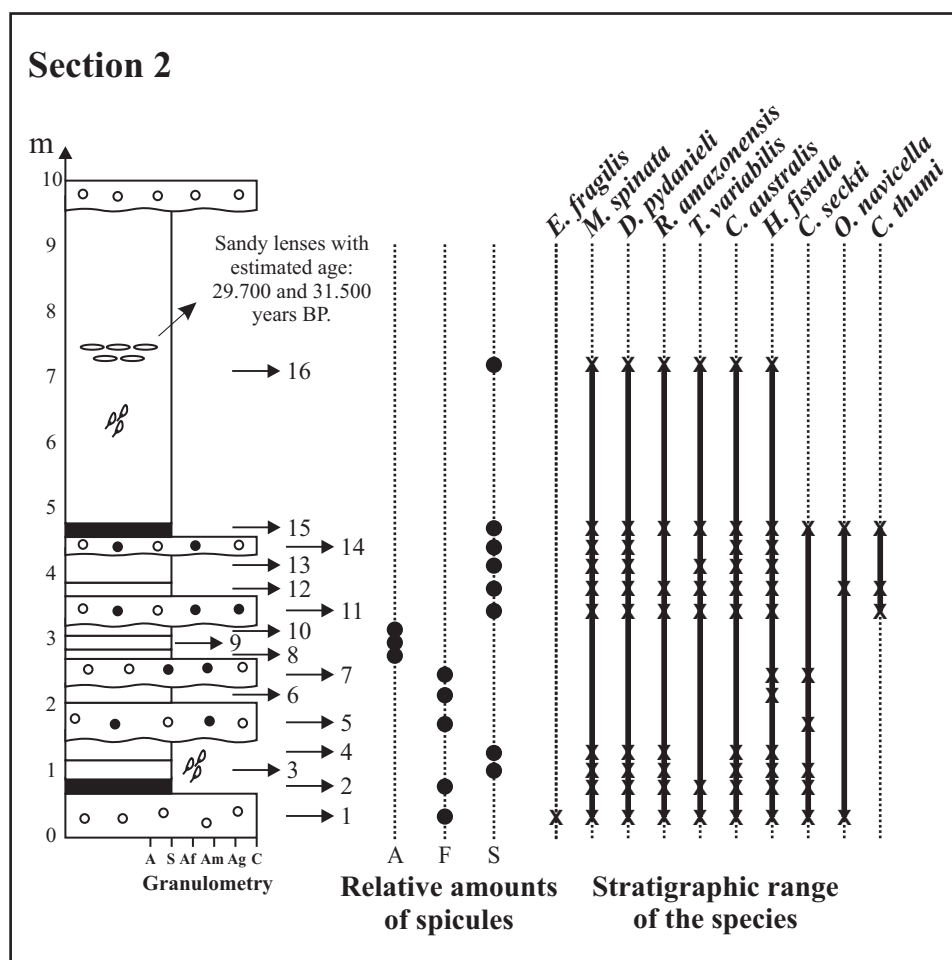


Fig. 7. Profile of Section 2 (meters) vis-a-vis the corresponding relative amounts of sponge spicules (A, absent; F, few; S, spongofacies) and stratigraphic range of the identified species. (X, occurrence of a particular species; A, argillite; S, siltstone; Af, fine sandstone; Am, medium sandstone; Ag, coarse sandstone; C, conglomerate). Legend of rocks as Figure 3. From V.S.M., unpublished data.

DISCUSSION AND CONCLUSION

The spicules found in the rocks of the Cemitério Paleolake revealed a predominance of sponges typical of lentic paleoenvironments: *Metania spinata* (Carter 1881), *Dosilia pydanieli* Volkmer-Ribeiro (1992), *Radiospongilla amazonensis* Volkmer-Ribeiro and Maciel (1983), *Trochospongilla variabilis* Bonetto and Ezcurra de Drago (1973), *Corvoheteromeyenia australis* (Bonetto and Ezcurra de Drago 1966), *Corvomeyenia thumi* (Traxler 1895) and *Heterorotula fistula* Volkmer-Ribeiro and Motta (1995) (Figs. 4, 5; Tables I,

II, III, IV, V, IX, X). With the exception of the last two, these species are abundant in the rocks and exhibit a prolonged stratigraphic range in the three analyzed sections (Figs. 6, 7, 8). The marked occurrence of this assemblage throughout the stratigraphic columns, comprising 25 layers characterized as spongofacies [Layers 5, 6, 9, 10, 11 and 14 from Section 1 (Fig. 6), Layers 3, 4, 11, 12, 13, 14, 15 and 16 from Section 2 (Fig. 7), and Layers 2, 3, 4, 6, 7, 8, 9, 10, 11, 12 and 13 from Section 3 (Fig. 8)], confirms the lentic nature of the system and indicates the assemblage as indigenous to the Cemitério Paleolake.

