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# Discinoids of the Malvinokaffric Realm: Stratigraphic, Paleogeographical Distribution and Systematic Review

# Discinideos do Domínio Malvinocáfrico: distribuição estratigráfica, paleogeográfica e revisão sistemática

# Discinóidos de la Provincia Malvinocáfrica: distribución estratigráfica, paleogeográfica y revisión sistemática

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**Abstract:** The main theme of this paper is the systematic review of discinoids the Lower to Middle Devonian of the Ponta Grossa (latest Pragian to early Emsian) and São Domingos formations (late Emsian to Frasnian), Paraná Basin, Paraná state, Brazil. Five discinoid species were recorded: *Orbiculoidea bainii, O. bodenbenderi, O. excentrica, Gigadiscina collis*, and *Rugadiscina stagona*. It was adopted the reallocation in *Gigadiscina collis*, instead of *Orbiculoidea collis,* the maintenance of other species, as well as new description data are accepted. Description of *Rugadiscina stagona,* a new species of discinoid for the Devonian of the Paraná Basin is made.

**Key words:** *Orbiculoidea*. *Rugadiscina*. *Gigadiscina*. Discinidae. Devonian.

**Resumo:** O objetivo principal deste artigo é a revisão sistemática dos discinoideos do Devoniano Inferior ao Médio, das Formações Ponta Grossa (final do Praguiano ao início do Emsiano) e São Domingos (final do Emsiano ao Frasniano), Bacia do Paraná, estado do Paraná, Brasil. Foram registradas cinco espécies de discinoideos: *Orbiculoidea bainii*, *O. bodenbenderi*, *O. excentrica*, *Gigadiscina collis* e *Rugadiscina stagona*. Foi adotada a reatribuição de *Gigadiscina collis* ao invés de *Orbiculoidea collis*, a manutenção de outras espécies, bem como novos dados de descrição, é proposta. É realizada a descrição de *Rugadiscina stagona*, uma nova espécie de discinoideo para o Devoniano da Bacia do Paraná.

**Palavras-chave:** *Orbiculoidea*. *Rugadiscina*. *Gigadiscina*. Discinidae. Devoniano.

**Resumen:** El principal objetivo del artículo es la revisión sistemática de los discinoides del Devoniano Inferior al Medio de las formaciones Ponta Grossa (Pragiano superior a Emsiano inferior) y São Domingos (Emsiano Superior a Frasniano) de la Cuenca del Paraná, Paraná, Brasil. Se han identificado cinco especies: *Orbiculoidea bainii, O. bodenbenderi, O. excentrica, Gigadiscina collis*, y *Rugadiscina stagona*. Se adoptó la reasignación de *Gigadiscina collis* en lugar de *Orbiculoidea collis,* el mantenimiento de otras especies, así como nuevos datos descriptivos son aceptados. Se realiza la descripción de *Rugadiscina stagona,* una nueva especies de discinoide para el Devónico de la Cuenca del Paraná.

**Palabras clave.** *Orbiculoidea*. *Rugadiscina*. *Gigadiscina*. Discinidae. Devoniano.

## INTRODUCTION

Orville A. Derby first time mentioned the occurrence of Devonian organophosphatic discinoids brachiopods (Family Discinidae) from the Paraná Basin in 1877 (Paraná State, South of Brazil). In the Paraná Basin, Clarke (1913), Kozlowski (1913) and Lange (1943) conducted taxonomic studies of the group. Clarke (1913) recognized *Orbiculoidea bainii* Sharpe, 1856, and described two new species: *Orbiculoidea bodenbenderi* and *Orbiculoidea collis.* In the same year, Kozlowski (1913) described *Orbiculoidea grandissima*. However, this species appears to have the same characteristics as the formerly published *O. collis*, and may be a junior synonym. John M. Clarke did not participate in any of the field campaigns in Brazil but he noticed, by careful observations, that the fossils exhibited a cosmopolitan character independent of the sedimentary facies in which they occurred.

This characteristic is unique among the discinoids recorded from the Ponta Grossa and São Domingos Formations (GRAHN et al., 2013); this means that this fossil group occurs in all fossiliferous assemblages, regardless of their associated facies. Lange (1943) was the other author who described a discinoid, (*Orbiculoidea excentrica*) from the Devonian of Brazil. Subsequent authors referred to the group only in generic terms. The aim of the work is revision of already described discinoids, but new paleoecological, stratigraphical and geographical data are presented. The study confirms the relocation of *O. collis* to *Gigadiscina collis* proposed by Mergl; Massa (2005), as well as the maintenance of Clarke's (1913) and Lange's (1943) discinoids species and the recognition of a new species (*Rugadiscina stagona*) to the Devonian of the Paraná Basin, Brazil.

## MATERIALS AND METHODS

Part of the fossil material analyzed for the present research was already deposited at the UEPG fossil collection; nevertheless, new field campaigns were implemented. The UEPG fossil material had no reference to bedding plane, stratigraphical position, and lithological or sedimentological data. These specimens were especially useful for the systematic revision. However, the new material collected allowed a more comprehensive analysis, which led to some additional information. The new material is also deposited at the UEPG.

