

A GUIDE TO FOSSILIFEROUS OUTCROPS FROM THE DEVONIAN OF MATO GROSSO DO SUL, CENTRAL-WEST BRAZIL

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Abstract

Mato Grosso do Sul has a significant area with Devonian outcrops containing fossils mainly of marine invertebrates, plants and, more rarely, fish fragments of the climax and impoverished Malvinoxhosan (= Malvinokaffric) fauna. Despite this, for a long time the state had a lack in studies related to the Devonian paleontology of the Paraná Basin, only gaining prominence from the 2010s onwards. Therefore, the objective of this work is to present a guide of the fossiliferous Devonian outcrops recognized so far in the state, which are located in the municipalities of Rio Negro, Rio Verde de Mato Grosso, Coxim and Pedro Gomes. The outcrops presented here represent a true geopaleontological heritage in situ. Divulge them is vital not only for their preservation, but also for the dissemination and appreciation of paleontological science among society in general.

Keywords: Malvinoxhosan fauna, Paleozoic, Paraná Basin, geopaleontologic heritage.

1. Introduction

The Devonian of the Paraná Basin and its fossiliferous content has been known since the mid-19th century, however most research has focused on

the state of Paraná (southern Brazil) with the Central-West Brazilian region being neglected for a long time (see Sedorko et al., 2021 and references therein for

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Devonian occurrences of paleoinvertebrates from Paraná, Mato Grosso do Sul, Mato Grosso and Goiás states and see Scheffler et al., 2020 for research history in the northwest border).

Smith (1883) pioneered the collection of fossils in central-western Brazil, more specifically in Chapada dos Guimarães (Mato Grosso) which were later studied by Derby (1890). Another noteworthy work from the 19th century in relation to paleontology is due to Ammon (1893) who studied specimens collected by Peter Vogel in the surroundings of Lagoinha, also in Chapada dos Guimarães, Mato Grosso (Vogel, 1893). Since then, works on the Devonian of the Central-West region has focused on the faunal diversity of Mato Grosso State, especially in Chapada dos Guimarães (e.g., Oliveira, 1915; Roxo, 1937; Erichsen and Lofgreen, 1940; Quadros, 1979, 1981, 1987; Quadros and Melo, 1989; Bosetti and Quadros, 1996; Caminha et al., 2021).

Studies in the Devonian of Mato Grosso do Sul are more recent and scarcer. Devonian rocks from this state were only recognized in the 1940s, with their fossils first cited by Caster (1947a, b). In the 20th century, only two papers focused on a more refined description including illustrations of Devonian macroinvertebrate fossils from Mato Grosso do Sul (Boucot and Caster, 1984; Carvalho et al., 1987), while the others only cited the occurrence of fossils without further details (e.g., Almeida, 1948, 1954; Del'Arco et al., 1982; Souza Jr. et al., 1987; Amaral Filho et al., 1989). Finally, Becker-Kerber et al. (2017) proposed a diagenetic model based on fossils found in Rio Verde de Mato Grosso (Mato Grosso do Sul).

Recent fieldwork has shown, however, that contrary to what was previously believed (e.g., CPRM, 2004;

Lacerda Filho et al., 2006; Scheffler et al., 2010) the Devonian strata are much more expressive in Mato Grosso do Sul (see Scheffler et al., 2020). Most of these outcrops have fossils of the typical Malvinohosan (= Malvinokaffric, sensu Penn-Clarke and Harper, 2021) fauna, which reached its apex between the late Pragian and early Emsian and was adapted to shallow, relatively cold seas with large contribution of terrigenous sediment in parts of Brazil (central-south), Argentina, Malvinas (= Falklands) Islands, Uruguay, Paraguay, Bolivia, southern Peru, South Africa and Antarctica (Melo, 1985, 1988; Isaacson and Sablock, 1988; Presser et al., 2004; Bosetti et al., 2012; Torsvik and Cocks, 2013; Boucot et al., 2013).

Two outcrops also have elements of the impoverished Malvinohosan fauna, post-early Emsian, which are useful in seeking to understand the causes that led to the extinction of several taxa along the Devonian in the Paraná Basin (Bosetti et al., 2012; Sedorko et al., 2018a; Gonçalves et al., 2018; Videira-Santos et al., 2020; Silva et al., 2021; Souza et al., 2022).

Therefore, the objective of the present work is to disclose the fossiliferous Devonian outcrops recognized so far in Mato Grosso do Sul.

2. Geological Setting

The Paraná Basin is one of the largest intracratonic basins in South America, covering parts of Argentina, Paraguay, Uruguay and south-central Brazil, corresponding to an area of about 1,500,000 km² (Melo, 1988; Grahn, 1992; Milani et al., 2007).

In Brazil, the Devonian of the Paraná Basin outcrops in the states of Paraná, Goiás, Mato Grosso and Mato Grosso do Sul. Although traditionally the

Paraná Basin is divided in the Devonian into two sub-basins, Alto Garças (northwest border - Goiás, Mato Grosso and Mato Grosso do Sul) and Apucarana (east border - Paraná) (Northfleet et al., 1969; Ramos, 1970), more recent studies have indicated that the Paraná Basin was not completely compartmentalized until at least the Emsian (~ 400 Ma), although the environment in the northwest border is generally shallower than in the east border (e.g., Grahn et al., 2010a; Sedorko et al., 2018a; Scheffler et al., 2020).

Grahn et al. (2010a) proposed dividing the Devonian of the northwest border of the Paraná Basin into units 1, 2, 3 and 4 of the Chapada Group, but in this study, we chose to follow the nomenclature used for the eastern border, proposed by Grahn et al. (2013), since works on biostratigraphy with microfossils (e.g., Mendlowicz Mauller, 2007, Mendlowicz Mauller et al., 2009; Grahn et al., 2013) mitigated the scarce knowledge of the stratigraphic correlation between the northwest and east borders of the Paraná Basin (see Scheffler et al., 2020). According to Grahn et al. (2013) the Devonian of the Paraná Basin is divided into the Furnas, Ponta Grossa and São Domingos formations.

The Furnas Formation can be divided into three units: lower, middle and upper. The lower unit consists of sandstones and conglomerates deposited in an alluvial coastal plain environment. The medium unit is constituted by sandstones of marine origin interspersed with pelites. The upper unit is constituted by residual

deposits of pebbles and sandstones deposited in a shallow continental shelf environment dominated by tides (Assine, 1999). The age of this formation is between Llandovery and Lochkovian according to Sedorko et al. (2017) and references therein.