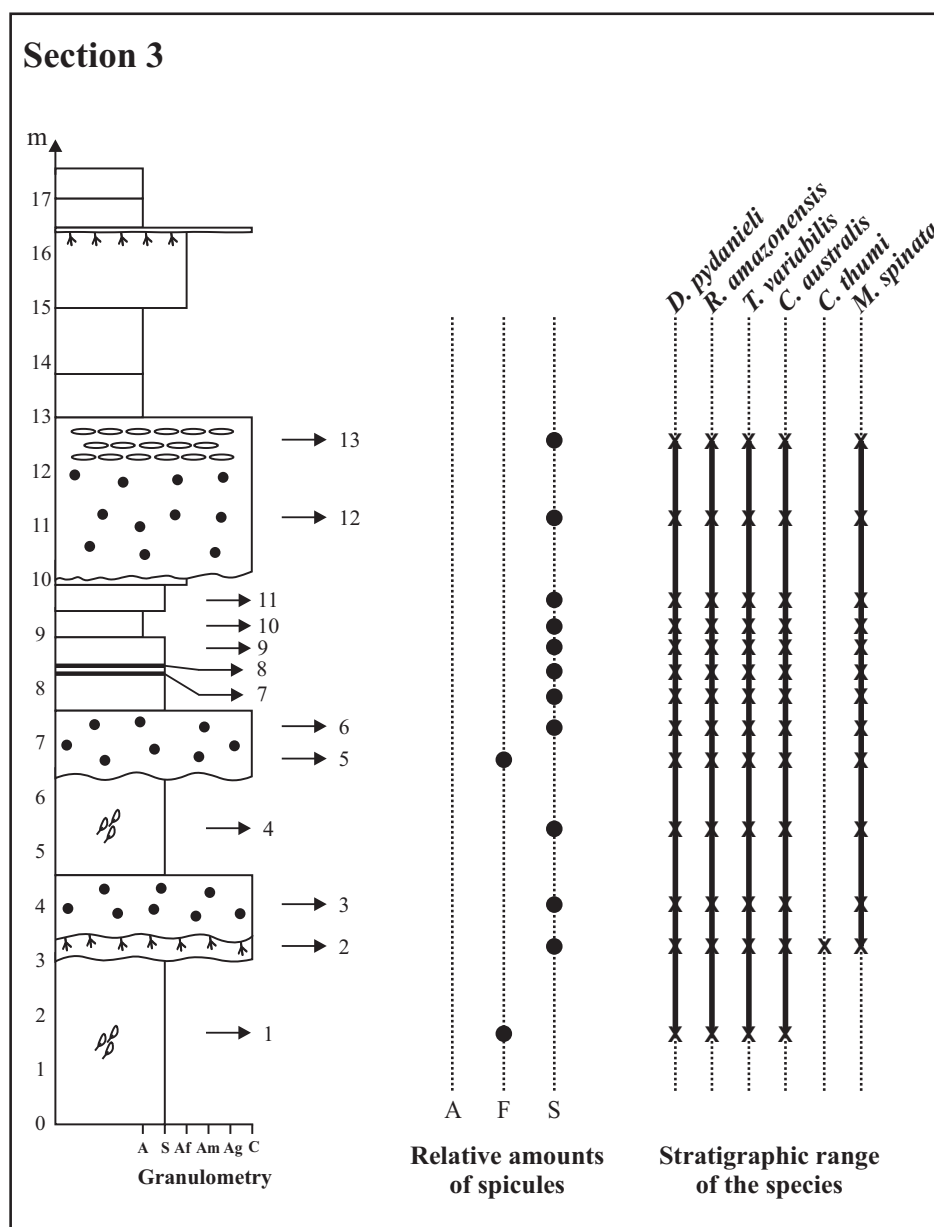


Fig. 8. Profile of Section 3 (meters) vis-a-vis the corresponding relative amounts of sponge spicules (A, absent; F, few; S, spongofacies) and stratigraphic range of the identified species. (X, occurrence of a particular species; A, argillite; S, siltstone; Af, fine sandstone; Am, medium sandstone; Ag, coarse sandstone; C, conglomerate). Legend of rocks as Figure 3. From V.S.M., unpublished data.