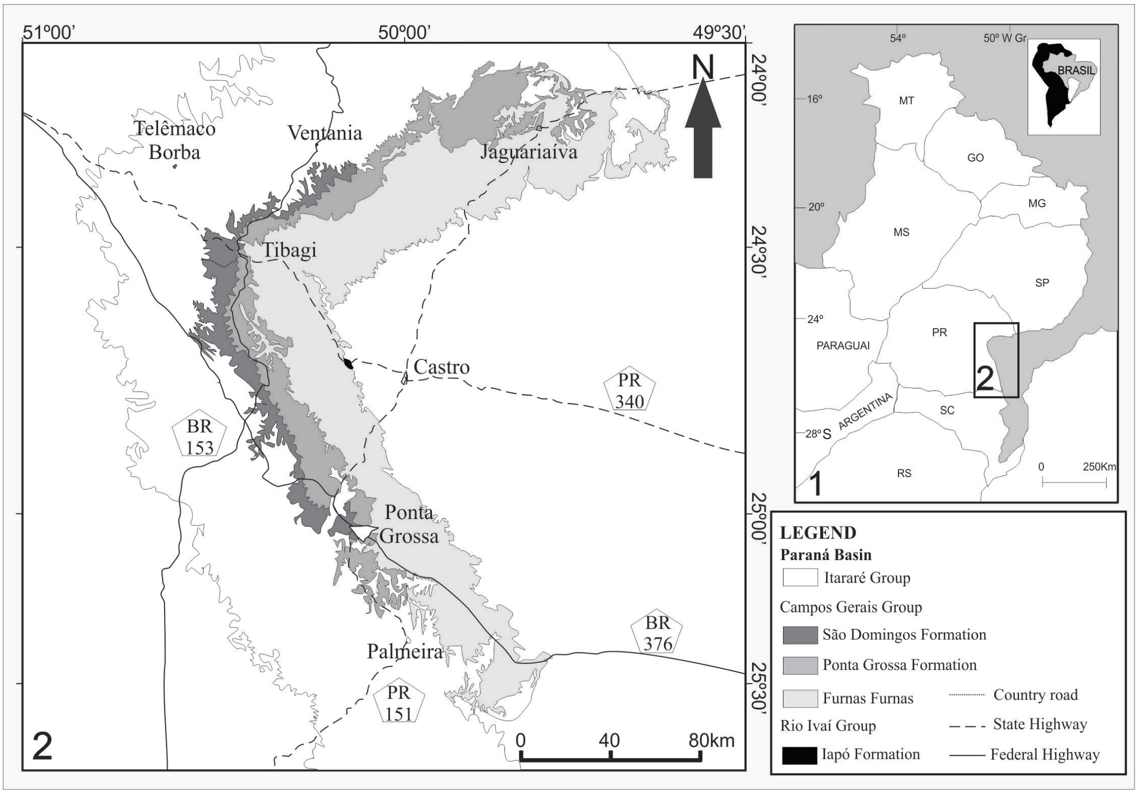
The collected samples belong to the following localities: Ponta Grossa [outcrops Boa Vista (25º 04′ 38,01″ S; 50º 11′ 25,01″ W), Vendrami (25º 08′ 57,07″ S; 50º 11′ 25,01″ W), Desvio Ribas - Tibagi (25º 12′ 02,73″ S; 50º 03′ 58,55″ W), Caça e Pesca (25º 11′ 24,15″ S;

50º 08′ 27, 36″ W), Fazenda Rivadávia (25º 15′ 05,47″ S; 50º 03′ 06,2″ W), Curva I (25º 03′ 34,56″ S; 50º 08′ 04,09″ W), Curva II (25º 04′ 03,06″ S; 50º 07′ 56,18″ W), Vila Francelina (25º 04′ 55″ S; 50º 06′ 54″ W), Pilão de Pedra (25º 05′ 17,95″ S; 50º 09′ 15,43″ W) and Vila Vilela (25º 05′ 17,40″ S; 50º 09′ 16,37″ W)]; Jaguariaíva city [railroad outcrop Jaguariaíva-Arapoti (24º 14′ 05″ S; 49º 42′ 34″ W)]; Tibagi city [outcrops Tibagi II (24º 29′ 51″ S; 50º 25′ 00″ W), Furnas/Ponta Grossa contact (24º 46′ 04″ S; 50º 09′ 24″ W), Sítio Wolff (24º 28′ 11,21″ S; 50º 32′ 08,46″ W), Fazenda Fazendinha (24º 28′ 04,50″ S; 50º 26′ 28,01″ W), Km 211 (24º 34′ 29,19″ S; 50º 27′ 05,03″ W), Km 217 (24º 36′ 34,88″ S; 50º 26′ 37,73″ W) and Km 220 (24º 38′ 02,19″ S; 50º 27′ 40,35″ W) of the BR 153 highway, and Fazenda Zezito = Tibagi Member type section *sensu* Lange; Petri, 1967 (24º 31′ 32,65″ S; 50º 27′ 52,05″ W)]; Palmeira city [Rio Caniú outcrop (25º 18′ 48″ S; 50º 05′ 32″ W)].

## GEOLOGY OF THE STUDY AREA

The Paraná Basin is an intracratonic, intercontinental and polycyclic sedimentary basin. It has an area of 1.5 million square kilometers (MILANI et al., 2007). This basin has two depocenters, the Alto-Garças Sub-Basin (to north) and the Apucarana Sub-Basin (to south), which constitute the middle portion of the South American continent. Milani et al. (2007) recognized six major rock packages that represent depositional periods of few millions of years. These units are limited by interregional discontinuities. The Paraná supersequence (Devonian), which bears the discinoids of this study, is represented by successive transgressive-regressive cycles that are linked to sea level oscillations (MILANI et al., 2007). The outcrops are a part of the Campos Gerais Group (Fig. 1), comprising from bottom to top the Furnas, Ponta Grossa, and São Domingos Formations (the last formation including the Tibagi Member) (GRAHN; PEREIRA, BERGAMASCHI, 2000; GAUGRIS; GRAHN, 2006; MENDLOWICZ MAULLER; GRAHN; MACHADO CARDOSO, 2009; GRAHN et al., 2013) A regional gap is recorded during the latest early Emsian and the earliest late Emsian, as a result from the Andean Pre-Cordillera epeirogenesis (GRAHN et al., 2013). The Ponta Grossa sits on the Furnas Formation. Regards its lithology it is composed of black shales to light gray, dark mudstones massive or laminated siltstones and, interspersed with sandy layers or sand lenses, with wave ripples or hummocky cross-stratification (GRAHN et al., 2013), and trace fossils. Deposits of marine shoreface to offshore in transgressive context characterize this unit, since the contact the Furnas Formation (BERGAMASCHI; PEREIRA, 2001). The São Domingos Formation is positioned stratigraphically above the Ponta Grossa Formation. The São Domingos Formation is composed of mudstones, shales, siltstones, sandstones and conglomeratic sandstones. These rocks record marine deposits of the inner and outer shelf.

Figure 1: Geological map of the study area.




BOSETTI et al. (2010, mod.).

## SYSTEMATIC PALEONTOLOGY

We analyzed 957 samples and about 3,500 discinoid specimens. The fossils are currently deposited at the Laboratório de Paleontologia e Estratigrafia, Departamento de Geociências, Universidade de Ponta Grossa (DEGEO- UEPG). For the systematic analyzes and the use of the morphological terms, we used the works of Mergl & Massa (2005) and Mergl (2006).

Order Lingulida Waagen, 1885
Superfamily Discinoidea Gray, 1840
Family Discinidae Gray, 1840
Genus *Gigadiscina* Mergl; Massa, 2005

***Type species. -*** *Gigadiscina lessardi* Mergl; Massa, 2005

***Gigadiscina collis*** (Clarke, 1913)
Fig. 2.1-2.2

1913 *Orbiculoidea collis*, Clarke, p. 306, pl. 25, figs 23−26.
1925 *Orbiculoidea* (*Roemerella*) cf. *collis*, Reed, p. 36, pl. 4, fig. 9a.
1971 *Orbiculoidea collis*, Mendez-Alzola; Sprechmann, p. 517-525.
1985 *Orbiculoidea collis*, Melo, p. 59−60, fig. 5−8.
1991 *Orbiculoidea collis*, Figueiras, p. 57 – 64.

