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The Passo das Tropas outcrop complex and the *Dicroidium* Flora in southern Brazil

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Abstract

The *Dicroidium* flora, composed of different genera of fossil plants, has its first records dating back to the Permian, expanded significantly in diversity in the Triassic, occupying several regions of the Gondwanan territory, becoming a biostratigraphic landmark for the Triassic. In Brazil, this paleoflora is found in the sedimentary rocks of the Santa Maria region, state of Rio Grande do Sul, in locations close to the Passo das Tropas Creek, an informal type section of the Passo das Tropas Member, of the Santa Maria Formation. Pioneering studies on the subject in the region began in 1952, at the Passo das Tropas outcrop, which described the first records of the *Dicroidium* flora. Over the years, different outcrops were found in this region, which also revealed this paleoflora, such as: "Dom Antônio Reis" outcrop, "Zenir Aita" outcrop and "Espuma" outcrop, where several paleontological collections were carried out. In addition to plant fossils, fish scales and insect wings were recorded in these outcrops. However, these outcrops were totally or partially buried due to the urbanization process in the city of Santa Maria and its surroundings, making further studies impossible. This article presents a historical and stratigraphic review, compiling the work carried out in the last 70 years on the outcrops of the Passo das Tropas Member and presents a new fossil site, the outcrop called Estância dos Montes. A total of 125 specimens were recovered from the Estância dos Montes outcrop, belonging to *Dicroidium odontopteroides*, D. *zuberi*, D. *lanceolum, Umkomasia* sp., *Pteruchus* sp., *Neocalamites* sp. and seeds. The fossils presented in this work come from a paleontological rescue carried out at the Estância dos Montes outcrop and are currently deposited in the Paleontological Collection of the Laboratório de Estratigrafia e Paleobiologia of the Universidade Federal de Santa Maria. Not only the importance of preserving and protecting fossil sites and their contents is highlighted, but also the uniqueness of these fossils for the valorization of the regional heritage of Santa Maria and the global relevance of adding more data to compress the biota during the Gondwanan Triassic.

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1. Introduction

The *Dicroidium* Flora is a phytoassembly found throughout the Gondwana supercontinent in the Triassic period, composed of several genera, such as *Neocalamites*, *Cladophlebis*, *Tetraptilon*, *Dicroidium*, *Ginkgoites* and *Williamsonia* (Guerra-Sommer et al. 1985; Guerra-Sommer et al; 1999, Da Rosa et al. 2009) and others. These plants play a crucial role as biostratigraphic markers for the Triassic, as they make up a group of plants that had their origins in the Permian, and persisted and diversified after the great extinction that marks the transition to the Mesozoic Era (Kerp et al. 2006).

The studies of the *Dicroidium* Flora in Santa Maria - Brazil began in 1952 by Gordon and Brown at the outcrop known as Passo das Tropas, a place where several fossil records of plants, insects, fish and conchostracans were collected. Over the years, other outcrops were described for the locality and generated important works on geology (Bortoluzzi 1974), or on the description and characterization of the *Dicroidium* Flora (Bortoluzzi 1975; Guerra-Sommer et al. 1985).

Passo das Tropas is the name of a creek that runs southwestwards from the city of Santa Maria, in which some outcrops were found (Gordon and Brown, 1952; Bortoluzzi, 1974). Those rocks proved to be highly fossiliferous, so they were described as part of the Santa Maria Formation, namely the Passo das Tropas Member (PTM) (Andreis et al. 1980). The area described in this contribution represents part of the undescribed type section of PTM (Fig. 1).

The aim of this work is to provide a comprehensive historical context of the fossiliferous outcrops of Passo das Tropas in Santa Maria, due to its paleobiogeographic importance and relevance in the fossil record. Additionally, this research presents a new fossiliferous locality in this geological unit, which contains new records of *Dicroidium* Flora.

2. Material and methods

The present study initiated with a historical compilation of geological and fossiliferous papers in the analyzed area. Those contributions allowed recognizing that different outcrops were prospected along the last 70 years, after the opening of the road to the city of São Sepé, circa 55 km south of Santa Maria. The area was designated as the type section of the Passo das Tropas Member, lower part of the Santa Maria Formation (but see 4. Stratigraphic context), although never formally and fully described. So, here we provide a stratigraphic context for those outcrops, presenting a new finding, namely the Estância dos Montes outcrop which is geologically and paleontologically presented here.

During the years 2020 to 2022, 125 fossil specimens were collected in Estância dos Montes outcrop, corresponding to plant fossils, in a paleontological rescue project related to the construction of a residential project in the area. These fossil plants were collected using paleontological tools such as: hammer, brush, chisel and pickaxe, with stratigraphic control within the geological profile. The outcrop called Estância dos Montes corresponds to part of the construction of a residential project in the area, located at the geographical coordinates 29°44'26.15"S, 53°47'28.61"W.