The Ponta Grossa Formation was deposited in a marine environment ranging from shoreface to offshore (Assine, 1996; Grahn et al., 2013; Sedorko et al., 2018b, c). In this formation there are records of the Malvinohosan climax fauna and most of the fossiliferous Devonian outcrops in Mato Grosso do Sul are representing this formation. According to Grahn et al. (2013), the most basal portions of the Ponta Grossa Formation are represented by sandstones, siltstones, sandy shales, calcareous nodules and sandy claystones. The uppermost portion is constituted by shales rich in pyrite and organic matter. This formation has an age between the late Pragian and the early Emsian, according to Grahn et al. (2010b).

Finally, the São Domingos Formation is also completely marine encompassing foreshore to offshore environments (Grahn et al., 2013; Sedorko et al., 2018b). In lithological terms this formation is constituted by poorly selected conglomerates and micaceous siltstones rich in plant fragments. In this formation there are records of impoverished Malvinohosan fauna (Bosetti et al., 2010, 2012; Sedorko et al., 2021) and its age is between the late Emsian and Frasnian (Melo and Loboziak, 2003; Grahn et al., 2013).

3. Field Trip Logistics

Mato Grosso do Sul is a Brazilian state located in the Central-West region. The fossiliferous Devonian outcrops are

distributed in the municipalities of Rio Negro, Rio Verde de Mato Grosso, Coxim and Pedro Gomes, all located in

the north-central portion of the state. The main air access is through the Campo Grande International Airport, located in the homonymous city, state capital. From Campo Grande, the main access roads to regions with Devonian outcrops are through MS-080, BR-163 and MS-418 (figure 1). The nearest fossiliferous town of Campo Grande, Rio Negro, is around 155 km away, while the furthest, Pedro Gomes, is around 310 km away. Some outcrops located along the Taquari River, in Coxim, are only accessible throughout water.

Mato Grosso do Sul is known worldwide for its natural beauty, especially the Pantanal biome. Cities with Devonian outcrops are outside the main tourist hub of the state, but still offer services that meet the demand of travelers.

Rio Negro, being a smaller city, has a more restricted offer of accommodation and food places that are located mainly on Avenida Brasil, in the downtown. Rio Verde de Mato Grosso, on the other hand, has a greater offer of accommodation and food places, mainly in the regions close to BR-163, as well as Coxim, which has different types of accommodation and food places in its urban region, especially close to Avenida Virgínia Ferreira and Rua Filinto Müller, where you will find hotels with leisure areas on the Taquari River (fishing tourism). Finally, to access the outcrops in Pedro Gomes, it is preferable to stay in Coxim because they are relatively close cities and Coxim has better infrastructure and services.

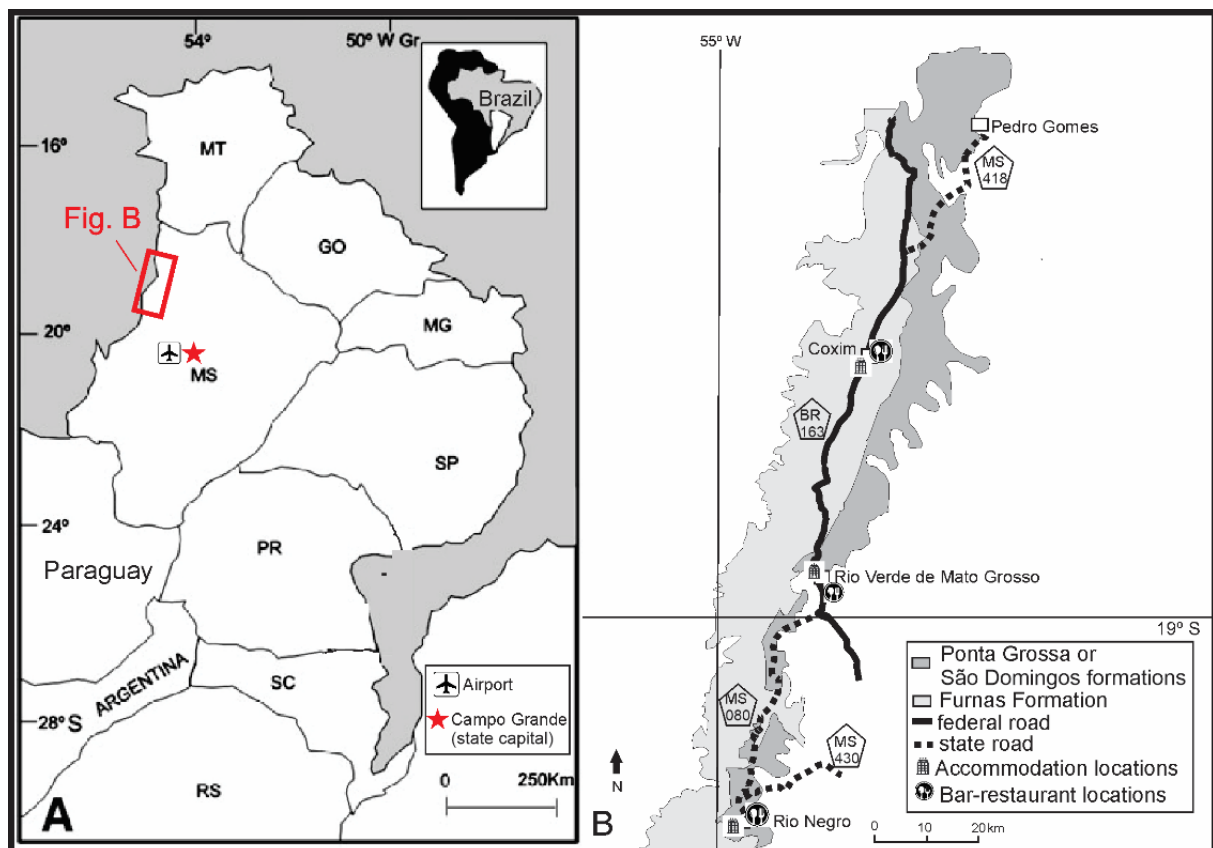


Figure 1: Map of the region with Devonian fossiliferous outcrops in the state of Mato Grosso do Sul (adapted from CPRM, 2006; Grahn et al., 2013; Scheffler et al., 2020).

It is recommended that field work on outcrops located along the Taquari River should be carried out by more restricted groups due to logistical issues of access. On the other hand, outcrops located on the side of the roads or inside quarries can have larger groups, provided that the basic safety rules to be followed in any type of fieldwork are always observed and, additionally, in the

4. Outcrops

Most of the fossils found in the Devonian outcrops of Mato Grosso do Sul are represented by invertebrates, plant fragments and rare fish fragments.

case of quarries, must have prior authorization. The best period for fieldwork in the state is in its dry season, which occurs between June to mid-October. Opting for works on the river, the best time is the end of this period, when the level of the river is very low. It is possible to arrange boats and pilots by talking to the riverside dwellers.

Most outcrops are aged between late Pragian and early Emsian, but there are two outcrops of more recent ages: MS 70 – Corredeira da Benedita, Taquari River (Givetian) and MS 46b – Fazenda Torrão de Ouro (Frasnian), the latter the only outcrop of Frasnian age in the entire Paraná Basin (Table 1, Figures 2, 3 and 4).