2001 *Orbiculoidea* sp. cf. *Orbiculoidea collis,* Boucot et al*.,* p. 113-114, fig. 5.
2005 *Gigadiscina collis*, Mergl; Massa, p. 400, fig. 2.
2010 *Gigadiscina collis*, Comniskey; Bosetti, p. 31.
2011 *Orbiculoidea collis*, Comniskey, p. 49-52, fig. 1 – 2.
2011 *Gigadiscina collis*, Lech, p. 07-16.
2013 *Gigadiscina collis*, Zabini; Comniskey, Bosetti, p. 43-58.
2016 *Gigadiscina collis* Silva; Comniskey, Scheffler, p. 85-86.

**Material.** MPI 97, 698, 1623, 3021, 5001, 5005, 5555, 5767, 5871, 5781, 5976, 6145 and 6148.

**Diagnosis.** Characterized by large and sub-triangular shell. Covered by fine regular concentric rugellae. Dorsal valve highly concave and ventral valve is flat. Pedicle tube is very short.

**Description.** The shell is sub-triangular in outline; large, with the length measures 60 mm and width 50 mm. They are approximately 30 rugellae per specimen. The rugellae are separated by interspaces about 1 to 3 mm distance between each rugellae. There are 7 to 9 rugellae per 5 mm in the anterior part of the shell. The thickness of rugellae is 1 mm in the dorsal and ventral valves. The rugellae are smoother on the dorsal valve in comparison to the ventral valves. Attachments of the adductor scars can be present.

The dorsal valve (Fig. 2.2) is high, strongly convex and sub-conical. Apex is strongly acuminate and pointed towards the posterior margin; prominent beak is present. The posterior region declines gently towards the anterior region and forms an angle of 35**0** to the commissural plane. The anterior slope is slightly concave.

The ventral valve is flat (Fig. 2.1), with its apical region elevated. The pedicle notch is closed and weakly defined, and occupies 26% the length of the shell (occupying one thirds of the posterior slope). Concentric and very fine rugellae, with interspaces of 1 mm. The posterior slope is slightly convex to flat. Anterior slope is slightly concave.

**Remarks.** *O. collis* was first described and proposed by Clarke (1913). *Orbiculoidea* has reduced size, thick and low rugellae, slightly elevated dorsal valve, and slightly inclined apex. Sub-circular outline is flat, ventral valve has a long pedicle notch. Biconvex shell is present. The taxonomic analysis of Clarke's (1913) type material showed that *O. collis* is strikingly different in comparison with other *Orbiculoidea* species. *O. collis* has fine and tall rugellae, conical and convex dorsal valve, sub-central apex, sub-triangular outline and a flat ventral valve. Mergl; Massa's (2005) description of the species is consistent with the samples studied here. *O. collis* is a species that departs, in a morphological sense, from the original description of the genus. The analysis of the Paraná Basin fossil material afforded the reallocation from *O. collis* to *Gigadiscina collis*, proposed by Mergl; Massa (2005).

The species *O. grandissima* Kozlowski, 1913, is apparently, the same species addressed by Clarke (1913). However, we have not reviewed Kozlowski's (1913) original fossil material and, for this reason, we chose to maintain this as a valid species, until a revision is made possible. Boucot et al. (2001) records *O. collis* for the Devonian strata of the Parecis Basin.

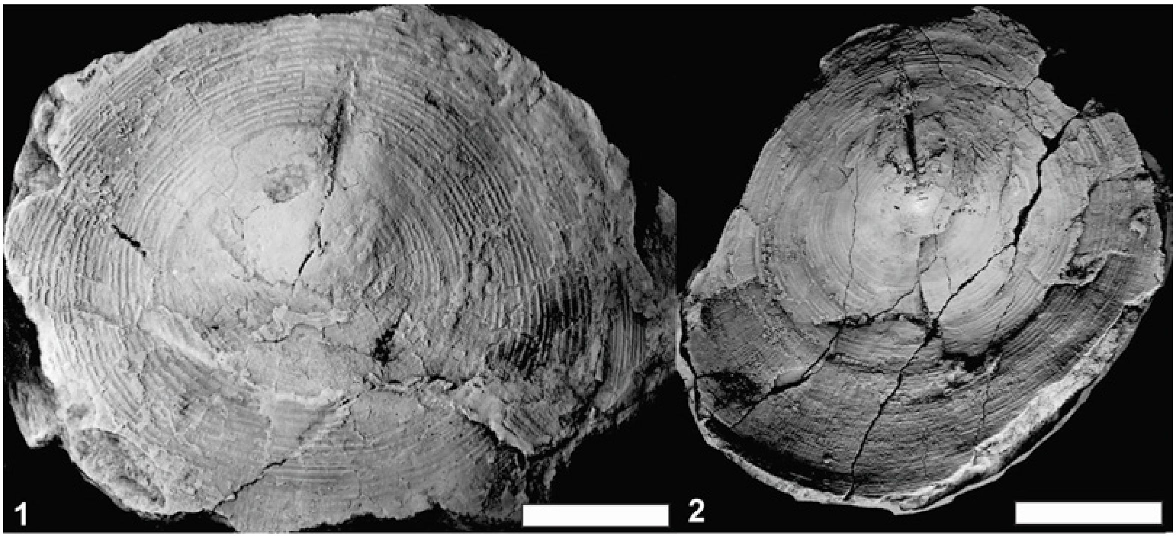
Lech (2011) does the review of the species *O. saltensis* Reed (in Du Toit, 1927), for the Carboniferous of Argentina. In the paper, the author recognizes that the *O. Collis* described for the lower Paleozoic of South America was re-assigned to the genus *Gigadiscina* (MERGL; MASSA, 2005).

Silva; Comniskey, Scheffler (2016) describe some discinoids for the Devonian of Mato Grosso do Sul, Paraná Basin, including the occurrence of *G. collis*, expanding its geographic range in Brazil.

**Geographic and stratigraphic provenance.** Brazil (Ponta Grossa and at the base of the São Domingos formations, Apucarana sub-Basin, Mato Grosso do Sul, Alto Garças sub-Basin and Morro Vermelho, Parecis Basin (BOUCOT et al., 2001)), South Africa (REED, 1925). Latest Pragian to Emsian.

**Outcrops.** Boa Vista, Caça e Pesca and Jaguariaíva.

Figure 2: ***Gigadiscina collis.*** 1, ventral valve, external mould, MPI 5005. 2, dorsal valve, external mould, MPI 5555.




