



# FIRST ARTICULATED SPONGE FROM THE PALEOZOIC OF BRAZIL, AND A NEW ORGANIZATION OF THE ORDER HEMIDISCOSA

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**ABSTRACT**—The first-described articulated Permian sponge from Brazil, representing Hexactinellida, has been recovered from the Lontras Shale in the Campáleo outcrop (Permian, Asselian–Sakmarian), Rio do Sul Formation, Mafra, in southern Brazil. It is assigned to the Hemidiscellidae and identified as *Microhemidiscia greinerti* n. sp. This fossil represents the first record of articulated sponges in Brazil from the Paleozoic Era, as well as the second species known from this genus. Moreover, it increases knowledge of the order Hemidiscosa, a monotypic group mostly defined by simple characters, which is here considered to comprise one family, Hemidiscellidae (Pennsylvanian–Cretaceous), and two genera, *Hemidiscella* and *Microhemidiscia*.

## INTRODUCTION

**P**ALEOZOIC SPONGES are commonly well preserved and described, especially in the Burgess Shale of the middle Cambrian, the lower Cambrian Chengjiang fauna, and the Permian fauna of North America and Europe. In South America, Paleozoic sponges are well represented in Cambrian and Ordovician rocks of the Precordillera terrane of Argentina (Beresi, 2007). However, late Paleozoic sponge faunas of South America, particularly the Permian, are rare and therefore poorly known. The first sponge fossil discovered in Brazil was reported by Ruedemann (1929) from the Permian black shale succession (Lontras Shales) in the southern state of Santa Catarina. In Santa Catarina, Ruedemann found several isolated hexactines associated with others fossil, such as small inarticulate brachiopods. There have been numerous reports of isolated spicules in sediments of Brazil from the Paleozoic to the Neogene (Pinto, 1947, 1952, 1955; Martins, 1948, 1951; Martins and Sena-Sobrinho, 1950; Zingano and Cauduro, 1959; Klepzig et al., 1980; Maranhão and Petri, 1996; Hessel, 1982; Cardoso, 2005; Mouro, 2010).

Fossils of articulated sponges, representing Hexactinellida, have been recovered in fossiliferous marine black shale of Permian (Asselian–Sakmarian) age from the Rio do Sul Formation, in the southern Itararé Group, Mafra, Brazil. Presented herein is the first description of an articulated sponge from the Paleozoic of Brazil. These findings necessitate a reorganization of the order Hemidiscosa, a monotypic group mostly defined by simple characters.

## GEOLOGIC SETTING

The Rio do Sul Formation is the uppermost unit of the Itararé Group in the Paraná Basin (Schneider et al., 1974) and in Santa Catarina State it has been subdivided informally into lower, middle, and upper intervals (Weinschütz, 2001). Holz et al. (2010) have dated the Rio do Sul Formation as Asselian–Sakmarian (299–284 Ma), against the previous date of Sakmarian–Artinskian (294–275 Ma) presented by Petri and Souza (1993) and Dino and Rösler (2001). The lower interval is almost 40 m thick and was deposited during a marine transgressive post-glaciation event. It consists of thin varved

shales with dropstones overlain by ichnofossiliferous siltstones, fossiliferous black shales with abundant concretions and shaly rhythmites at the top (Hamel, 2005). The main fossils accompanying the sponges in the Lontras Shales are actinopterygian fishes, bivalves, coelacanth scales, coprolites, conodont elements, inarticulate brachiopods, insects, scolecodonts, shark teeth, and fragments of wood (Schneider et al., 1974; Castro, 1980; Rösler, 1985; Dias et al., 2008; Mouro, 2010).

The Campáleo outcrop (S 26°09′30.22″, W 49°48′52.82″) is at km 5 of the road BR-280, in the city of Mafra, State of Santa Catarina, Brazil (Fig. 1). It comprises an area of almost 38 m<sup>2</sup>. Consisting of varved shales with dropstones, bioturbated siltite, and the fossiliferous black shale with thickness of 1.10 m, the outcrop is divided informally into four levels, including sub-levels, based on concentrations of pyrite, rocks fracture, and fossil content (Weinschütz, 2010; Fig. 2). In view of the fact that the first outcrop in which several paleoniscoid fishes were identified (Malabarba, 1988; Richter, 1991; Hamel, 2005) was destroyed and now is a factory, the Campáleo, discovered in 1997, is now the only place where the fossiliferous black shales from the Lontras Shale outcrop.

## MATERIAL AND METHODS

Specimens come from only one outcrop at the base of the Rio do Sul Formation (Asselian–Sakmarian), namely Campáleo. During 2010 and 2011 almost 700 samples were collected, but thus far, only 25 samples have been recovered with fragments of articulated sponges. Those samples are housed in the invertebrate collection of the Museu da Terra e da Vida, which belongs to the Universidade do Contestado under the institutional abbreviation CPI, as well as in the invertebrate collection of the Museu Nacional under the institutional abbreviation MN-I.

The specimens were measured by an electronic caliper associated with an Olympus SZ51 stereomicroscope. The photographs were taken with a Canon EOS Rebel T2i digital camera. A few photographs were also taken using a Zeiss stereomicroscope with Axiovision.