Figure 2: Devonian outcrops in Mato Grosso do Sul. a – MS 18 (Estrada da Ponte Nova, Rio Negro), b – MS 30 (Barreiro da Figueira, Rio Verde de Mato Grosso), c – MS 70 (Corredeira da Benedita, Coxim), d – MS 46b (Fazenda Torrão de Ouro, Pedro Gomes), e – MS 14 (Estância Nhecolândia, Rio Negro), f – MS 58 (Pedro Gomes), g – MS 82 (Rio Negro), h – MS 72 (Coxim).

Table 1: Devonian outcrops containing fossils in Mato Grosso do Sul (adapted from Scheffler et al., 2020; Sedorko et al., 2021).

City	Formation	Toponymy	Coordinates	Lithology	Occurrences
Rio Negro	Ponta Grossa	MS 08 – MS-080 highway cut	19°28'21.13" S; 54°59'33.80" W	Fine micaceous sandstones with horizontal lamination and, at the base, fine sandstones without evident structure, both covered by conglomerates with clasts of these lithologies	Brachiopoda
Rio Negro	Ponta Grossa	MS 11 – MS-340 highway cut	19°27'52.74" S; 54°59'12.95" W	Fine silty and micaceous sandstones with horizontal lamination, convoluted laminations, wavy marks with NW-SE orientation.	Trace fossils
Rio Negro	Ponta Grossa	MS 13 – MS-080 highway cut	19°24'51.84" S; 54°59'0.90" W	Medium to fine silty sandstones and siltstones with horizontal lamination. More massive towards the top.	Trace fossils, Mollusca, Brachiopoda, plant fragments

Rio Negro	Ponta Grossa	MS 14 – MS-080 road cut, Estância Nhecolândia	19°24'41.91" S; 54°58'59.92" W	Fine to medium massive to laminated sandstones, tabular to lenticular, laminated sandy siltstones.	Trace fossils, Tentaculitoid ea, Brachiopoda, Trilobita, Mollusca, Echinodermata, <i>Conularia</i> sp., <i>Serpulites</i> sp.
Rio Negro	Ponta Grossa	MS 15 – MS-430 highway cut	19°22'12.54" S; 54°57'29.80" W	Fine to medium laminated sandstones, with ripples.	Trace fossils, Tentaculitoid ea, Brachiopoda
Rio Negro	Ponta Grossa	MS 17 – Cut of MS-080, near the junction with MS-430	19°23'21.62" S; 54°58'47.41" W	Fine sandstones with fine horizontal lamination and symmetrical ripples with SW-NE orientation (40-50°).	Trace fossils
Rio Negro	Ponta Grossa	MS 18 – Estrada Ponte Nova	19°26'16.37" S; 55° 0'2.41"W	Fine to medium micaceous sandstones, yellowish to purplish, with horizontal lamination, claystones and shales. Symmetric ripples occur.	Trace fossils, Mollusca, <i>Conularia</i> sp., Brachiopoda Echinodermata, Ostracoda, Tentaculitida, plant fragments
Rio Negro	Ponta Grossa	MS 19 – Estrada Ponte Nova	19°26'10.50" S; 55° 0'17.86"W	Sandy siltstones and fine laminated sandstones, sometimes	Trace fossils, Brachiopoda, Mollusca, <i>Conularia</i> sp., plant fragments

				tabular. Fine to medium micaceous sandstones, yellowish to purplish, with horizontal lamination, claystones and shales. Symmetric ripples occur.	
Rio Negro	Ponta Grossa	MS 20 – Road cut and bridge over river on the MS-080 highway	19°21'38.56" S; 54°59'35.39" W	Sandy siltstones and claystones at the base grading to massive sandstones at the top.	Trace fossils, Brachiopoda
Rio Negro	Ponta Grossa	MS22 – cut on the MS-080 highway on the bank of a stream	19°18'18.35" S; 54°58'4.38"W	Massive fine to medium yellowish to pinkish and purple friable sandstones but harder layers also occur.	Trace fossils
Rio Negro	Ponta Grossa	MS 80 – MS-080 highway, near the village	19°11'18.77" S; 54°55'33.79" W	Fine to medium yellowish sandstones, angular, well sorted, friable.	Trace fossils
Rio Negro	Ponta Grossa	MS 81 – Rio Negro, passing by the farm	19°24'53.27" S; 55° 0'22.84"W	Very fine to fine, silty and laminated sandstones, moderately	Trace fossils, Brachiopoda

				to well selected.	
Rio Negro	Furnas/Ponta Grossa	MS 82 – Rio Negro, upstream of MS 81	19°25'3.22"S; 55° 0'21.32"W	Moderately selected, sub-angular, very fine to medium sandstones; very fine to fine silty and tabular sandstones	Trace fossils
Rio Negro	Ponta Grossa	MS 102 – MS-80 road bridge, km 87, over Salu stream	19°16'35.09" S; 54°57'21.55" W	Medium silty sandstones.	Trace fossils
Rio Verde de Mato Grosso	Ponta Grossa	MS 24 – Section of BR-163 at the entrance to Rio Verde de Mato Grosso	18°55'55.49" S; 54°49'52.43" W	Fine sandstones, siltstones and claystones, massive to laminated and dark shales; Symmetric ripples and hummocky structures also occur.	Trace fossils, Brachiopoda, Trilobite
Rio Verde de Mato Grosso	Ponta Grossa	MS 26 – mining front of Cerâmica Campo Grande, Rio Verde mining company	18°56'18.25" S; 54°50'8.11"W	Siltstone and claystone, massive to laminated, greyish	Trace fossils, Brachiopoda, Tentaculitoid ea, Trilobite, Echinodermata
Rio Verde de Mato Grosso	Ponta Grossa	MS 27 – Cerâmica Campo Grande, Rio Verde mining company	18°56'24.06" S; 54°50'8.83"W	Tabular, massive to laminated, grayish to yellowish sandstones	Trace fossils, Brachiopoda, Trilobite, Mollusca, <i>Conularia</i> sp.,

				and siltstones.	Tentaculitoid ea
Rio Verde de Mato Grosso	Ponta Grossa	MS 28 – West mining front at Cerâmica Campo Grande	18°56'23.65" S; 54°50'12.98" W	Fine sandstones with hummocky structures, clayey siltstones, claystones.	Trace fossils, Brachiopoda
Rio Verde de Mato Grosso	Ponta Grossa	MS 29 – Pedreira Fênix	18°55'43.23" S; 54°50'19.68" W	Fine sandstones with hummocky structures, clayey siltstones, claystones, shales.	Trace fossils, Brachiopoda, Trilobite
Rio Verde de Mato Grosso	Ponta Grossa	MS 30 – Barreiro da Figueira	18°55'11.27" S; 54°48'51.64" W	Fine sandstones, siltstones, sandy siltstones, clayey siltstones, shales.	Trace fossils, Brachiopoda, Trilobite
Rio Verde de Mato Grosso	Ponta Grossa	MS32 – Old quarry of the Figueira mining company	18°50'14.61" S; 54°46'32.46" W	Alternating layers of siltstones and claystones, tabular to lenticular sandstones.	Trace fossils, Mollusca, Brachiopoda
Rio Verde de Mato Grosso	Ponta Grossa	MS 34 – Residual soil of Ponta Grossa Formation on a side road	18°48'47.98" S; 54°44'5.58"W	Soil with rock residues: fine to medium sandstones and ferruginous concretions.	Trace fossils?