Genus *Orbiculoidea* D' Orbigny, 1847

***Type species***. - *Orbicula forbesii* Davidson, 1848

***Orbiculoidea bainii*** Sharpe, 1856
Fig. 3.3-4, 4.5

1846 *Orbicula sp*., Morris; Sharpe, pp. 277.
1856 *Orbicula bainii*, Sharpe, p. 210, pl. 26, figs. 20 – 23.
1893 *Discina baini*, von Ammon, p. 359-360, fig. 4.
1903 *Orbiculoidea baini,* Reed, p.168, pl. 20, figs. 4 -5.
1913 *Orbiculoidea baini*, Clarke, p. 301, pl. 25, figs. 5 – 15.
1913 *Orbiculoidea baini*, Kozlowski, p. 8-108, pl. 1, figs. 11-13.
1925 *Orbiculoidea (Roemerella) baini*, Reed, p. 36 – 38.
1954 *Orbiculoidea baini*, Lange, p.33.
1967 *Orbiculoidea baini*, Davila; Rodriguez, p. 921-935.
1971 *Orbiculoidea baini*, Mendez-Alzola; Sprechmann, p. 517-525.

1985 *Orbiculoidea baini*, Melo, p. 48-57, fig. 1 – 2.
1991 *Orbiculoidea baini*, Figueiras, p. 57 – 64.
2001 *Orbiculoidea falklandensis*, Boucot et al., p. 111, pl. 2, figs. 1-17.
2011 *Orbiculoidea baini*, Comniskey, p. 54-58, pl. 4 – 7.
2013 *Orbiculoidea baini*, Zabini; Comniskey, Bosetti, p. 43-58.
2016 *Orbiculoidea baini*, Comniskey; Bosetti, Horodyski, p. 55-64.
2016 *Orbiculoidea baini*, Carbonaro; Ghilardi, p. 135-149, fig.6.

**Material.** MPI 635, 1728, 1837, 5025 - 5028, 5218, 5705, 5755, 5921, 5945 and 5975.

**Diagnose.** Shell circular to sub-circular outline, small, fine, regular and well-marked rugellae, pedicle large and expressive. Spaced regularly with small shallow interspaces. The pedicle is long and robust.

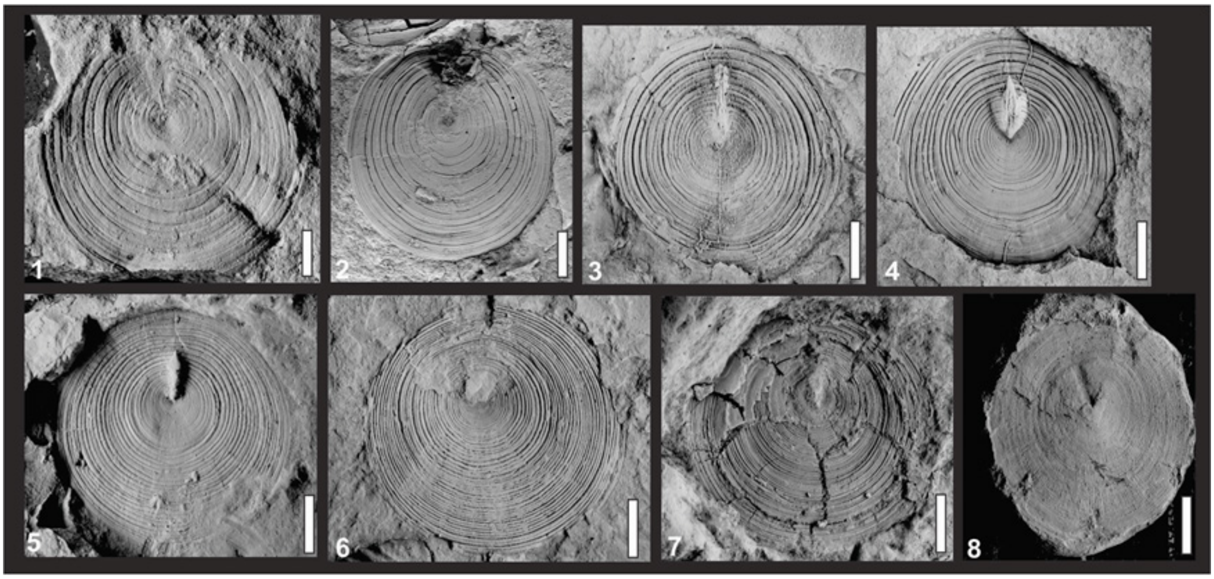
**Description.** The shell has a circular to sub-circular, with width varying from 10 to 29 mm. The rugellae are concentric and separated by interspaces with 0.4 to 0.9 mm of distance between each rugellae. The thickness of rugellae is 0.5 mm. There are approximately 24 rugellae per specimen. There are 8 to 10 rugellae per 10 mm in the anterior part of the shell. The dorsal valve is lightly concave. The apex of the dorsal valve (Fig. 4.5) is slightly shifted towards the posterior slope. On the internal mold, rugellae are almost imperceptible, though spaced regularly with small interspaces. On the external mold the rugellae are more pronounced and spaced regularly with small shallow interspaces. The posterior slope is slightly convex and forms an angle of 80**0** to the commissural plane. The anterior slope is weakly concave. The ventral valve is flat, (Fig. 3.3, 4) with marked concentric rugellae with wide interspaces. The pedicle opens behind the apical region and has half of its length (occupies 50% of the shell). A callosity is observed at the beginning of the pedicle in some specimens. The posterior and anterior slope is plan.

**Remarks.** *O. bainii* differs from *O. bodenbenderi* and *O. excentrica* in having noticeable rugellae and larger interspaces. Another difference is the circular shell outline and smaller dimensions of *O. bainii*. The pedicle notch has a greater size and it is robust, occupying half the valve diameter. *O. bodenbenderi* has a smaller notch, which is restricted to the valve apex. In *O. excentrica* the pedicle notch does not extend to half of the valve diameter. The species *O. bainii* differs from *O. saltensis* Reed, 1927 to present rugellae strongly marked, large interspaces, pedicle notch is robust and occupying half the valve diameter and the dorsal valve is less concave and less high than *O. saltensis*. *O. bainii* also differs from *Orbiculoidea falklandensis* Rowell, 1965 by presenting a low dorsal valve; the apex in *O. bainii* is more subcentral than in *O. falklandensis* and the rugellae are thicker in *O. bainii.* Unlike to Lech (2011), the present authors do not accept the allocation of the species for the *Gigadiscina* genus. All specimens analyzed in the Paraná Basin, showed smaller of shell if compared to *Gigadiscina* (MERGL; MASSA, 2005) and the specimen *O. bainii* have the pedicle track higher than the representatives of the genus *Gigadiscina do*. The dorsal valve is less concave and the dorsal apex is more central in *O. bainii* than in *Gigadiscina.* The anterior slope in *Gigadiscina* it is almost double the posterior slope, whereas in *O. bainii* the anterior and posterior slope having substantially the same size.