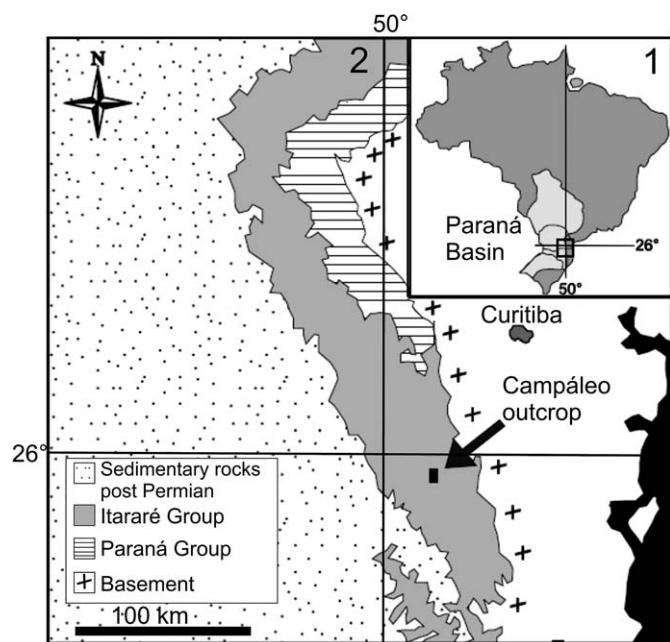


FIGURE 1—Locality map denoting the Paraná Basin, the Itararé Group and the Campáleo outcrop. 1, an overview of Paraná Basin (light gray) extension in Brazil, which comprises the states of South, Southeast and Midwest; 2, location of Campáleo outcrop (square) almost 117 km from the city of Curitiba and the geological distribution of Itararé Group, modified from Weinschütz and Castro (2005).

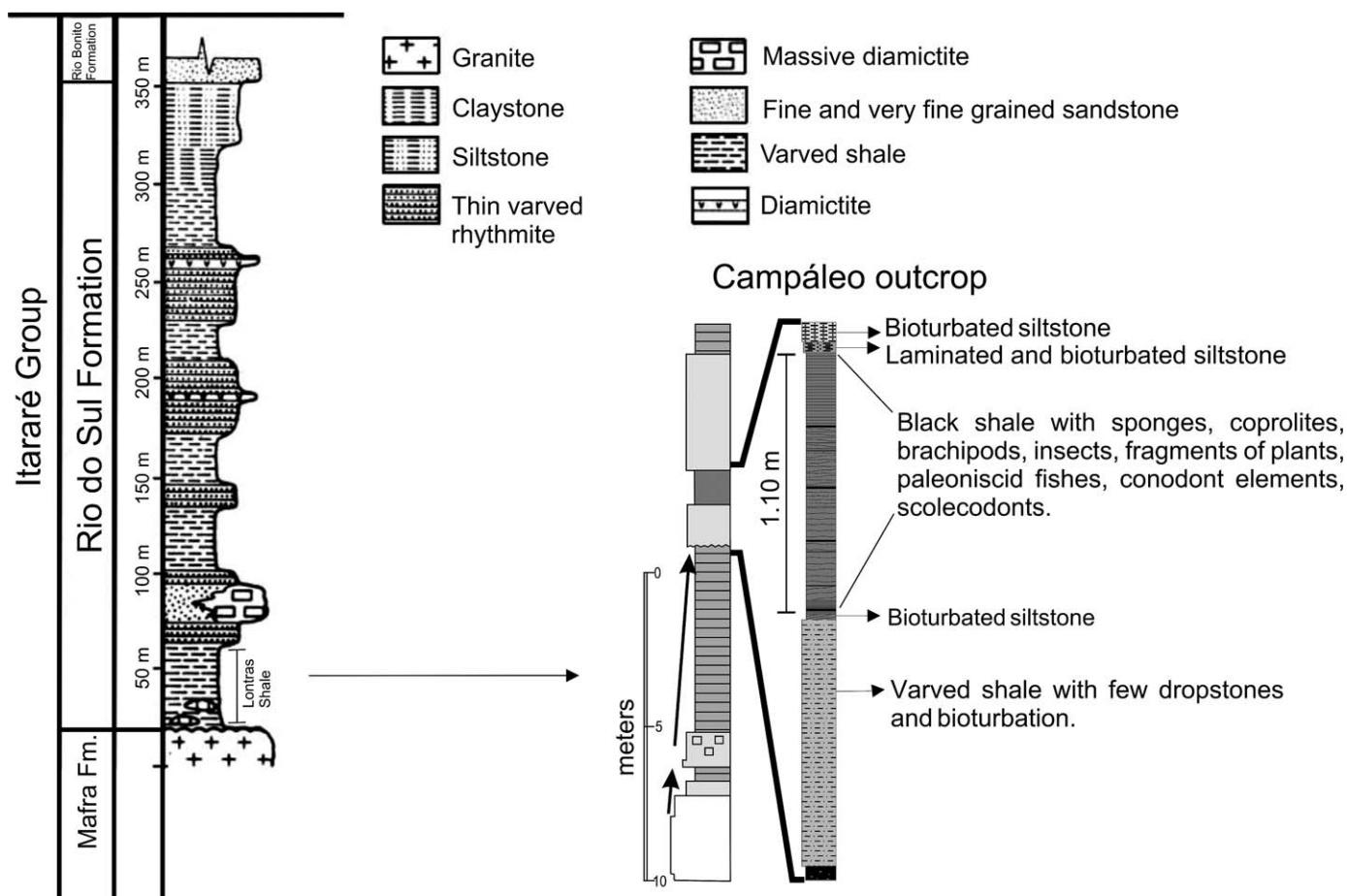


FIGURE 2—Stratigraphic section of the Rio do Sul Formation from Schneider et al. (1974) and Hamel (2005) and columnar section of the Campáleo outcrop modified from Weinschütz (2010).

#### SYSTEMATIC PALEONTOLOGY

Phylum PORIFERA Grant, 1836

Class HEXACTINELLIDA Schmidt, 1870

Subclass AMPHIDISCOPHORA Schulze, 1886

Order HEMIDISCOSA Schrammen, 1924

Family HEMIDISCELLIDAE Kling and Reif, 1969

Genus MICROHEMIDISCIA Kling and Reif, 1969

*Type species.*—*Microhemidiscia ortmanni* Kling and Reif, 1969

*MICROHEMIDISCIA GREINERTI* new species

Figures 3.1, 3.2, 4.1–4.3, 5, 6.1–6.3, 7.1, 7.2, 8, 9.1, 9.2

*Diagnosis.*—Conical-cylindrical shaped sponge with skeletal net composed of hexactines of ranked sizes with sub-parallel rays of each rank. Quadrules irregularly arranged and have three sizes. Hemidiscs have five long blades in major umbel and minor umbel with thornlike rays. Free pentactines and stauractines also present. Attachment from rounded base by root tuft of longer diactines.