Rio Verde de Mato Grosso	Ponta Grossa	MS 75 – Dirt road Rio Verde – Rio Negro	19° 0'41.12"S; 54°51'55.19" W	Very fine to fine sandstones, silty, well selected, heavily altered, with clasts.	Trace fossils?
Rio Verde de Mato Grosso	Ponta Grossa	MS 76 – Dirt road Rio Verde – Rio Negro, MS-080	19° 2'2.76"S; 54°53'8.20"W	Very fine to medium sandstones, poorly selected, massive.	Trace fossils, Brachiopoda
Rio Verde de Mato Grosso	Ponta Grossa	MS 78 – Stream on the dirt road Rio Verde – Rio Negro, MS-080	19° 8'6.39"S; 54°55'25.85" W	Finely laminated sandy siltstones, very fine to fine silty and laminated sandstones, well selected, with wave lamination.	Trace fossils, plant fragments
Rio Verde de Mato Grosso	Ponta Grossa	Serra da Boa Sentença	MS 24 or between MS 24 (18°55'55.49" S; 54°49'52.43" W) and MS 25 (18°57'31.62" S; 54°49'43.01" W)	Shales, siltstones and fine grained sandstones (see Boucot and Caster (1984))	Brachiopoda
Coxim	Ponta Grossa	MS 39 – Quarry of mining company Rio Verde in Coxim	18°28'8.20"S; 54°35'51.14" W	Claystones, siltstones, small lenses of fine to medium sandstone.	Trace fossils, Brachiopoda
Coxim	Ponta Grossa	MS 40 – Tijopiso	18°27'55.43" S;	Claystones, tabular	Trace fossils

		Ceramic Quarry	54°35'54.02" W	siltstones, small lenses of fine to medium sandstone, fine reddish sandstones.	
Coxim	Ponta Grossa	MS 42 – Lajedo next to Taquari River, Palmeiras Waterfall	18°21'48.77" S; 54°36'40.59" W	Very fine to fine massive to laminated sandstones, with clasts or clayey intercalations.	Trace fossils, <i>Conularia</i> sp., Brachiopoda
Coxim	Ponta Grossa	MS 50 – bridge on the Pedro Gomes – Coxim dirt road, Olho d'Água stream	18°21'49.70" S; 54°36'44.64" W	Very fine to fine, micaceous, subangular, massive to horizontal sandstones.	Trace fossils
Coxim	Ponta Grossa	MS 51 – Palmeiras Waterfall, Taquari River	18°21'49.70" S; 54°36'44.64" W	Very fine to fine sandstones, sometimes silty, micaceous, subangular, massive to horizontal.	Trace fossils, Brachiopoda
Coxim	Ponta Grossa	MS 52 – Stream that flows into the Taquari River	18°22'12.34" S; 54°37'48.82" W	Micaceous and laminated sandy siltstones.	Brachiopoda
Coxim	Ponta Grossa	MS 53 – Downstream of the Corredeira Sabão, Taquari River	18°22'55.35" S; 54°37'50.62" W	Sandstone siltstones and well-stratified horizontal sandstones	Trace fossils

Coxim	Ponta Grossa	MS 54 – Residual islet in the middle of the Corredeira Sabão, Taquari River	18°23'1.11"S; 54°37'50.79" W	Very fine, subangular, massive to horizontal sandstones and shales. Ripple marks occur.	Trace fossils, Mollusca
Coxim	Ponta Grossa	MS55 – Bank of the Taquari River, Cabo de Aço farm	18°24'48.78" S; 54°38'14.67" W	Sandy and clayey siltstones, claystone, horizontal lamination.	Trace fossils, plant fragments
Coxim	Ponta Grossa	MS 56 – Bank of the Taquari River, after the Corredeira Cabo de Aço	18°25'22.61" S; 54°38'12.90" W	Sandy siltstones followed by shales.	Trace fossils
Coxim	Ponta Grossa	MS 57 – Taquari River, Corredeira Sumidor	18°28'41.95" S; 54°39'46.64" W	Low stratified silty sandstones, horizontal, very fine sandstone levels with symmetrical ripples.	Trace fossils, Brachiopoda, Echinodermata
Coxim	Ponta Grossa	MS 65 – Taquari River above Palmeiras Waterfall, Corredeira Caeté	18°18'31.06" S; 54°36'30.60" W	Very fine to fine sandstones, subangular, well selected, incipient horizontal lamination.	Trace fossils, Brachiopoda, Mollusca, Porifera, Crustacea, Echinodermata?, <i>Conularia</i> sp., Conodonts, fish?, plant fragments
Coxim	Ponta Grossa	MS 66 – Taquari	18°14'48.59" S;	Very fine to fine	Trace fossils

		River, corredeira Cachoeirão	54°34'49.61" W	sandstones, silty, subangular, well selected, with horizontal lamination.	
Coxim	Ponta Grossa	MS 67 – <i>Rugadiscina</i> point	18°14'46.65" S; 54°34'44.92" W	Very fine to fine sandstones, silty, subangular, well selected, with horizontal lamination.	Trace fossils, Brachiopoda, <i>Conularia</i> sp.,
Coxim	Ponta Grossa	MS 68 – 150 meters upstream of MS 67, Taquari River	18°14'32.88" S; 54°34'35.85" W	Very fine subangular sandstones, very well to well selected, with little evident horizontal lamination.	Trace fossils, Brachiopoda, Mollusca, Echinodermata, plant fragments
Coxim	Ponta Grossa	MS 69 – stream upstream of the Corredeira Cachoeirão, Taquari River	18°14'11.36" S; 54°34'3.89" W	Very fine to fine sandstones, silty, subangular, well selected, with little evident horizontal lamination.	Trace fossils
Coxim	São Domingos	MS 70 – Corredeira Benedita, Taquari River	18°12'59.21" S; 54°33'22.32" W	Very fine to fine sandstones, sometimes silty, subangular to angular, well	Trace fossils, Brachiopoda, plant fragments