**Geographic and stratigraphic provenance**. Brazil (Ponta Grossa and São Domingos formations, Apucarana Sub-Basin; Unit 4, Alto Garças Sub-Basin; Morro Vermelho, Parecis Basin (BOUCOT et al., 2001), South Africa (REED, 1925), Argentina (MENDEZ-ALZOLA; SPRECHMANN, 1971), Bolivia (DAVILA; RODRIGUEZ, 1967), Uruguay (FIGUEIRAS, 1991) and Falkland Islands (CLARKE, 1913). Latest Pragian to early Givetian.

**Outcrops.** Ponta Grossa city - Boa Vista, Vendrami, Desvio Ribas - Tibagi, Caça e Pesca, Fazenda Rivadávia, Curva I, Curva II, Vila Francelina, Pilão de Pedra and Vila Vilela; Jaguariaíva city - railroad outcrop Jaguariaíva-Arapoti, Tibagi city - Tibagi II, Furnas/Ponta Grossa contact, Sítio Wolff, Fazenda Fazendinha, Km 211, Km 217 and Km 220, of the BR 153 highway, and Fazenda Zezito, and Palmeira city - Rio Caniú.

Figure 3: ***Rugadiscina stagona*** *sp. n.,* ***1-2****, ventral valve, external mould, MPI 6104 and ventral valve, external mould, MPI 10881.* ***Orbiculoidea bainii, 3-4****, ventral valve, external mould, MPI 5705 and ventral valve, external mould, MPI 1728.* ***Orbiculoidea excentrica, 5-6****, ventral valve, external mould, MPI 5762 and dorsal valve, MPI 10882.* ***Orbiculoidea bodenbenderi, 7-8****, ventral valve, internal mould, MPI 6125 and ventral valve, internal mould, MPI 5485.*




***Orbiculoidea bodenbenderi*** Clarke, 1913
Fig. 3.6-3.7, 4.3

1913 *Orbiculoidea bodenbenderi*, Clarke, p. 306, pl. 25, figs. 16-22.
1954 *Orbiculoidea bodenbenderi*, Lange, p. 41.
1985 *Orbiculoidea bodenbenderi*, Melo, p. 58, figs. 3-4.
1991 *Orbiculoidea bodenbenderi*, Figueiras, p. 57 – 64.
2011 *Orbiculoidea bodenbenderi*, Comniskey, p. 59-62, pl. 8-10.
2013 *Orbiculoidea bodenbenderi*, Zabini; Comniskey, Bosetti, p. 43-58.
2016 *Orbiculoidea bodenbenderi* Silva; Comniskey, Scheffler, p. 85-86.

**Material.** MPI 639, 5122, 5123, 5274, 5317, 5861, 5485, 5755, 5758, 5759, 6125, 10148.

**Diagnose.** Shell is sub-circular. The rugellae are smooth, concentric and elevated. The interspaces are small. The dorsal valve is slightly elevated and the ventral valve is planar. The pedicle notch is short and fine.

**Description.** Shell outline is sub-circular with a thinning at posterior margin. The shell is large, with the length 25 mm and width 25 mm. The rugellae (thickness is about 0.4 mm) are smooth, concentric, slightly elevated, and spaced regularly with occasional irregular spacing and small interspaces. The thickness of interspaces measures from 0.3 to 0.6 mm. There are approximately 23 to 43 rugellae per specimen or there are found 12 to 15 rugellae per 5 mm in the anteromedian part of the shell. The dorsal valve is slightly elevated and conical, and has a subcentral apex nearer to the posterior margin. The posterior slope is slightly convex and forms an angle of 75**0** to the commissural plane. The posterior slope is weakly convex and the anterior slope is concave. The ventral valve is planar (Fig. 3.6-3.7). The ventral apex is subcentral. At the ventral valve, the rugellae are very neat and elevated. The pedicle notch is small (Fig. 4.3). The pedicle track occupies 29% of length of the shell (about one third of the shell).

**Remarks.** The shell is regularly spaced concentric and clearly elevated rugellae with no differences in either valve is the feature that distinguishes *O. bodenbenderi* from *O. bainii*. In adult specimens of *O. bodenbenderi*, the pedicle track is very short and small, and restricted to the apex. It differs from the other species, which have larger pedicle notches that occupy half of the shell's total length. *O. bodenbenderi* differs from *O. saltensis* and *O. falklandensis* for presenting their rugellae and interspaces with smaller thickness, a short pedicle track and a sub-central apex. Lech (2011) proposes the allocation of *O. bainii* and *O. bodenbenderi* to *Gigadiscina baini* and *Gigadiscina bodenbenderi,* however, after reviewing *O. bodenbenderi* and *O. baini* specimens of the Paraná Basin, the present authors don't accept such allocation genus, because was verified differences that don't allow the allocation for *Gigadiscina*, such as: the dorsal valves in *O. bainii* and *O. bodenbenderi* are lower than in representatives of the genus *Gigadiscina.* The apex in *O. bodenbenderi* is slightly concave and turned the posterior slope, whereas in *Gigadiscina* the apex is strongly concave. The pedicle track in *O. bodenbenderi* is short and narrow, while in *Gigadiscina* the pedicle track is larger, occupying 35% of length of the shell. The species *O. bainii* and *O. bodenbenderi* cannot be allocated to the genus *Gigadiscina*, as commented by Lech (2011). The representatives of the genus *Gigadiscina* differ from the genus *Orbiculoidea* by presenting convex-planar shell, large size and short and fine pedicle track.

**Geographic and stratigraphic provenance**. Brazil (Paraná, Apucarana sub-Basin and Mato Grosso do Sul, Alto Garças sub-Basin), Uruguay (FIGUEIRAS, 1991) and Falkland Islands (CLARKE, 1913). Latest Pragian to early Eifelian.

**Outcrops.** Ponta Grossa city - Boa Vista, Vendrami, Desvio Ribas, Fazenda Rivadávia, Curva I and Curva II, Jaguariaíva city - railroad outcrop Jaguariaíva-Arapoti, Tibagi city - Km 211and Km 220, of the BR 153 highway, and Fazenda Zezito.

***Orbiculoidea excentrica*** Lange, 1943
Fig. 3.5-6, 4.1- 2

1943 *Orbiculoidea excentrica*, Lange, p.223, pl. 17, p. 1.
1954 *Orbiculoidea excentrica*, Lange, p. 41-81.
1985 *Orbiculoidea excentrica*, Melo, p. 61, p. 1.
2011 *Orbiculoidea excentrica*, Comniskey, p. 63-65, pl. 11.
2013 *Orbiculoidea excentrica*, Zabini; Comniskey, Bosetti, p. 43-58.
2016 *Orbiculoidea excentrica*, Comniskey; Bosetti; Horodyski, p. 55-64.
2016 *Orbiculoidea excentrica*, Carbonaro; Ghilardi, p. 135-149, fig.6.