*Description.*—Overall morphology conical-cylindrical. Specimen height from rounded base to upper edge varies from 40 to 151 mm, width varies from 20 to 79 mm. First-order quadrules in holotype and paratypes 3.7 mm high, 4.5 mm wide, subdivided into second-order quadrules 3.5 mm high, 3.5 mm wide. Third-order quadrules 1 mm high, 1 mm wide. Fourth-order quadrules 0.26–0.45 mm high and wide, these less commonly preserved. Almost all spicules preserved are hexactines, but free stauractines and pentactines also found. First-order of hexactine-based spicules have vertical rays 2–5 mm long, horizontal rays 2–4.5



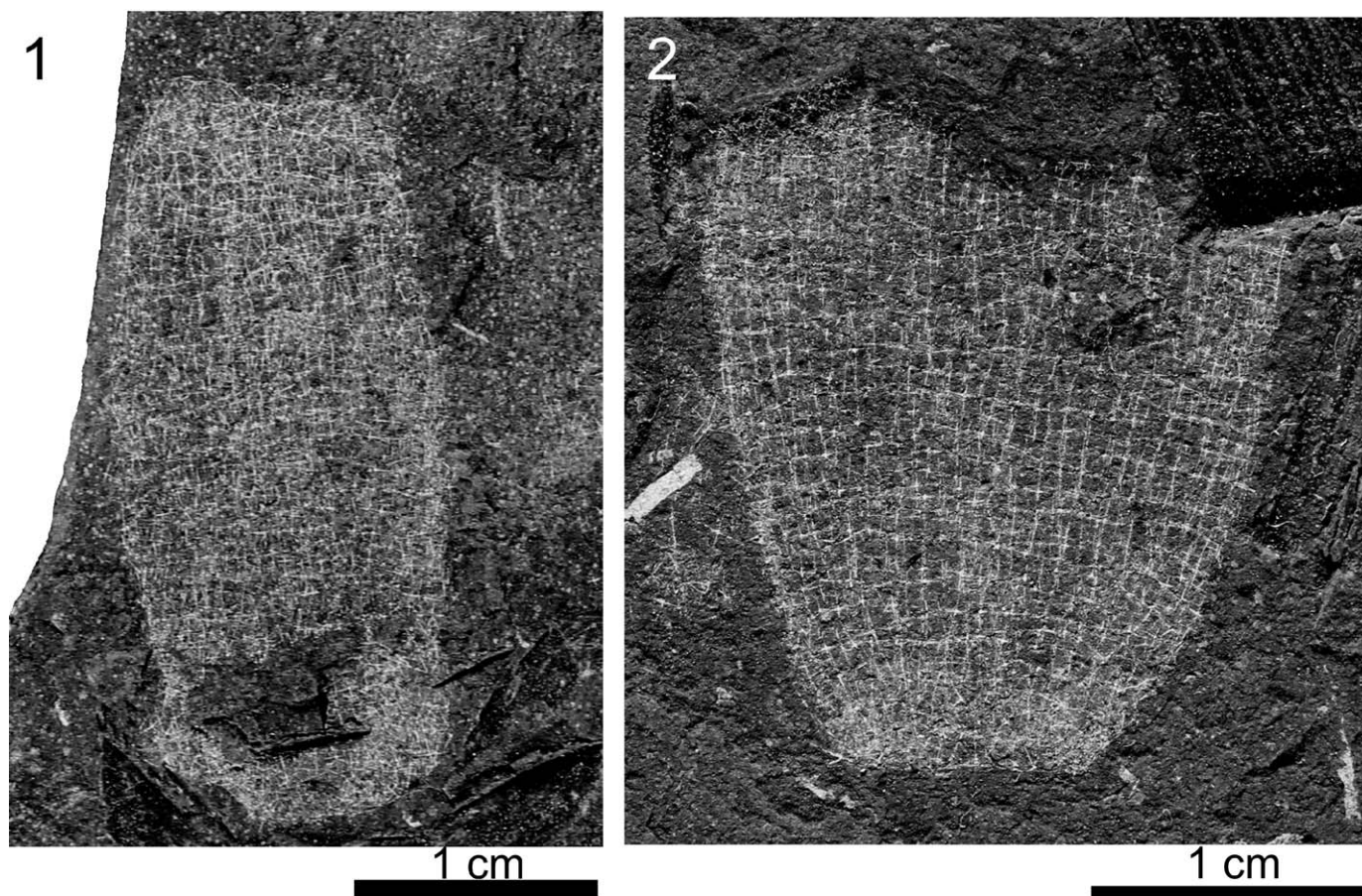


FIGURE 3—*Microhemidiscia greinerti* n. sp. 1, CPI 450, almost complete articulated sponge; 2, CPI 451, lower portion of articulated sponge with fragments of root tuft preserved.

mm long. Diameters of rays are 0.1–0.3 mm, tapering to sharp tips, at least in spicules where tips are exposed and most complete. Second-order spicules have horizontal and vertical rays 0.48–3.5 mm long. Third-order spicules have vertical rays 0.3–0.6 mm long, horizontal rays 0.2–0.5 mm long. Free and less well-preserved fourth-order spicules have horizontal and vertical rays 0.13–0.22 mm long. In almost all samples, ranked quadrules can be observed, especially in center part of sponges. Root tufts composed by longer diactine 20–80 mm in length with diameter 0.1–0.3 mm; only a few samples with root tufts have been found. Irregularities in quadrule and spicule sizes of all orders could be related to life stages of sponges as well as preservation condition.