				selected, with little evident horizontal lamination. Sandy siltstones at the base.	
Coxim	Ponta Grossa	MS 72 – point above Palmeiras Waterfall, Taquari River	18°21'36.03" S; 54°36'17.22" W	Shales with sandy lenses, very fine to fine siltstones and sandstones, silty, subangular to angular, well sorted, with horizontal lamination	Trace fossils, Brachiopoda, plant fragments
Coxim	Ponta Grossa	MS 95 – road to fazenda Torrão de Ouro	18°17'26.50" S; 54°37'17.75" W	Very fine to fine, silty and micaceous sandstones.	Trace fossils, plant fragments
Coxim	Ponta Grossa	MS 96 – Córrego da Figueira, Taquari River	18°25'19.30" S; 54°38'10.02" W	Silty claystones with horizontal lamination.	Plant fragments
Coxim	Ponta Grossa	MS 97 - Taquari River, right bank, upstream of Corredeira Cabo de Aço	18°24'57.09" S; 54°38'8.69" W	Clay siltstones, siltstones and claystones.	Trace fossils, Brachiopoda, plant fragments
Coxim	Ponta Grossa	MS 100 –on the left bank of the Taquari River, 200 m	18°14'21.49" S; 54°34'15.22" W	Fine to medium clayey sandstones, tabular, with	Trace fossils

		downstream from MS 69		small cross bedding.	
Coxim	Ponta Grossa	MS 118 – Side road southeast of Coxim	18°36'11.30" S; 54°38'35.50" W	Very fine to fine sandstones with plane- parallel bedding, sometimes with tabular geometry. Residual pebbles from the Aquidauana Formation	Trace fossils
Pedro Gomes	São Domingos	MS 46b – fazenda Torrão de Ouro	18° 9'52.01"S; 54°29'52.07" W	Shales clear (by weathering), sometimes wavy, grading towards the top to very fine to fine sandstones with hummocky cross- bedding.	Trace fossils, Brachiopoda, plant fragments
Pedro Gomes	Ponta Grossa	MS 58 – Dirt road north of the Sonora- Coxim boundary	17°48'3.32"S; 54°38'21.76" W	Laminated sandy siltstones, very fine to fine sigmoidal to massive sandstones, well selected and subrounded.	Trace fossils
Pedro Gomes	Ponta Grossa	MS 59 – Dirt road north of the Sonora- Coxim	17°49'11.37" S; 54°38'33.91" W	Horizontal claystones, very fine to fine sandstones	Trace fossils, Tentaculitoid ea

		boundary, south of MS 58		laterized on top, forming crusts, well selected and subrounded, very fine to medium poorly selected and subangular sandstones, well laminated sandy siltstones.	
Pedro Gomes	Ponta Grossa	MS 63 – NE exit from Pedro Gomes	18° 4'31.54"S; 54°32'12.27" W	Very fine to fine massive to horizontal sandstones, well sorted and subangled, very fine laminated silty sandstones	Trace fossils
Pedro Gomes	Ponta Grossa	MS 64 – Stream north of Pedro Gomes	17°52'12.13" S; 54°35'10.63" W	Very fine to fine sandstones with cross stratification and horizontal lamination, sometimes silty and micaceous.	Trace fossils
Pedro Gomes	Ponta Grossa	MS 99 – Corredeira da rede de luz	18°13'49.09" S; 54°33'57.27" W	Fine to medium sandstones, sometimes silty.	Brachiopoda



Figure 3: Devonian outcrops in Mato Grosso do Sul. a – MS 75 (Rio Verde de Mato Grosso), MS 65 (Coxim), c – MS 54 (Coxim), d – MS 28 (Rio Verde de Mato Grosso), e – MS 64 (Pedro Gomes), f – MS 39 (Coxim), g – MS 24 (Rio Verde de Mato Grosso), h – MS 19 (Rio Negro).