**Material.** MPI 631, 5317, 5762, 6007 and 10882.

**Diagnose.** Show a shell sub-circular and a flat profile. The dorsal valve is slightly elevated; apex towards the posterior margin. The pedicle notch begins nearer to the posterior margin and it is very short, smooth and thin.

**Description.** The shell has a sub-circular outline and a flat lateral profile. The shell has a maximum of 20 mm of width and 21 mm of length. There are approximately 36 rugellae per specimen. The rugellae thickness is about 0.5 mm. The rugellae are separated by interspaces with 0.1 to 0.2 mm distance between each rugellae. There are 10 to 15 rugellae per 5 mm in the anteromedian part of the shell. The dorsal valve is slightly elevated; apex towards the posterior margin and beak is more prominent than the other species (Fig. 4.1- 4.2). This species presents a greater apex displacement, which makes the shell more elongated throughout the anterior region. External and internal molds have irregularly spaced growth lines and small interspaces. The anterior region is somewhat inclined, and there is a site with a greater number of rugellae. The posterior slope also presents a slight inclination towards the beak. The posterior slope is slightly convex and forms an angle of 62**0** to the commissural plane. The ventral valve is flat. The pedicle notch begins nearer to the posterior margin and it is very short, smooth and thin (Fig. 3.5-3.6). The proximal portion of the notch sometimes displays a callosity. The pedicle track occupies 16% of the length of the shell. The anterior and posterior slope is plan.

**Remarks.** Lange (1943) described this new species from only one available ventral valve. The species was recorded at the transitional beds of the lower Ponta Grossa Formation (PETRI, 1948). The region that surrounds the pedicle notch is a little depressed. Distinct but irregularly spaced rugellae ornament the shell. The rugellae are bifurcate near the anterior region. Interspaces are small at the posterior region and relatively large at the anterior region. The pedicle track is completely closed, relatively short, and restricted to the apical region. According to Lange (1943), similarities between *O. excentrica* and *O. bainii* appear only at the younger stages until the rugellae bifurcation appears; from this stage, onwards the *O. excentrica* shell differs in being extremely irregular. The dorsi-ventral compression is a common taphonomic signature in discinoids; in the work, beginning is suspected that *O. excentrica* was a taphonomic artifact of *O. bainii*. Lucas (2001) proposed the term taphotaxon to define taxa that suffer morphological alterations due to taphonomic processes, displaying a distinct morphology formed by diagenetic processes. However, this is not the case with *O. excentrica*, as the characteristics observed by Lange (1943) are evident in a series of samples from several stratigraphic levels, and in several ontogenetic phases. *O. excentrica* differs from other discinoid species cited herein especially by its rugellae disposition, which are fewer in the posterior margin in *O. excentrica* but constant in numbers throughout their shells in other species. The shell outline is also different when compared to the other species: it has a more acuminated posterior margin than the anterior. The species *O. excentrica* differs from *O. saltensis* and *O. falklandensis* for possessing a shell more elongate and has the pedicle track shorter and more close to the posterior margin than *O. saltensis*. The dorsal valve in *O. excentrica* is more conspicuous and its apex is sub-central. Another notable feature is the rugellae in *O. excentrica* being closer together at the posterior margin, with a smaller interspace between them.

**Geographic and stratigraphic provenance**. Brazil (Ponta Grossa and São Domingos formations, Apucarana sub-Basin; Goiás and Mato Grosso do Sul (SILVA; COMNISKEY, SCHEFFLER (2016, 2017), Alto Garças sub-Basin). Latest Pragian to early Givetian.

Genus *Rugadiscina* Mergl, 2006

***Type species***. – *Orbicula rugata* Sowerby, 1839

***Rugadiscina stagona*** sp.n.
Figure 3.1-2, 4.4

2012 *Rugadiscina* sp. Comniskey; Bosetti, p. 27.
2013 *Rugadiscina* sp., Zabini; Comniskey, Bosetti, p. 43-58.
2016 *Rugadiscina* sp., Comniskey; Bosetti, Horodyski, p. 55-64.
2016 *Rugadiscina* sp. Silva; Comniskey, Scheffler, p. 85-86.
2017 *Rugadiscina* sp. Silva; Comniskey, Scheffler, p. 318.

***Derivation of name***. Tear drop = in latim, *stagona*.

**Material.** Holotype - MPI 6162; Paratype - MPI 5122, 5730, 6163, 6104 and 10881.

**Diagnosis.** Presents the shell convexoplane. Rugellae and interspaces are large. Dorsal valve is oval and ventral valve is circular. The apex is small and conspicuous. Pedicle track is fine.

**Description.** Convexoplane outline. The shell has a maximum of length of 29 mm and 30 mm of width. They are approximately 18 to 20 rugellae per specimen. The rugellae thickness is about 0.8 mm. The rugellae are separated by interspaces with 0.8 to 1.8 mm distance between each rugellae. There are 6 to 8 rugellae per 5 mm in the anteromedian part of the shell. Dorsal valves are oval with very closely rugellae and small and shallow interspaces. The apex is small, conspicuous, and faces the posterior region (Fig. 4.3). No external dorsal valve molds were found. Ventral valves have a circular outline; rugellae and interspaces are broadly separated (Fig. 3.1). The pedicle track is thin and occupies about 20% of the length of the shell. All of the above-cited features exclude these specimens from *Orbiculoidea* and justify assignment to a separate genus.

**Remarks.** Until the end of this work, few examples of Rugadiscina are known for the Brazilian Devonian. The representatives of the genus *Rugadiscina* differ from the genus