Regarding the curatorial work, the fossil plants were registered and stored in the Paleontological Collection of the Laboratório de Estratigrafia e Paleobiologia (Stratigraphy and Paleobiology Lab) at the Universidade Federal de Santa Maria, under the acronym UFSM. Numbers range from UFSM12163 to UFSM12286 (12 = paleobotanical collection). They were then mechanically prepared using needles, spatulas and brushes. The samples were analyzed using a SteREO ZEISS Discovery V12 stereomicroscope at the Laboratório de Paleobotânica e Evolução Ambiental (Paleobotany and Environmental Evolution Lab), of Universidade do Vale do Taquari, Univates. Photographs of the frond specimens were taken with camera CANON SX50 HS and processed in Adobe Photoshop, while the photographs of the smaller samples were taken with Canon EOS Rebel T5i using a Sigma DG Macro 105mm 1:2.8 and processed in Adobe Photoshop Lightroom. A morphoanatomical comparison was made with other specimens of the *Dicroidium* Flora, namely the Espuma outcrop (Cenci 2013; Barboni e Dutra 2015), deposited at the paleontological collection of the Museu de História Geológica do Rio Grande do Sul (MUGEO) at the Universidade do Vale do Rio dos Sinos.

3. Historical context

Although the first paleobotanical records for Rio Grande do Sul were made by Friedrich Sellow, between 1823 and 1825 (Marchiori et al. 2018), in relation to the silicified trunks of Mata and São Pedro do Sul, the first references of the genus *Dicroidium* Gothan 1912 for Brazil were carried out by Gordon Jr. and Brown (1952), when there were no Geology schools in the country, and much of the geological research was carried out by foreign researchers. With the aggregation of professors at the Federal University of Rio Grande do Sul, to create the School of Geology, Brazilian researchers began to carry out their research in the national territory. Thus, Irajá Damiani Pinto, in 1956, described a fossil insect for the same location described by Gordon Jr., on the road that connected Santa Maria to São Sepé, close to the Passo das Tropas creek (Pinto 1956). In the same location, another fossil insect was described in 1974, being the only insect records published to date for the Santa Maria Formation (Pinto and Ornellas 1974). In addition to these fossils, fishes (Lima et al. 1984; Perez and Malabarba 2002; Richter and Toledo 2008) and conchostracans (Gallego 1996) were also described.

In 1974, Carlos Alfredo Bortoluzzi carried out a geological survey in the municipality of Santa Maria, finding several fossil outcrops and presenting a geological section (Fig. 2A) (Bortoluzzi 1974). Many of those outcrops were lost, due to urban growth (Da Rosa 2004), namely the "Parque Dom Antônio Reis" and "Escola Zenir Aita". This work allowed the recognition of different plant impressions, in a first work of international relevance (Bortoluzzi 1975), with the description of two forms of *Dicroidium*: *D. odontopteroides* (Morris) Gothan 1912 and *D. zuberi* (Szajnocha) Archangelsky 1968. Subsequently, Margot Guerra-Sommer and various collaborators carried out important work on the *Dicroidium* Flora in southern Brazil, including demonstrating its biostratigraphic importance (e.g. Guerra-Sommer et al 1985; Guerra- Sommer et al 1999 a;b; Guerra-Sommer and Cazzulo-Klepzig, 2000).

After several years without collection records, a new outcrop was discovered near the Passo das Tropas outcrop at the end of the 2000s. It was named the 'Espuma outcrop' because it resulted from the rupture of a sewer gallery, likely mixed with industrial waste, which caused foam to form at the

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site, giving the outcrop its name. On this outcrop, insect wings and insect-plant interactions were recorded (Cenci 2013; Cenci and Adami-Rodrigues 2017), as well as ginkgophytes, ginkgo fertile organs and leaves (Barboni and Dutra 2015) (Fig. 2B). Unfortunately, this outcrop was buried, making further paleontological explorations impossible.

In 2009, the Brazilian Commission of Geological and Paleontological Sites (SIGEP) proposed the preservation of the Passo das Tropas outcrop, with online dissemination (Da Rosa et al. 2009), and subsequent printed publication (Da Rosa et al. 2013). This proposition was based on a map of the fossiliferous sites of Santa Maria, produced in 2000 (Da Rosa 2004), and later incorporated into the thematic map of the Santa Maria Urban Development Master Plan, in its initial version. This thematic map allowed the Municipality of Santa Maria to control and monitor existing fossil sites in the urban area, and promote their preservation through environmental licensing of residential and industrial enterprises.

To summarize the historical context of the geological and paleontological information of the Passo das Tropas area, we provide a graphical summary (Fig. 3).