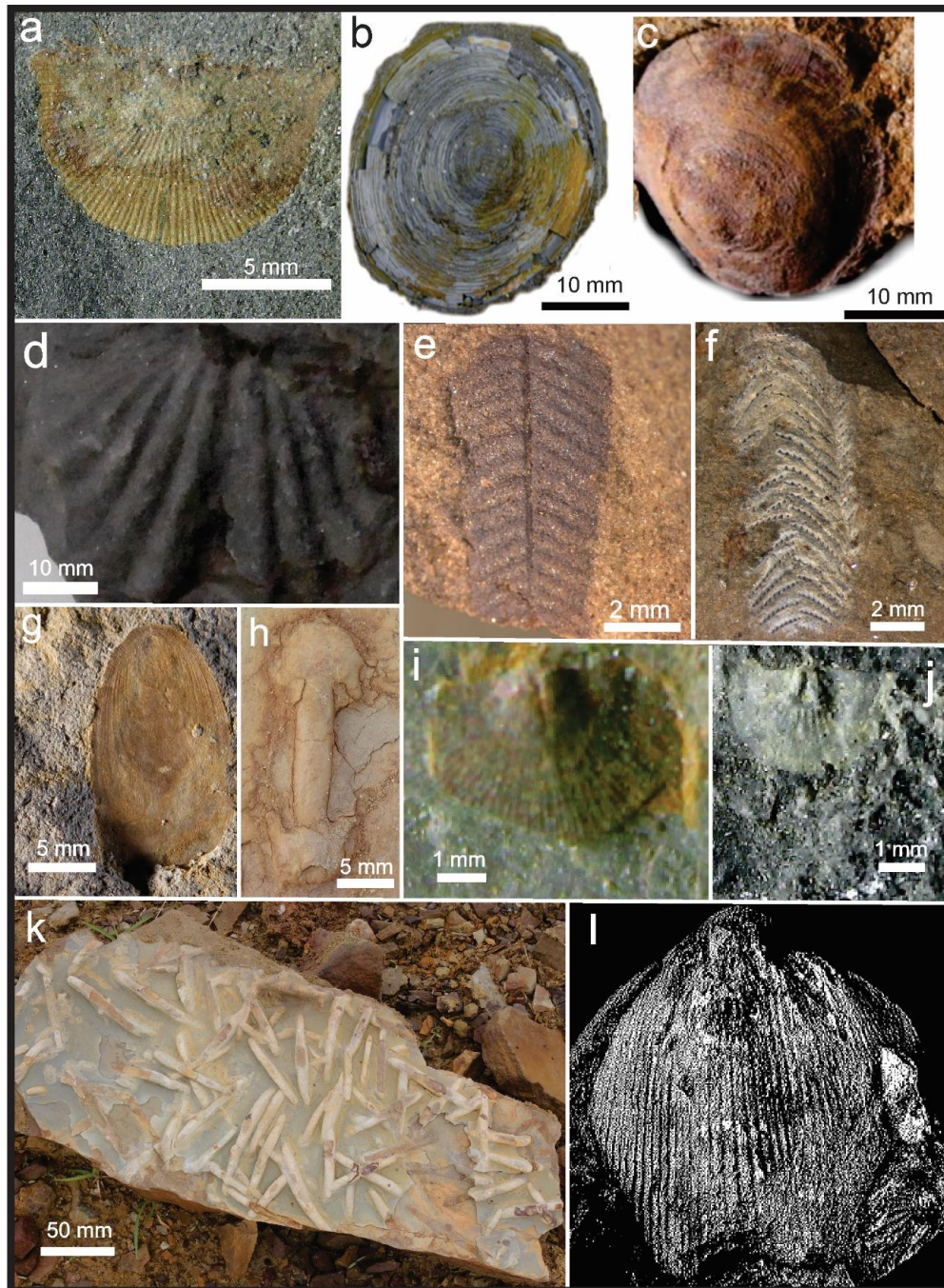


Figure 4: Fossils from Devonian outcrops in Mato Grosso do Sul. a – *Australostrophia mesembria* (Clarke, 1913) (MS 30 – Barreiro da Figueira, adapted from Videira-Santos, 2020), b – *Orbiculoidea excentrica* Lange, 1943 (MS 30 – Barreiro da Figueira or MS 67 – Cachoeirão, adapted from Silva et al., 2021), c – *Rugadiscina* sp. (MS 65 – Corredeira do Caeté or MS 67 – Cachoeirão, adapted from Silva et al., 2021), d – *Australospirifer* sp. (MS 30 – Barreiro da Figueira), e – *Paraconularia ulrichana* (Clarke, 1913) (MS 14), f – *Reticulaconularia* sp. (MS 65 – Corredeira do Caeté), g – Lingulidae indet. (MS 15 – Rodovia MS 430), h - *Bifungites* isp. (MS 46b – Fazenda Torrão de Ouro), i – *Sanjuanetes?* sp. (MS 30 – Barreiro da Figueira, adapted from Videira-Santos et al., 2022), j – *Chonostrophia?* aff. *truyolsae* Racheboeuf, 1992 (MS 30 – Barreiro da Figueira, adapted from Videira-Santos et al., 2022), k – *Planolites* isp. (MS 29 – Pedreira Fênix), l

- *Scaphiocoelia* cf. *S. boliviensis* Whitfield, 1898 (without scale, adapted from Boucot and Caster, 1984).

5. Final Comments

The outcrops presented here represent a true geopaleontological heritage in situ. Disseminating this knowledge not only to the scientific community, but also to the society of Mato Grosso do Sul is of vital importance for its preservation and avoiding destruction, as has already occurred in historical outcrops in other parts of Brazil or practices that make it difficult for researchers to access. It is noteworthy that although it is possible to collect fossils and deposit them in scientific institutions, many paleontological works such as ichnology and taphonomy depend on in situ analysis.

Mato Grosso do Sul represents the area with the highest paleolatitude, currently outcropping, of the Devonian Sea on the northwest border of the Paraná Basin. Therefore, it is of great importance to elucidate issues of geographic distribution of the Malvinohosan Realm and its relations with other existing realms in the Devonian.

We hope, therefore, that this work will encourage more research to be carried out in the Devonian of the state, especially those that address paleontology. It is also expected that such outcrops will serve as teaching material for subjects in the Geology, Biology and Geography courses of universities located, especially in the Brazilian Central-West, being useful even to develop pedagogical activities with students from elementary schools located in the municipalities in the north-central part of Mato Grosso do Sul.

Finally, the outcrops can and should also be used in scientific dissemination

actions with the local population in order to create a feeling of bond with their natural heritage and in this way contribute to the dissemination and appreciation of the paleontological science.

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References

- Almeida, F.F.M., 1948. Contribuição à geologia dos estados de Goiás e Mato Grosso. Notas Preliminares e Estudos, DGM, 46, 1-17.
- Almeida, F.F.M., 1954. Geologia do centro-leste Mato-grossense. Boletim da Divisão de Geologia e Mineralogia, 150, 1-97.

- Amaral Filho, Z.P., 1989. Macrozoneamento Geoambiental do Estado de Mato Grosso do Sul. Campo Grande.
- Ammon, L., 1893. Devonianische Versteinerungen von Lagoinha in Matto Grosso (Brasilien). Z.G.E.B. 28, 1-15.
- Assine, M.L., 1996. Aspectos da estratigrafia das sequencias pré-carboníferas da Bacia do Parana no Brasil. Ph.D. thesis, Universidade de São Paulo.
- Assine, M.L., 1999. Fácies, icnofósseis, paleocorrentes e sistemas deposicionais da formação furnas no flanco sudeste da bacia do paraná. Rev. Bras. de Geoc. 29(3), 357-370.
- Becker-Kerber, B., Osés, G.L., Curado, J.F., Rizzutto, M.A., Rudnitzki, I.D., Romero, G.F., Onary-Alves, S.Y., Benini, V.G., Galante, D., Rodrigues, F., Buck, P.V., Rangel, E.C., Ghilardi, R.P., Pacheco, M.L.A.F., 2017. Geobiological and diagenetic insights from Malvinokaffric Devonian biota (Chapada Group, Paraná Basin, Brazil): Paleobiological and Paleoenvironmental implications. *Palaios* 32, 238-249.
- Bosetti, E.P., Grahn, Y., Horodyski, R.S., Mauller, P.M., 2012. The first recorded decline of the Malvinokaffric Devonian fauna in the Parana Basin (southern Brazil) and its cause; taphonomic and fossil evidences. *J. S. Am. Earth Sci.* 37, 228-241
- Bosetti, E.P., Grahn, Y., Horodyski, R.S., Mauller, P.M., Breuer, P., Zabini, C., 2010. An earliest Givetian "Lilliput Effect" in the Paraná Basin, and the collapse of the Malvinokaffric shelly fauna. *Palaontol. Z.* 85, 49–65.
- Bosetti, E.P., Quadros, R., 1996. Contribuição ao estudo dos Lingulida (Brachiopoda: Inarticulata) da Formação Ponta Grossa, Devoniano da Bacia do Paraná, Município de Chapada dos Guimarães, Mato Grosso, Brasil. In: UEPG-UFPR, Simp. Sul Amer. Sil. -Dev.: estrat. e paleont. 1, Anais, p.167-192.
- Boucot, A.J., Caster, K.E., 1984. First occurrence of Scaphiocoelia (Brachiopoda, Terebratulida) in the Early Devonian of the Paraná Basin, Brazil. *J. Paleontol.* 58(6), 1354-1359.
- Boucot, A.J., Xu, C., Scotese, C.R., Morley, R.J., 2013. Phanerozoic paleoclimate: an atlas of lithologic indicators of climate. SEPM (Society for Sedimentary Geology) concepts in sedimentology and paleontology, 11: Map folio.
- Caminha, S.A.F.S., Ribeiro, V.R., Cruz, D.R.R., Ghilardi, R.P., Neves, A.V.S., D'Apolito, C., 2021. Registros paleontológicos do Paleozoico, in: Kuhn, C.E.S., Santos, F.R.P. (Orgs.), Geoparque Chapada dos Guimarães: uma viagem pela história do planeta. Federação Brasileira de Geólogos-FEBRAGEO and Associação Profissional dos Geólogos do Estado de Mato Grosso – AGEMAT, Cuiabá, pp. 91-96.
- Carvalho, M.G.P., Melo, J.H.G., Quadro, L.P., 1987. Trilobitas Devonianos do flanco noroeste da Bacia do Paraná. In: Congresso Brasileiro de Paleontologia, 10, Anais, p. 36.
- Caster, K.E., 1947a. Expedição Geológica em Goiás e Mato