Holotype MN 8700-I/A 80.44 mm tall, 47.41 mm wide in central part, 41.40 mm wide at base (Fig. 6). Upper portion of sponge, which includes oscular margin, is absent and estimated to represent more than one-third of original height. In this sample, 14 sponges of different size are present, two of which were identified as well-preserved hemidiscs. Four paratypes were used in identification. Paratype MN 8700-I/B 25.10 mm high and 20.21 mm wide, paratype MN 8700-I/C 33.15 mm high and 23.20 mm wide; found in these paratypes were more than 20 preserved hemidiscs ranging from 80 to 105  $\mu$ m in length, all characterized by five long blades in major umbel in addition to minor umbel with thorn-like rays (Fig. 7). Diameter of major umbel 50–60  $\mu$ m, diameter of minor umbel 25–30  $\mu$ m. No particular orientation observed.

Paratype MN 8701-I 54 mm high and 36 mm wide, with oscular margin 5 mm high and 18.56 mm wide (Fig. 8). Lower

portion of sponge is absent and estimated to represent one-fourth of original height. Paratype CPI 449 44.84 mm high, 35.50 mm wide in central part. Upper portion of sponge absent, well preserved root tufts 6 mm long with diameter 0.1 mm (Fig. 9).

**Etymology.**—Referring to Vilson Greinert, amateur paleontologist who has discovered articulated sponges.

**Types.**—Holotype MN 8700-I/A, and paratypes MN 8700-I/B, MN 8700-I/C, MN 8701-I and CPI 449.

**Material.**—Twenty five (25) samples with 38 specimens.

**Occurrence.**—Sublevel 3B (36–42 cm above base of black shale) in Campáleo outcrop (Permian, Asselian–Sakmarian), Lontras Shale, lower portion of Rio do Sul Formation, Itararé Group, Paraná Basin, Brazil.

**Remarks.**—The family Hemidiscellidae is composed of two genera, *Microhemidiscia* Kling and Reif, 1969, and *Hemidiscella* Reid, 1958. Until now, only one species has been registered to genus *Microhemidiscia*, *Microhemidiscia ortmanni* Kling and Reif, 1969, from the Carboniferous (Upper Pennsylvanian) of Uruguay, known only from disaggregated spicules. This species is characterized by short shafted hemidiscs 115–140  $\mu$ m long, pentactines and hexactines with rays ranging from 0.2 to 0.5 mm long, and rhabdodiactines accompanied by uncinates. *Microhemidiscia greinerti* n. sp. differs from *Microhemidiscia ortmanni* in several ways, possessing smaller hemidiscs (ranging from 80 to 105  $\mu$ m long) with long shovel-shaped blades in the major umbel. The hexactine rays range from 0.26 to 5 mm long, the free pentactine and stauroactine rays are 0.26–3 mm long, and there is evidence that the root tuft formed by diactines 20–80 mm long; furthermore, there is no presence of rhabdodiactines accompanied