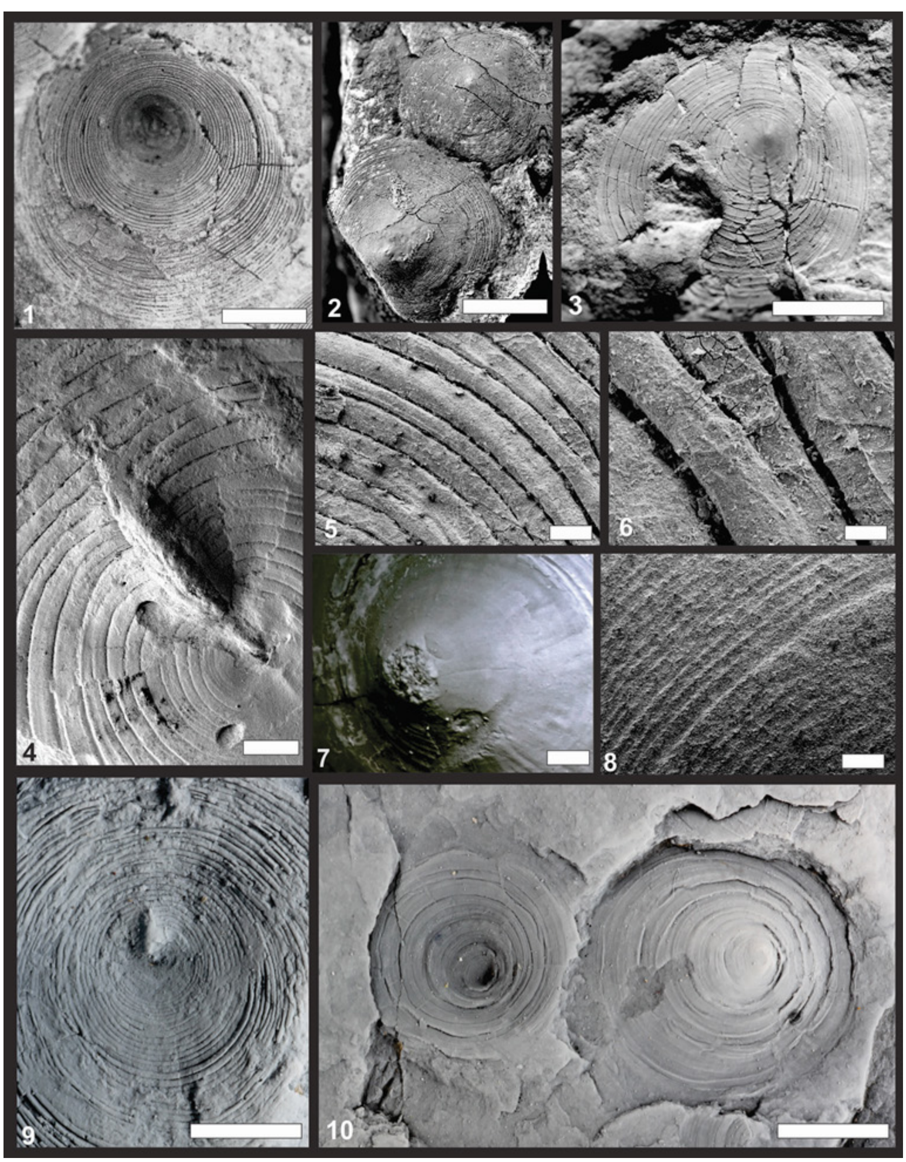
*Orbiculoidea* because the contour is almost circular with a uniformly curved margin, a long pedicle track with a narrower listrium, and a slightly asymmetrical ventral valve, and ornamentation in pieces (MERGL, 2006). All of the above-cited features exclude these specimens from *Orbiculoidea* and justify assignment to a separate genus.

The first record of the genus *Rugadiscina* for the Brazilian Devonian strata occurred with the work of Comniskey; Bosetti (2012) with few examples occurring in the city of Tibagi, Paraná. After this, the works of Zabini; Comniskey, Bosetti (2013) and Comniskey; Bosetti, Horodyski (2016) report the occurrence of more specimens, but for the same region. Only with the works of Silva; Comniskey, Scheffler (2016, 2017), they register the genus *Rugadiscina* for the State of Mato Grosso do Sul (Brazil), with this increasing the geographic range of the genus in Brazil

**Geographic and stratigraphic occurrence**. Brazil (Ponta Grossa formations, Apucarana sub-Basin and Mato Grosso do Sul (SILVA; COMNISKEY, SCHEFFLER (2016, 2017), Alto Garças sub-Basin) and Silurian, England (MERGL, 2006). Silurian to Early Emsian.

**Outcrops.** Tibagi city - Fazenda Fazendinha.

Figure 4: ***Orbiculoidea excentrica, 1***, *dorsal valve, internal mould, MPI 5945.* ***Orbiculoidea bodenbenderi, 2, 7-9***, *dorsal valve, external mould, MPI 10148; apex of the dorsal valve, MPI 5755; rugellae with scale of 500 μm; ventral valve, MPI 5122.* ***Rugadiscina stagona*** *sp n.*, **3**, *dorsal valve, internal mould, MPI 5759.* ***Orbiculoidea bainii, 4-6***, 10, *robust pedicle in O. baini; rugellae with scale of 200 μm; rugellae with scale of 500 μm and dorsal valve, MPI 5345.*



## STRATIGRAPHY AND PALEOGEOGRAPHICAL DISTRIBUTION OF DISCINOIDS OF THE MALVINOKAFFRIC REALM

*Orbiculoidea* had a wide geographical distribution during the Brazilian Devonian, being recorded in the Paraná, Parecis, Amazonas and Parnaíba Basins (CLARKE, 1913; LANGE, 1943; MELO, 1988; BOUCOT et al., 2001). *Gigadiscina* (= *O. collis sensu* CLARKE, 1913; LANGE, 1954; MELO, 1988; BOUCOT et al., 2001) however, was only recorded in the Paraná and Parecis Basins. *Rugadiscina* was only recorded in the Paraná Basin.

According to the field data and recent relative dating of the outcrops (see GRAHN et al., 2010, 2013; BOSETTI et al., 2011, 2012; ZABINI; BOSETTI; HOLZ, 2010), it was possible to determine the discinoid stratigraphic distribution at the deposition areas during the Devonian (Figure 5).

The five discinoids species (*O. bainii*, *O. bodenbenderi*, *O. excentrica*, *G. collis,* and *Rugadiscina stagona*) were analyzed in relation to their relative abundance and stratigraphic range based on the field data. The prospected outcrops were correlated to each other based on surface data published by Bergamaschi (1999), Bosetti et al., (2011, 2012) and Grahn et al., (2010, 2013). The relative abundance degrees (great abundance, low abundance and disappearing of the fossil records) were established with the total number of each specimen found and can be visualized in the Figure 5.