- Grosso. *Min. Metal.* 12(69), 126-127.
- Caster, K.E., 1947b. Devonian System in Goiás and Mato Grosso, Brazil. (Abstract) *GSA Bulletin* 58, 1172.
- CPRM., 2004. Carta Geológica ao Milionésimo do Brasil. Departamento Nacional de Produção Mineral/Companhia de Pesquisa em Recursos Minerais, CD-ROM, folhas SE. 21 - Corumbá e SF. 21 - Campo Grande.
- CPRM., 2006. Mapa geológico do estado de Mato Grosso do Sul. Serviço Geológico do Brasil, scale 1:1.000.000.
- Del'Arco, J., Silva, R.H., Tarapanoff, I., Freire, F.A., Pereira, L.G.M., Souza, S.L., Luz, D.S., Palmeira, R.C.B., Tassinari, C.C.G., 1982. Geologia. In: Projeto RADAMBRASIL: levantamento de recursos naturais - Folha SE.21, Corumbá 27, 25-160.
- Derby, O.A., 1890. Nota sobre a Geologia e Paleontologia de Matto-Grosso. *Arch. Mus. Nac.* 9, 59-88.
- Erichsen, A.I., Lofgreen, A., 1940. Geologia de Goiaz a Cuiabá. Departamento Nacional de Produção Mineral, Boletim da Divisão de Geologia e Mineralogia 102: 1-40.
- Gonçalves, C.G., Trindade, V., Carvalho, M. A., Araujo, L.R., Scheffler, S.M., 2018. Registro Palinológico Preliminar de Escolécodontes nas Seções Devonianas da Borda Noroeste da Bacia do Paraná, Mato Grosso Do Sul. In: Simpósio Brasileiro de Paleoinvertebrados 4, Anais, p. 87-88.
- Grahn, Y., 1992. Revision of silurian and devonian strata of Brazil, *Palynology* 16(1), 35-61.
- Grahn, Y., Mauller, P.M., Bergamaschi, S., Bosetti, E.P., 2013 Palynology and sequence stratigraphy of three Devonian rock units in the Apucarana Subbasin (Paraná Basin, south Brazil): additional data and correlation. *Rev. Palaeobot. Palynol.* 198, 27-44.
- Grahn, Y., Mauller, P.M., Breuer, P., Bosetti, E.P., Bergamaschi, S., Pereira, E., 2010b. The Furnas/Ponta Grossa contact and the age of the lowermost Ponta Grossa Formation in the Apucarana Sub basin (Paraná Basin, Brazil): integrated palynological age determination. *Rev. Bras. Paleontol.* 13, 89–102.
- Grahn, Y., Mauller, P.M., Pereira, E., Loboziak, S. 2010a. Palynostratigraphy of the Chapada Group and its significance in the Devonian stratigraphy of the Paraná Basin, south Brazil. *J. S. Am. Earth Sci.* 29, 354-370
- Isaacson, P.E., Sablock, P.E. 1988. Devonian System in Bolivia, Peru and Northern Chile, in: McMillan, N.J., Embry, A.F., Glass, D.J. (Eds.), *Devonian of the World: Proceedings of the 2nd International Symposium on the Devonian System*. Canadian Society of Petroleum Geologists, Memoir 14, 719-728.
- Lacerda Filho, J.V., Brito, R.S.C., Silva, M.G., Oliveira, C.C., Moreton, L.C., Martins, E.G., Lopes, R.C., Lima, T.M., Larizzatti, J.H., Valente, C.R., 2006. Geologia e recursos minerais do Estado de Mato Grosso do Sul. Programa Geologia do Brasil (Convênio CPRM/SICME): Integração, Atualização e Difusão de Dados da Geologia do Brasil, Campo Grande.

- Melo, J.H.G., 1985. A Província Malvinocáfrica no Devoniano do Brasil: estado atual dos conhecimentos. M.Sc. dissertation, Universidade Federal do Rio de Janeiro.
- Melo, J.H.G., 1988. The Malvinokaffric Realm in the Devonian of Brazil, in: McMillan N.J., Embry, A.F., Glass, D.J. (Eds.), *Devonian of the World: Proceedings of the 2nd International Symposium on the Devonian System*. Canadian Society of Petroleum Geologists, Memoir 14, 669-703.
- Melo, J.H.G., Loboziak S., 2003. Devonian–Early Carboniferous miospore biostratigraphy of the Amazon Basin, Northern Brazil. *Rev. Palaeobot. Palynol.* 124, 131–202.
- Mendlowicz Muller, P., 2007. Bioestratigrafia do Devoniano da Bacia do Paraná – Brasil com ênfase na Sub-Bacia de Alto Garças. PhD thesis, Universidade do Estado do Rio de Janeiro.
- Mendlowicz Muller, P., Grahn, Y., Cardoso, T.R.M., 2009. Palynostratigraphy from the Lower Devonian of the Paraná Basin, South Brazil, and a revision of contemporary Chitinozoan biozones from Western Gondwana. *Stratigraphy*, 6(4), 313-332.
- Milani, E.J., Melo, J.H.G., Souza, P.A., Fernandes, L.A., França, A.B., 2007. Bacia do Paraná. *Bol. Geociênc. Petrobras* 15(2), 265-287.
- Northfleet, A.A., Medeiros, R.A., Mühlmann H. 1969. Reavaliação dos dados geológicos da Bacia do Paraná. *Bol. Tec. Petrobrás* 12(3), 291-346.
- Oliveira, E.P., 1915. *Geologia: Reconhecimento Geológico do Noroeste de Matto Grosso. Expedição científica Roosevelt-Rondon. Comissão de linhas telegráficas estratégicas de Matto Grosso ao Amazonas*, Rio de Janeiro.
- Penn-Clarke, C.R., Harper, D.A., 2021. Early–Middle Devonian brachiopod provincialism and bioregionalization at high latitude: a case study from southwestern Gondwana. *GSA Bulletin* 133, 819–836.
- Petri, S., 1948. Contribuição ao estudo do Devoniano paranaense. *Boletim da Divisão de Geologia e Mineralogia* 129, 1-125.
- Presser, J.L.B., Buonghermini, E., Amabile, V.O.F., Crossa, V.F., Almada, A.B.B., Lima P.R.Z., Migone, O.O., 2004. Algunos antecedentes paleontológicos de Paraguay. *Bol. Mus. Nac. Hist. Nat. Paraguay* 15, 95–110.
- Quadros, R., 1979. Braquiópodes Devonianos do afloramento Topo de Fita – Chapada dos Guimarães – Mato Grosso – Brasil. M.Sc. dissertation, Universidade Federal do Rio Grande do Sul.
- Quadros, R., 1981. Braquiópodes Devonianos do Afloramento Tope de Fita, Chapada dos Guimarães, Mato Grosso, Brasil. *An. Acad. Bras. Cienc.* 53(4), 767-784.
- Quadros, R., 1987. Paleontologia dos Brachiopoda – Lingulida, Strophomenida, Spiriferida, Terebratulida – Devonianos, da Serra de Atimã e Arredores Mato Grosso - Brasil. Ph.D. thesis, Universidade Federal do Rio Grande do Sul.