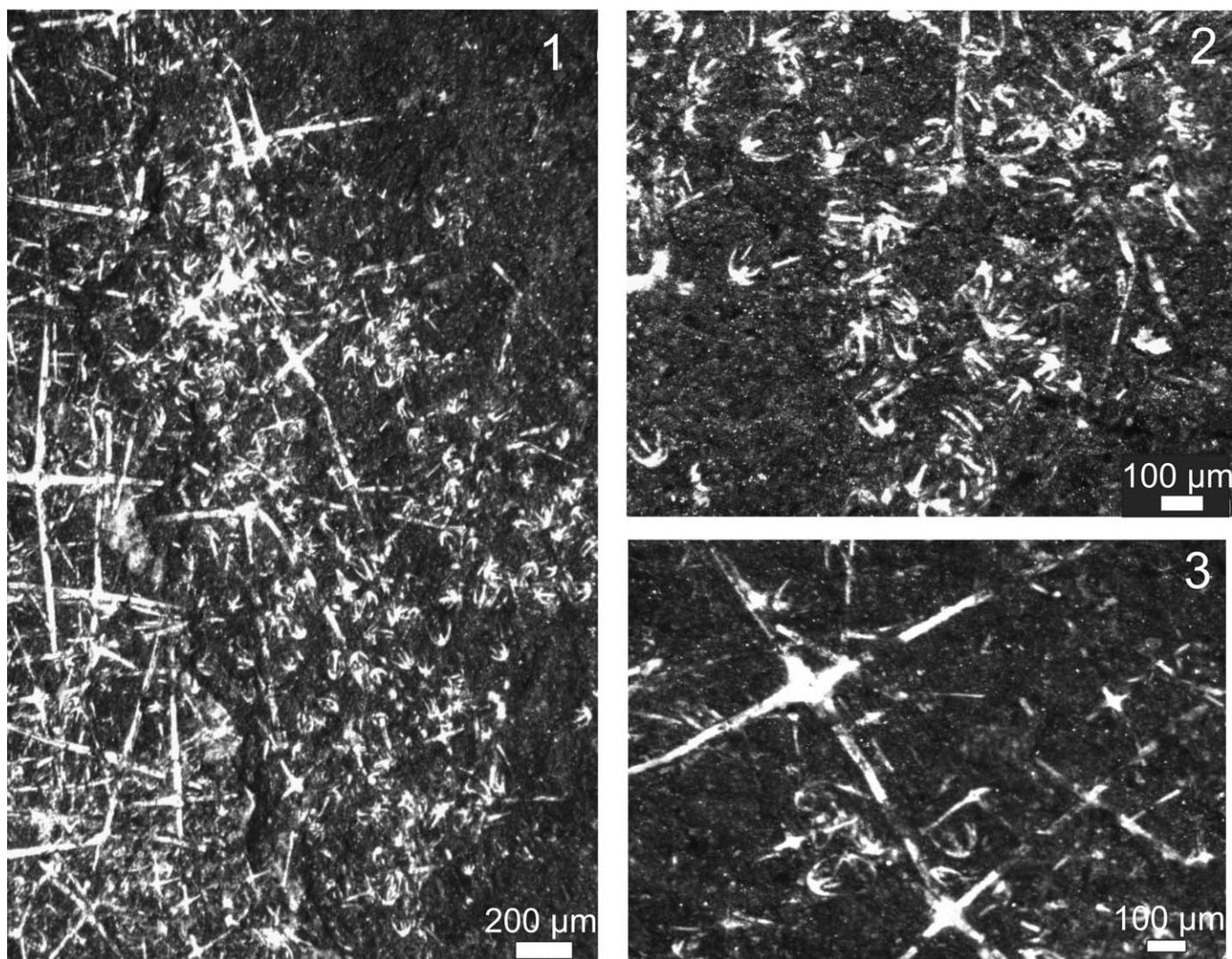


FIGURE 4—*Microhemidiscia greinerti* n. sp. (MN 8700-I/B). 1, overview of skeletal-net with presence of hexactines, pentactines and hemidiscs; 2, details of hemidiscs; 3, numerous hemidiscs between hexactines.

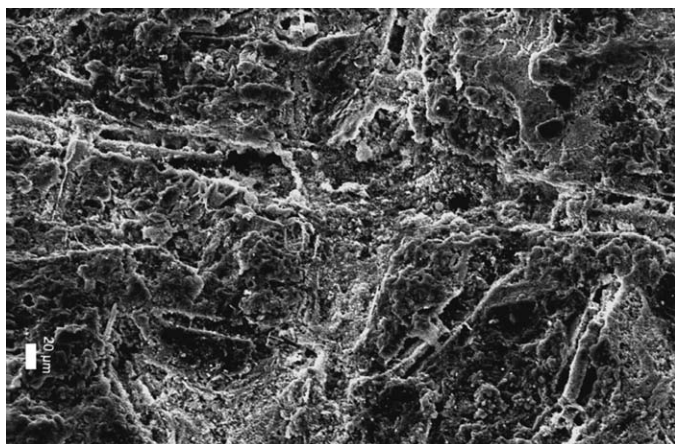


FIGURE 5—Internal portion of a free stauractine from *Microhemidiscia greinerti* n. sp.

by uncinates, and the bigger external form (40–151 mm high and 20–79 mm wide) has a conical-cylindrical shape with a fused principal skeleton. The time gap between the previous species recovered in the Itararé Formation (Gzhelian) of Uruguay and the species from the Lontras Shale (Asselian–Sakmarian) of Brazil is an estimated 8 million years.

#### DISCUSSION

The order Hemidiscosa was created by Schrammen (1924) and was briefly described in the last Treatise of Invertebrate Paleontology, Part E, Porifera, published in 2004. According to Finks and Rigby (2004), the order is monotypic, restricted to the late Paleozoic and composed by Amphidiscophora whose principal microscleres are hemidiscs.

Comparing the descriptions by Kling and Reif (1969) and Finks and Rigby (2004) of the families Hemidiscellidae and Microhemidiscidae, respectively, it is difficult to see a real difference between them and it is probably rather a question of history. Hemidiscellidae was described as Amphidiscophora with birotulates in the form of hemidiscs with basic structure of free, unfused megascleres including hexactines, pentactines and smooth diactines; the type genus, *Hemidiscella*, was described