Except for the species *C. australis*, the lentic assemblage found in the rocks of the Cemitério paleolake was recorded in spongillite deposits in the Cerrado region of Conceição das Alagoas and Santa Vitória, Minas Gerais State; São Simão, Goiás State; Paranaíba, Mato Grosso do Sul State,

and Porto Ferreira, São Paulo State (Volkmer-Ribeiro and Motta 1995, Volkmer-Ribeiro 1992, Almeida et al. 2009). The species *H. fistula* has also been described from spongillite deposits found in the region of Conceição das Alagoas, Minas Gerais State (Volkmer-Ribeiro and Motta op cit.), and was

subsequently registered in a column of sediment recovered from the floodplain of the Esperança River, Taquarussu region, Mato Grosso do Sul State (Parolin et al. 2007). Intriguingly, no living specimens of *H. fistula* have ever been recorded and, as a consequence, their ecology and habitat preferences are generally unknown. However, Volkmer-Ribeiro and Motta (1995) pointed out that the species of the genus *Heterorotula*, hitherto endemic to Australia, appear in environments that are seasonally exposed to drought and form delicate crusts on the roots of aquatic vegetation, with a consistency ranging from fragile to hard, but brittle. Volkmer-Ribeiro (1992) also reported this same assemblage, with the exception of *H. fistula*, in a seasonal lake on the island of Maraca, Roraima State, and in lakes between Boa Vista and the island of Maraca. This island is considered to exhibit a transitional environment between Amazon Forest and the Cerrado. The temporary lake consists of a small body of water that during the rainy season does not exceed two meters in the center and can dry up completely at the height of the dry season. Volkmer-Ribeiro et al. (1998b) noticed the similarity of this assemblage of live sponges, occurring in the Brazilian Cerrado Biome, with the assemblage found in the spongillite, and pointed to the possibility that these deposits represent a remnant of typical lakes from the Cerrado. Later, Volkmer-Ribeiro (1999) reported the occurrence of the species *R. amazonensis*, *D. pydanieli*, *T. variabilis*, *M. spinata* and *C. thumi* for the state of São Paulo, and indicated that assemblage as typical of lakes in the current Cerrado Biome.

C. australis, identified for the first time in an assemblage formed by biosiliceous deposits, is endemic to South America and was described based on the material collected in Argentina, with the type locality being Setúbal Lake, but also in Don Felipe Lake and in waterbodies of Carabajal Island, being all of them environments of the Middle Paraná River floodplain that is located in the province of

Santa Fe, Argentina (Ezcurra de Drago 1979). The specimens were found near the mouths of streams, exposed to considerable flowing water (Ezcurra de Drago op cit.). Regarding Brazil, the species was first recorded for the Jacuí Delta, Rio Grande do Sul, encrusting the roots of the macrophyte *Eichornia azurea* (Sw.) Kunth (Tavares et al. 2003), with very similar environmental characteristics to those of the type locality.

The taxonomic analysis of the basal portion of the Cemitério Paleolake deposit (Layers 1 and 2 from Section 1 and throughout Section 2) (Figs. 6, 7) also revealed the presence of spicules from the sponges *Corvospongilla seckti* Bonetto and Ezcurra de Drago (1966), *Oncosclera navicella* (Carter 1881) and *Eunapius fragilis* (Leidy 1851) (Fig. 5; Tables VI, VII, VIII), which are indicator species of lotic environments (Batista and Volkmer-Ribeiro 2002, Tavares et al. 2003). The presence of spicules from these three species in the basal rocks, combined with the short stratigraphic range observed, points to the influence of a lotic environment in the proximity of the paleolake, which would be responsible for the transmission of spicules to the depocenter of the basin and results in the deposition and sedimentation of distinct sponge assemblages (sponge species/assemblages characteristic of lentic and lotic environments). It follows that *C. seckti*, *O. navicella* and *E. fragilis* constitute elements of the allochthonous sponge fauna from the Cemitério Paleolake. This interpretation is supported by the stratigraphy at Section 1 whose the basal section is dominated by coarse particle sizes suggesting deposition in a strong uni-directional flow.

Parolin et al. (2007) had previously identified the occurrence of continental sponge species that are characteristic of different environments, lotic (*Trochospongilla repens* Hinde 1888 and *C. seckti*) and lentic (*R. amazonensis* and *H. fistula*), in two sediment profiles in the floodplain of the Esperança River, Taquarussu region, Mato Grosso

do Sul State, Brazil. According to these authors, the species *H. fistula*, which is indicative of lentic environments, occurred from the most basal portion to the top of the deposit, while others occurred only in some layers. Thus, they concluded that there had been a lentic habitat marginal to the river caused by pulses of flooding of the river, which were well defined by the punctuated presence of spicules of *C. seckti* and *T. repens*. Furthermore, they highlighted the moment when the gemmoscleres of *H. fistula* occurred together with well-formed megascleres of *R. amazonensis*, a species identified as an indicator of peat, showing an increase in the residence of water in the lentic body that was responsible for the accumulation and formation of peat along the banks of the Esperança River from the early Holocene.