- Quadros, R., Melo J.H.G., 1989. Occurrence of *Tropidoleptus carinatus* (Conrad) (Brachiopoda, Orthida) in the northwestern Paraná Basin, Brazil. In: Congresso Brasileiro de Paleontologia, 11, Resumo de Comunicações, p. 21–22.
- Ramos, A.N., 1970. Aspectos paleoestruturais da Bacia do Paraná e sua influência na sedimentação. Bol. Téc. Petrobrás 13 (3-4), 85-93.
- Roxo, M.G.O., 1937. Notas geológicas sobre a chapada de Matto Grosso. Notas Prelim. e Estudos 15, 4-7.
- Sedorko, D., Bosetti, E.P., Ghilardi, R.P., Myszyński Jr., L.J., Silva, R.C., Scheffler, S.M., 2018a. Paleoenvironments of a regressive Devonian section from Paraná Basin (Mato Grosso do Sul state) by integration of ichnologic, taphonomic and sedimentologic analyses. Braz. J. Geol. 48(4), 805-820.
- Sedorko, D., Netto, R.G., Horodyski, R.S., 2018c. A Zoophycos carnival in Devonian beds: paleoecological, paleobiological, sedimentological, and paleobiogeographic insights. Palaeogeogr. Palaeoclimatol. Palaeoecol. 507, 188–200. <https://doi.org/10.1016/j.palaeo.2018.07.016>.
- Sedorko, D., Netto, R.G., Savrda, C.E., 2018b. Ichnology applied to sequence stratigraphic analysis of Siluro-Devonian mud-dominated shelf deposits, Paraná Basin, Brazil. J. S. Am. Earth Sciences 83, 81–95.
- Sedorko, D., Netto, R.G., Savrda, C.E., Assine, M.L., Tognoli, F.M.W., 2017. Chronostratigraphy and environment of Furnas Formation by trace fossil analysis: Calibrating the lower Paleozoic Gondwana realm in the Paraná Basin (Brazil). Palaeogeogr. Palaeoclimatol. Palaeoecol. 487, 307-320.
- Sedorko, D., Netto, R. G., Scheffler, S.M., Horodyski, R.S., Bosetti, E.P., Ghilardi, R. P., Mauller, P.M., Vargas, M.R., Videira-Santos, R., Silva, R.C., Myszyński Jr., L., 2021. Paleoecologic trends of Devonian Malvinokaffric fauna from the Paraná Basin as evidenced by trace fossils. J. S. Am. Earth Sciences 109, 103200.
- Scheffler, S.M., Martins, G.R., Kashimoto, E.M., Oliveira, A.M., 2010. A paleontologia no estado do Mato Grosso do Sul: fósseis e afloramentos conhecidos. Braz. Geograph. J. 1, 65-99.
- Scheffler, S.M., Silva, R. C., Sedorko, D., 2020. O Devoniano no estado do Mato Grosso do Sul, Brasil: nova área de distribuição e presença de típica fauna malvinocáfrica. Estud. Geol. 30(2), 38-76.
- Silva, M.B., Comniskey, J.C., Scheffler, S.M., 2021. The Devonian Discinids of the Northwest Edge of the Paraná Basin (Ponta Grossa Formation, Mato Grosso do Sul), Brazil. Terr@ Plural (UEPG Online), 15, e2117755-22.
- Smith, H.H. 1883. Discovery of Paleozoic rocks in Western Brazil. The American Naturalist, 17(11), 1156-1157.
- Souza, L.B.G., Gonçalves, C.G., Scheffler, S.M., 2022. Análise Preliminar De Escolecodontes do Devoniano da Borda Noroeste da Bacia do Paraná, Mato Grosso do Sul. In: Congresso Brasileiro de Paleontologia 27, Boletim de Resumos, p. 13.

- Souza Jr., J.J., Trindade, C.A.H., Tarapanoff, I., 1987. Macrozoneamento geoambiental do Estado do Mato Grosso do Sul. Relatório Temático de Geologia, Secretaria de Planejamento da Presidência da República, Fundação Instituto Brasileiro de Geografia e Estatística, Convênio IBGE/SEPLAN-MS, Goiânia.
- Torsvik, T. H., Cocks L.R.M., 2013. Gondwana from top to base in space and time. *Gondwana Res.* 24(3-4), 999–1030.
- Videira-Santos, R., 2020. Revisão taxonômica dos Chonetoidea (Brachiopoda) do Devoniano da Bacia do Paraná. M.Sc. dissertation, Universidade Federal do Rio de Janeiro.
- Videira-Santos, R., Scheffler, S.M., Fernandes, A.C.S., 2022. New Occurrences of Malvinokaffric Chonetoidea (Brachiopoda) in the Paraná Basin, Devonian, Brazil. *Rev. Bras. Paleontol.* 25(1), 3-23.
- Videira-Santos, R., Scheffler, S.M., Fernandes, A.C.S.F., Silva, M. B., Gonçalves, C.G., 2020. Primeiras descrições de Chonetoidea (Brachiopoda) do devoniano de Mato Grosso do Sul, borda noroeste da Bacia do Paraná, Brasil. In: Congresso Brasileiro de Zoologia 33, Resumos, p. 394-394.
- Vogel, P., 1893. Viagens a Mato Grosso (1887/88) (Segunda Expedição ao Xingu). Translated by Krähenbühl, M.A., 2010. *Revista de História*, 2(3), 173-205, from the german original: Vogel P. 1893. *Reisen in Mato Grosso 1887/88 (Zweite Schingu-Expedition)*, in: *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 28, D. Reimer, Berlin.