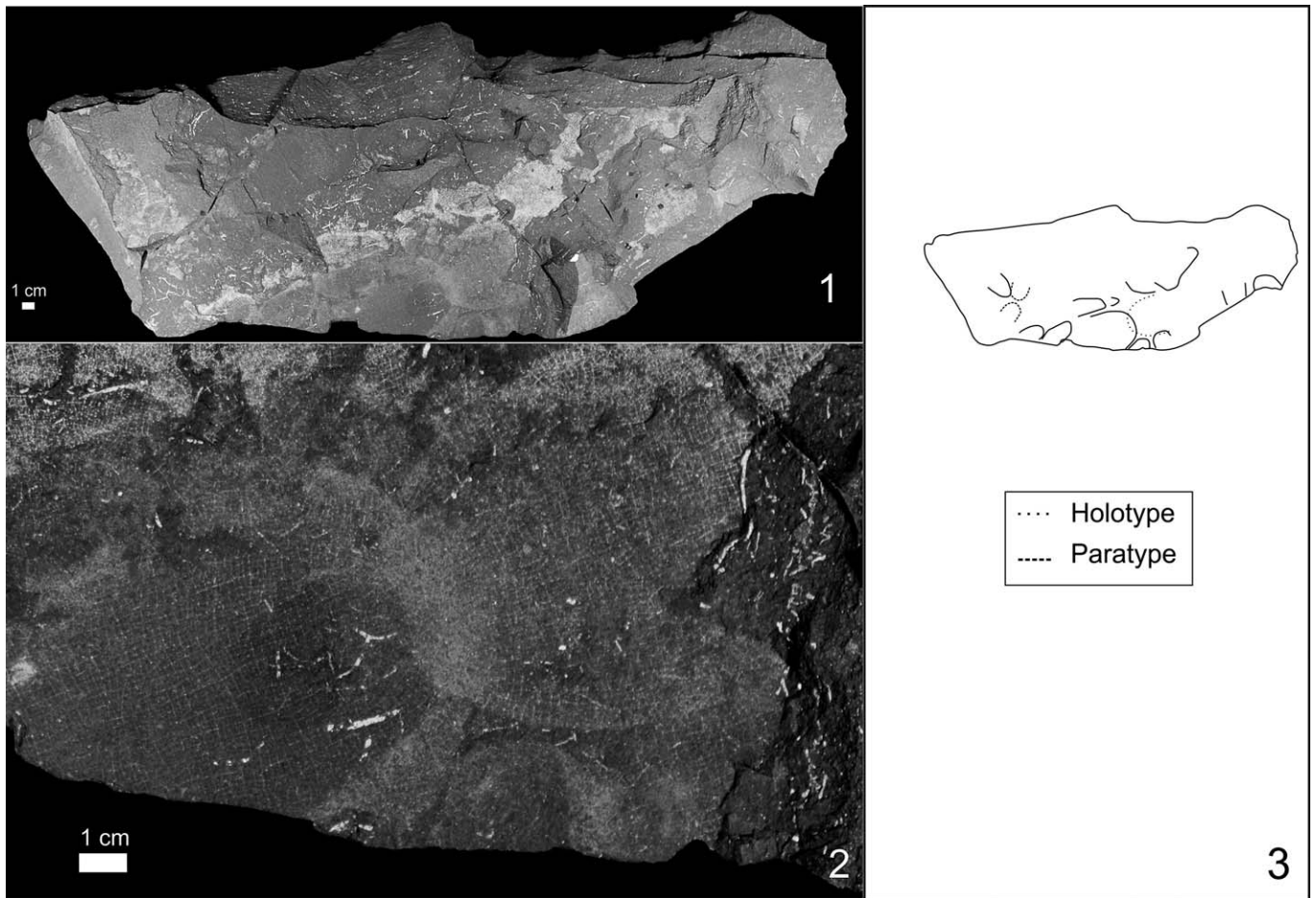


FIGURE 6—1, 3, Fourteen specimens of *Microhemidiscia greinerti* n. sp. with different sizes and two paratypes (MN 8700-I/B and MN 8700-I/C) with well-preserved hemidiscs; 2, holotype (MN 8700-I/A).

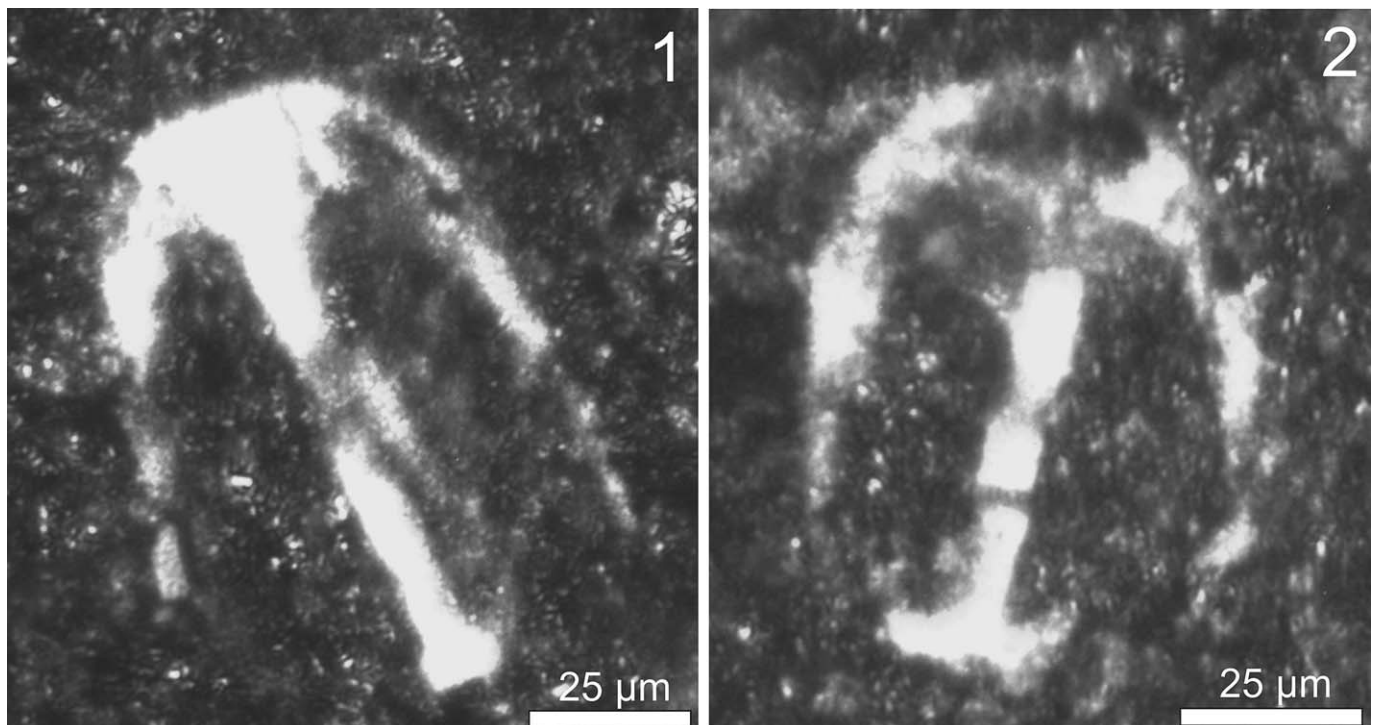


FIGURE 7—Hemidisc form of *Microhemidiscia greinerti* n. sp. (MN 8700-I/B and MN 8700-I/C). 1, 2, long shovel-shaped blades on major umbel and spatulate teeth on minor umbel.





FIGURE 8—*Microhemidiscia greinerti* n. sp., paratype MN 8701-I. Articulated sponge with oscular margin preserved; oscular margin has width 18.56 mm, height 5 mm and is formed by hexactines.