The analysis of the basal rocks from the Cemitério Paleolake also allows a discussion regarding their formation. Layers 1, 2, 3 and 4 of Section 2 (Fig. 7) are characterized by the progression of a few spicules (Layer 1, 2) to the spongofacies (Layers 3, 4 - Fig 7), indicating that the initial volume of water in the basin was minimum, followed by an increase in water with the probable establishment of macrophytic vegetation, which acts as a substrate for sponges and is always present in shallow lakes. The following layers (Layers 5, 6, 7, Fig 7) show a reduction in spicules, showing a decline in the water column of the basin with the possible occurrence of acid water, which can form karstic lakes in terrains made up of carbonatite rocks. Ribeiro et al. (2001) suggested two hypotheses for the genesis of a “Dry Paleolake”, which is a deposit located in the same Catalão complex and is similar to the Cemitério Paleolake. The first one is based on the leaching of the underlying carbonatite and phoscorite, a process that could result in large caves or dolines, thereby decreasing the size of the rock by up to five times. The second hypothesis involves a small-scale localized collapse, which could result in a reduction in the volume of the rock that causes subsidence. Either way, both

hypotheses point to the lakes appearing as a result of the erosion occurred in an area of karstic relief. The accumulation of humic substances, which resulted from a natural process of eutrophication caused by the production of macrophyte vegetation in the basin, would contribute to the acceleration of an erosive karstic process that leads to subsidence at the bottom of lakes. The alternation of clay (Layers 2, 3, 4, 6, 8, 9, 10, 12, 13, 15 and 16, Section 2) and conglomerates (Layers 1, 5, 7, 11 and 14, Section 2) is indicative of such a process (Fig. 7).

In addition, we interpret a strong lotic influence at the beginning of the paleolake's history, as indicated by the species *C. seckti*, *O. navicella* and *E. fragilis* (Fig. 6, 7). The conditions of lotic environments may have contributed to greater volumes of water and, consequently, to increased physical and chemical weathering at the bottom of the lake, which is typical of karstic lakes. Auler et al. (2005) report that, at the bottom of these karstic lakes, sediments of allochthonous and autochthonous origin can be found, respectively, derived from the production within the lake system and from the influx of rainwater from the slopes of the drainage basin.

The ages obtained by N.C., unpublished data, for layer 16 of Section 2 (Figs. 3, 7) of the Cemitério Paleolake allow one aspect to be addressed by this study. The author used two methods of dating for the sediments (sand lenses) found in this layer, thermoluminescence (TL) and optically stimulated luminescence (OSL) (Aitken 1985, Madsen and Murray 2009). TL resulted in an age of 34,700 + / - 5,000 years BP., while that obtained with OSL was 27,500 + / - 4,000 years BP. Considering the range of overlap of the error bars of these two geochronologies, this layer is believed to have an age between 29,700 and 31,500 years BP. (Figs. 3, 7). Given the presence of spongofacies at the base of Section 2, which represents the oldest rocks of the Cemitério Paleolake, with a marked occurrence of the sponge assemblages that are characteristic of lentic environments (*M. spinata*, *D. pydanieli*, *R.*

amazonensis, *T. variabilis*, *H. fistula* and *C. thumi*), it seems reasonable to suggest a maximum age of at least 39,700 years BP., considering the margin of error of the oldest dating.

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RESUMO

O Paleolago Cemitério, Catalão, Goiás, é um depósito lacustre rico em espículas de esponjas continentais. Essas espículas, que estão presentes em três seções (1-3), foram analisadas para identificação taxonômica das espécies, a fim de reconstruir o paleoambiente do Quaternário tardio. Foi encontrada uma assembleia nativa de esponjas lênticas, consistindo de *Metania spinata* (Carter 1881), *Dosilia pydanieli* Volkmer-Ribeiro (1992), *Radiospongilla amazonensis* Volkmer-Ribeiro e Maciel (1983), *Trochospongilla variabilis* Bonetto e Ezcurra de Drago (1973), *Corvomeyenia thumi* (Traxler 1895), *Heterorotula fistula* Volkmer-Ribeiro e Motta (1995), acrescida de *Corvoheteromeyenia australis* (Bonetto e Ezcurra de Drago 1966), que aqui tem o seu primeiro registro em assembleia formadora de depósitos biosilicosos. Além disso, na base das seções, foram detectadas espículas de esponjas de ambiente lótico, incluindo *Corvospongilla seckti* Bonetto e Ezcurra de Drago (1966), *Oncosclera navicella* (Carter 1881)

e *Eunapius fragilis* (Leidy 1851), o que sugere uma contribuição de águas com fluxo. Foram identificados 25 horizontes de espongo fácies produzidos por assembleia de esponjas típicas de ambiente lêntico, datado de pelo menos 39.700 anos AP., e atualmente ocorrente em lagoas típicas do Bioma Cerrado.

Palavras-chave: Bioma Cerrado, esponjas continentais, paleointerpretações do Quaternário, sedimentos, espículas.

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