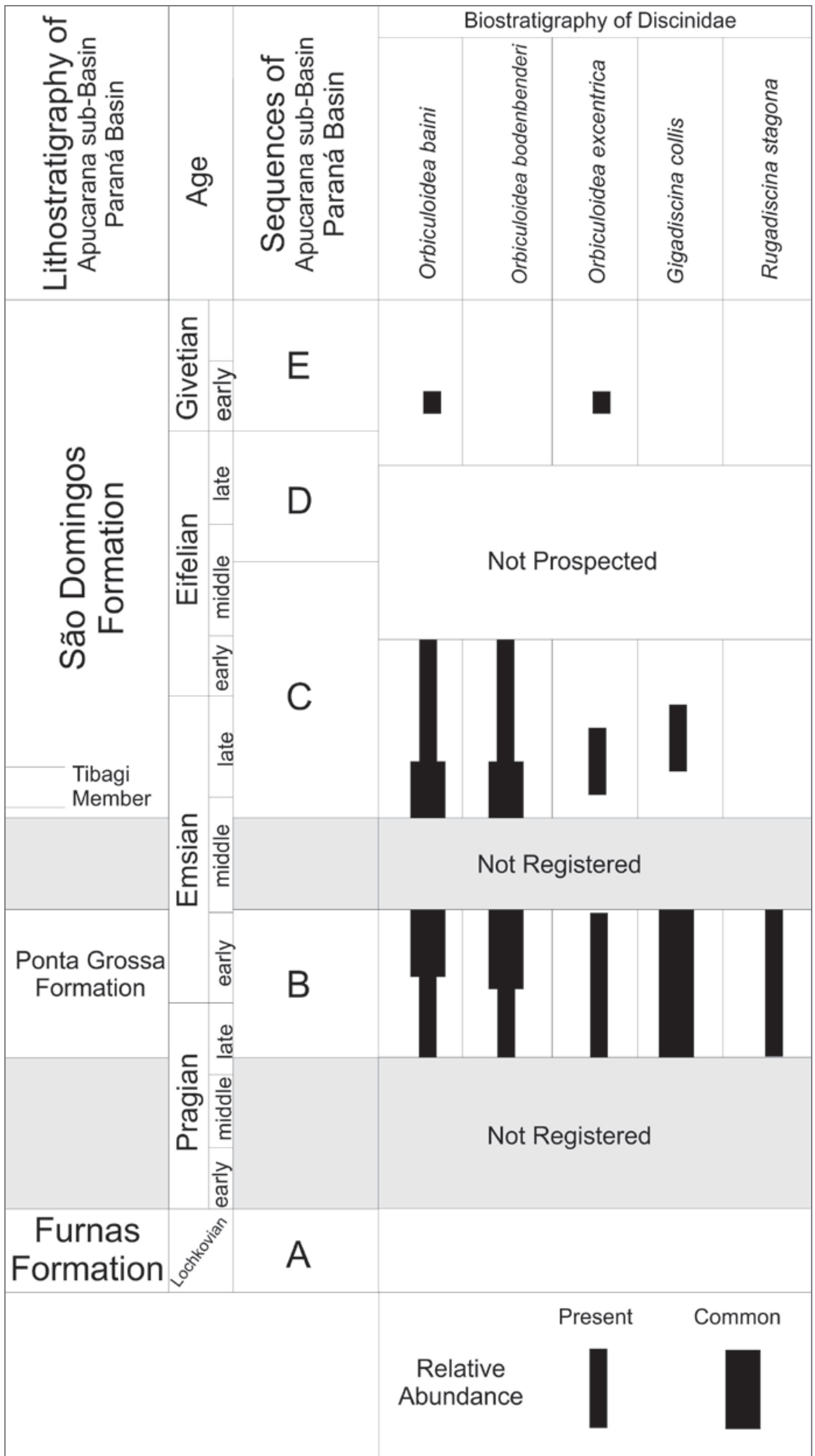
*O. bainii* and *O. excentrica* are the species that have the widest biostratigraphic distribution. They range from the latest Pragian until the early Givetian. The species *O. bainii* is extremely abundant in all the studied stages and regions, independent from their lithology. In comparison with *O. bainii*, *O. excentrica* is rare. Until now *O. excentrica* has not been found in early Eifelian strata, but since it was recorded in early Givetian time, its absence from Eifelian beds must be a taphonomic bias.

The species *G. collis* was recorded in the latest Pragian – late Emsian interval. *Orbiculoidea bodenbenderi* occurred in the latest Pragian to early Eifelian. *Rugadiscina stagona* occurred at only one locality (latest Pragian – Emsian). The five discinoids species occurred at the same locality during the same period, associated with the other invertebrates of the paleofauna that comprised the Malvinokaffric Realm during the Early Devonian (BOSETTI et al., 2012; HORODYSKI, 2014). From the late Emsian, the discinoids began to decline in terms of distribution and abundance. The species *O. bodenbenderi*, *G. collis* and *R. stagona* disappeared from the fossil record together with other very common Malvinokaffric representatives (see BOSETTI et al., 2012). The early Eifelian is marked by the decline in diversity of all the faunal elements that were common during the previous stages (*sensu* MELO, 1988; BOSETTI et al., 2010a, 2010b, 2012; HORODYSKI et al., 2014); it caused the Eifelian/Givetian transition Kačák Event (HOUSE, 2002) diagnosed by Horodyski et al. (2014) in the Paraná Basin. This is confirmed by the discinoid record, which declined in species number from this stage on. In the boundary Eifelian/Givetian outcrops, only *O. bainii* and *O. bodenbenderi* are recorded, but in smaller numbers than in the underlying beds.

The stratigraphic distribution analysis was based on Bergamaschi and Pereira (2001), Bosetti et al. (2012), Grahn et al. (2013), and Horodyski et al. (2014). At the latest Pragian

– early Emsian, a major discinoid domain of the group is recorded, which is represented by their abundance and the paleobiodiversity climax of all the Malvinokaffric fauna (*sensu* BOSETTI et al. 2012). During the Eifelian/Givetian interval, discinoids were rare and only *O. excentrica*, *O. bodenbenderi* and *O. bainii* are recorded. This low discinoid abundance is justified by the decline of all Malvinokaffric fauna (*cf.* BOSETTI et al., 2012; HORODYSKI et al., 2014).

Figure 5: Stratigraphic distribution of Devonian discinoids, of the Apucarana sub-Basin, Paraná Basin, Brazil. For geological setting information of the Paraná Basin, see Grahn et al. (2013).



## CONCLUSIONS

It was adopted the reallocation of *Orbiculoidea collis* to *Gigadiscina collis.* Lange's (1943) species. *O. excentrica,* regardless of being proposed based only on one valve and not being cited in any other paper until now, does not represent a taphotaxon. *G. collis*, *O. bainii*, *O. excentrica*, *O. bodenbenderi*, and *Rugadiscina stagona* represent the Devonian discinoids from the Paraná Basin. Devonian discinoids from the Paraná Basin, Paraná state, are considered epibenthonic and sessile. They can occur isolated (*G. collis* and *O. bodenbenderi*) or in clusters (*O. bainii, O. bodenbenderi* and *O. excentrica*).

The five-discinoid species lived at the same region, during the late Pragian to early Emsian, associated with other invertebrates; this characterizes the climax of the Malvinokaffric Realm during Lower Devonian. *Orbiculoidea bainii* and *O. excentrica* had the widest stratigraphic distribution. They occurred from the late Pragian to early Givetian. *O. bainii* had the widest paleogeographic distribution, occurring in Brazil, South Africa, Argentina, Bolivia, Uruguay, and Falkland Islands. The species *O. excentrica* is the least common species. *O. bodenbenderi* is the second in abundance and occurrence. It occurred during the late Pragian and disappeared at the early Emsian, before the Middle Devonian Kačák Event. From the late Emsian, the discinoid fauna began to decline in terms of abundance and distribution, and *Gigadiscina collis* disappeared from the paleontological record along with other Malvinokaffric representatives.

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