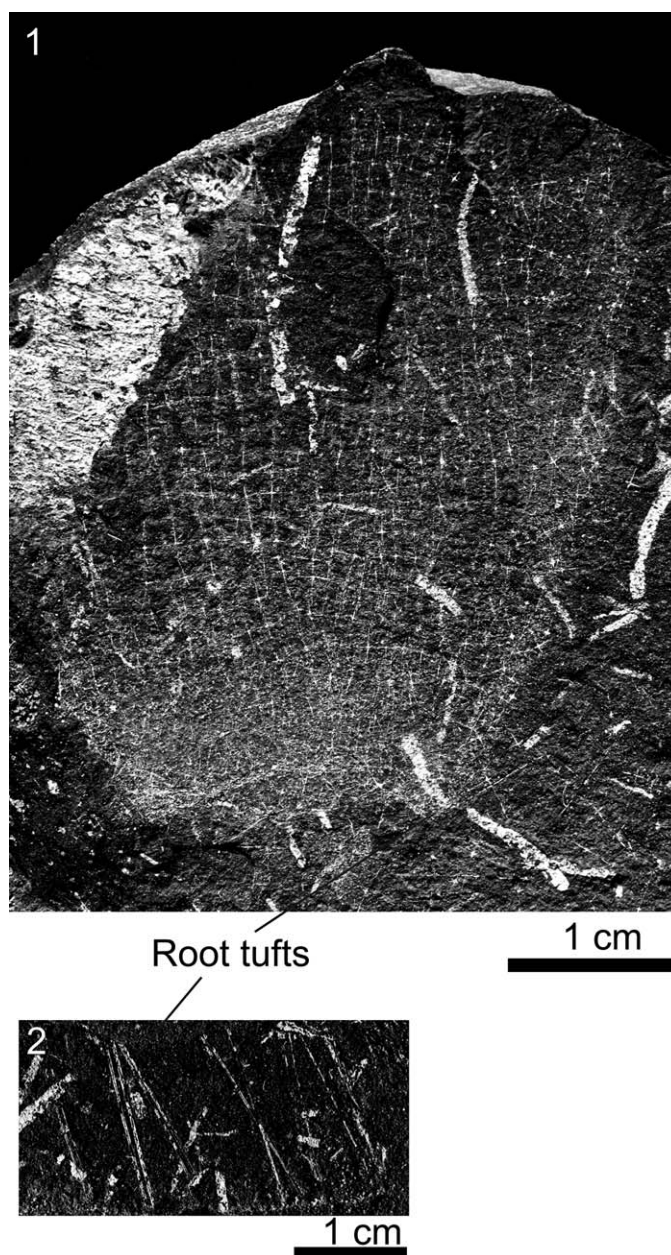


FIGURE 9—*Microhemidiscia greinerti* n. sp., paratype CPI 449. 1, articulated sponge with the lower portion preserved, including root tuft diactines; upper portion of sponge is not preserved; 2, details of root tufts from *Microhemidiscia greinerti* n. sp. (CPI 454).

by Reid (1958). *Microhemidisciidae* was reported as sponges formed by hemidiscs with spatulate teeth on major umbel, occurring together with uncinates. Despite the descriptions and the time gap between those families (*Hemidiscellidae*, Cretaceous; *Microhemidisciidae*, Gzhelian to Sakmarian), the only main character separating them is the size of hemidiscs, which is not a strong reason to create new families. Therefore, we propose to maintain the *Hemidiscellidae* as the only family in the order Hemidiscosa, due to its older and more detailed description and insufficient distinct characters to recognize an additional family. *Hemidiscellidae* comprises two genera, *Hemidiscella* Reid, 1958 and *Microhemidiscia* Kling and Reif, 1969, and three species, *Hemidiscella schrammii* Reid, 1958,

*Microhemidiscia ortmanni* Kling and Reif, 1969 and *Microhemidiscia greinerti* n. sp.

Considering and revising the phylogeny of Hexactinellida reported by Mehl (1996), the data from Reid (1958), Kling and Reif (1969), Mostler (1986), Finks and Rigby (2004) and the description of Schrammen (1924), we consider the order Hemidiscosa as originating in the Late Pennsylvanian (Gzhelian) and extending to the Late Cretaceous, contradicting the chronological distribution as proposed by Finks and Rigby (2004).

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#### REFERENCES

- BERESI, M. S. 2007. Fossil sponges of Argentina: a review, p. 11–21. In M. R. Custódio, G. L. Hajdu, E. Hajdu and G. Muricy (eds.), *Porifera Research: Biodiversity, Innovation and Sustainability*. Museu Nacional, Rio de Janeiro, Brasil.
- CARDOSO, T. R. M. 2005. Acrítarcos do siluriano da bacia do Amazonas: Bioestratigrafia e geocronologia. *Arquivos do Museu Nacional*, 63(4):727–759.
- CASTRO, J. 1980. Facies, ambientes e seqüências deposicionais das formações Rio do Sul e Rio Bonito, leste de Santa Catarina; facies e evolução sedimentar do Grupo Passa Dois na BR-470-SC. XXXI Congresso Brasileiro de Geologia, Camboriú, Anais, p. 283–299.
- DIAS, E. V., F. SEDOR, AND L. WEINSCHUTZ. 2008. Ocorrência de dentes Chondrichthyes na Formação Rio do Sul (Carbonífero Superior-Permiano Inferior) de Santa Catarina, Brasil. III Congresso Latinoamericano de Paleontologia de Vertebrados, 2008, Neuquén. Libro de Resúmenes, 1:81–81.
- DINO, R. AND O. RÖSLER. 2001. Significado estratigráfico e paleoambiental da palinoflora de concreções da Formação Rio do Sul (Neopaleozóico da Bacia do Paraná) na região de Mafra, SC. *Revista Brasileira de Paleontologia*, 2: 148–149.
- FINKS, R. M. AND J. K. RIGBY. 2004. Paleozoic hexactinellid sponges, p. 320–448, figs. 384–504. In R. L. Kaesler (ed.) *Treatise on Invertebrate Paleontology*. Pt. E. Porifera (revised). Geological Society of America and University of Kansas Press, Lawrence.
- GRANT, R. B. 1836. Animal Kingdom, p. 107–118. In R. B. Todd and Robert Bentley (eds.), *The Cyclopaedia of Anatomy and Physiology*. London, 1:1–813.
- HAMEL, M. H. 2005. A new lower actinopterygian from the early Permian of the Paraná Basin, Brazil. *Journal of Vertebrate Paleontology*, 25:19–26.
- HESEL, M. H. R. 1982. Curso prático de paleontologia geral. Editora Universidade, Porto Alegre, p. 250.
- HOLZ, M., A. B. FRANÇA, P. A. SOUZA, R. IANNUZZI, AND R. ROHN. 2010. A stratigraphic chart of the Late Carboniferous/Permian succession of the eastern border of the Paraná Basin, Brazil, South America. *Journal of South American Earth Sciences*, 29:381–399.
- KLEPZIG, M. C., M. G. SOMMER, AND G. E. BOSSI. 1980. Revisão fitoestratigráfica do Grupo Itararé no Rio Grande do Sul, acampamento Velho, Cambaí Grande, Budó e Morro Papaleó. *Boletim do Instituto de Geociências*, 11:31–189.
- KLING, S. A. AND W. E. REIF. 1969. The Paleozoic history of amphidisc and hemidisc sponges: new evidence from Carboniferous of Uruguay. *Journal of Paleontology*, 43:1429–1434.
- MALABARBA, M. C. L. 1988. A new genus and species of stem group actinopteran fish from the lower Permian of Santa Catarina State, Brazil. *Zoological Journal of the Linnean Society*, 94:287–299.
- MARANHAO, M. S. A. S. AND S. PETRI. 1996. Novas ocorrências de fósseis nas Formações Corumbataí e Estrada Nova do estado de São Paulo e considerações preliminares sobre seus significados paleontológico e bioestratigráfico. *Revista do Instituto Geológico*, 17:33–54.

- MARTINS, E. A. 1948. Fósseis marinhos na Série Maricá, Rio Grande do Sul. *Mineração e Metalurgia*, XII(71):237–239.
- MARTINS, E. A. 1951. *Aviculpecten cambahyensis* n. sp. no Permo-carbonífero do Rio Grande do Sul. *Boletim do Museu Nacional, Série Geologia*, 13:1–5.
- MARTINS, E. A. AND M. SENA-SOBRINHO. 1950. Novos fósseis e a idade da Formação Maricá, Rio Grande do Sul. *Boletim do Museu Nacional, Série Geologia*, 8:1–7.
- MEHL, D. 1996. Phylogenie und Evolutionsökologie der Hexactinellida (Porifera) im Paläozoikum. *Geologie Paläontologie Mitteilungen*, Innsbruck, 4:1–55.
- MOSTLER, H. 1986. Beitrag zur stratigraphischen Verbreitung und phylogenetischen Stellung der Amphidiscophora und Hexasterophora (Hexactinellida, Porifera). *Mitteilungen Österreichische Geologische*, 78:319–359.
- MOURO, L. D. 2010. Análise tafonômica de Porifera e fósseis associados no Afloramento Campáleo, Formação Rio do Sul, Mafra, SC, p. 44. Universidade Estadual do Oeste do Paraná, Monograph.
- PETRI, S. AND P. A. SOUZA. 1993. Síntese dos conhecimentos e novas concepções sobre a bioestratigrafia do subgrupo Itararé, Bacia do Paraná, Brasil. *Revista do Instituto Geológico*, 14:7–18.
- PINTO, I. D. 1947. Novos fósseis na Formação Maricá. *Ciências e Letras*, 1:9.
- PINTO, I. D. 1952. Fósseis na Formação Maricá (Bagé). VI Congresso de Geologia, Porto Alegre, Abstract.
- PINTO, I. D. 1955. Série Maricá, Camaquã e Formação Teixeira Soares no Rio Grande do Sul. Porto Alegre, Instituto de Ciências Naturais, URGs, Boletim, 2:19–27.
- REID, R. E. H. 1958. Upper Cretaceous Hexactinellida of Great Britain and Northern Ireland, Pt. 1. *Palaeontographical Society, Monograph*, 46 p.
- RICHTER, M. 1991. A new marine ichthyofauna from the Permian of the Paraná Basin of southern Brasil. Unpublished Ph.D. dissertation, King's College London, University of London, p. 233.
- RÖSLER, O. 1985. Sobre algumas contribuições e paleontologia do Paleozóico Superior do Brasil. Late Paleozoic of South America-Annual Meeting of the Working Group, Bogotá, Abstract.
- RUEDEMANN, R. 1929. Fossils from the Permian Tillite of São Paulo, Brazil, and their bearing on the origin of tillite. *Geological Society of America Bulletin*, 40:417–425.
- SCHMIDT, O. 1870. Grundzüge einer Spongien-Fauna des Atlantischen Gebietes. Wilhelm Engelmann-Leipzig: iii–iv, 1–88, pls. I–VI.
- SCHNEIDER, R. L., H. MUHLMANN, E. TOMMASI, R. A. MEDEIROS, R. F. DAEMON, AND A. A. NOGUEIRA. 1974. Revisão estratigráfica da Bacia do Paraná. XXVIII Congresso Brasileiro de Geologia, Porto Alegre, Anais, p. 41–65.
- SCHRAMMEN, A. 1924. Die Kieselspogien der oberen Kreide von Nordwestdeutschland und letzter Teil. Mit Beiträgen zur Stammgeschichte. *Monograph Geologie Paläontologie*, p. 159.
- SCHULZE, F. E. 1886. Über den Bau und das System der Hexactinelliden. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, Physikalisch-Mathematische Classe*, p. 1–97.
- WEINSCHÜTZ, L. 2001. Sucessões Estratigráficas do Grupo Itararé na região de Mafra-SC e Rio Negro-PR. *Revista Brasileira de Paleontologia*, 2:135–136.
- WEINSCHÜTZ, L. C. AND J. C. CASTRO. 2005. A sequência Mafra Superior/ Rio do Sul Inferior (Grupo Itararé, PermoCarbonífero) em sondagens testemunhadas da região de Mafra (SC), margem leste da Bacia do Paraná. *Revista de Geociências*, 24: 131–141.
- WEINSCHÜTZ, L. 2010. Divisão do afloramento Campáleo. I Conodont Meeting, Mafra, Brazil, Proceedings, p. 1–3.
- ZINGANO, A. G. AND A. D. CAUDURO. 1959. Afloramentos fossilíferos do Rio Grande do Sul. Porto Alegre, Instituto de Ciências Naturais, URGs, Boletim, 8:1–48.

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