4. Stratigraphic context

The stratigraphic framework of the Paraná Basin was defined in the beginning of the 20th century, with the report on the coal basins of southern Brazil (White 1908), the result of which became internationally known as the White Column (Orlandi Filho et al. 2006). However, the existing stratigraphic column in Serra do Rio do Rastro, state of Santa Catarina, does not record the Triassic rocks only outcropping in the state of Rio Grande do Sul. So, the first record of Triassic rocks and fossils was only in the second half of the 20th century, initially in a undefined form (Gordon Jr. and Brown 1952), then as "Santa Maria beds" (Bortoluzzi and Barberena 1967), as part of the Rosário do Sul Formation (Gamermann 1973).

Considering geological studies in the city of Santa Maria, it was possible to recognize an individualized and mapable sedimentary package, recording sandstones with intraclasts and intraformational conglomerates ("Passo das Tropas beds"), at the base of reddish mudstones ("Alemoa beds") (Figure 4 of Bortoluzzi 1974). At that time, the "Passo das Tropas beds" only recorded leaf imprints and invertebrate remains, while the "Alemoa beds" provided a plethora of vertebrate fauna (Huene 1942; Colbert 1970). Later, Andreis et al. (1980) elevated this unit to the status of Rosário do Sul Group, divided into the Sanga do Cabral (Early Triassic), Santa Maria (Middle to Upper Triassic) and Caturrita (Upper Triassic) formations. The Santa Maria formation, by its turn, was divided into a "basal" Passo das Tropas Member and an "upper" Alemoa Member.

The recognition of Middle to Upper Triassic beds along an W-E outcrop belt in Rio Grande do Sul State (Wildner et al. 2008; Da Rosa 2015), with different assemblage zones (AZ) of vertebrate fossils (Barberena 1977; Schultz et al. 2020), recorded in different post-depositional structural blocks (Da Rosa and Faccini, 2005) showed that there is a more intricate stratigraphic framework. For example, considering the whole Paraná Basin, (Milani et al. 1998) assigned all Triassic rocks to his Gondwana I Supersequence, while Zerfass et al. (2003) recognized two second-order supersequences, namely Sanga do Cabral and Santa Maria. The Sanga do Cabral Supersequence stands for the homonymous formation, whilst the Santa Maria Supersequence congregated the Santa Maria and Caturrita formations, although there was a discussion if the "Mata Sandstone" should or not be included (Faccini, 2000). Presently, the Santa Maria Supersequence is divided into four third-order sequences, namely the Pinheiros-Chiniquá, Santa Cruz, Candelária and Mata (Horn et al. 2014), corresponding the first three of them to the deposition of sandstones and mudstones, thus provoking a misuse of the name "Passo das Tropas Member" or "Passo das Tropas sandstones". Although all sandstones are considered as Passo das Tropas Member, we consider that each AZ sandstone must have its own name.

After the geological and hydrostratigraphic characterization of different sandstones in the vicinities of Santa Maria, Wankler et al. (2007) recognized the Sarandi and São Valentim units, respectively linked to the *Hyperodapedon* and *Dinodontosaurus* Assemblage Zones. Considering that the sandstones of the Santa Cruz Sequence outcrop at the Schmitt sand quarry, south of the city of Venâncio Aires, here in we call this the Schmitt unit. Therefore, the Passo das Tropas Member of the Santa Maria Formation is constituted by the São Valentim (late Ladinian? - early Carnian), Schmitt (early Carnian) and Sarandi (late Carnian) units.

The present work provides the location and geological profile of a new outcrop (Fig. 4), the Estância dos Montes, from which a number of leaf imprints and reproductive organs will be described afterwards. In addition, we compiled the geological profiles of the remaining outcrops of the Sarandi unit of the Passo das Tropas Member, at the vicinity of the Passo das Tropas creek, south of Santa Maria, to present a paleoenvironmental reconstruction. The Estância dos Montes outcrop stands for an artificial exposure due to excavation to the implementation of the homonymous residential plan, in which there is a two-meter thick sedimentary package, with a 50 cm mudstone bed, embedded in medium to fine sandstones.

5. Paleontological description

A total of 125 samples of plant fossils were collected at the Estância dos Montes outcrop and these records correspond to impressions of leaves and fronds, reproductive organs and seeds. Some of the plants have been recognized to a more inclusive level, by their anatomical characteristics. First, the plants were identified as belonging to the genus *Dicrodium* due to the constant presence of dichotomized fronds with forked rachis in addition to pinnate and bipinnate specimens, also due to the venation being odontopteroid and allopteroid. Then, in this preliminary description of the fossils, three species of *Dicroidium* were initially identified: *Dicroidium lancifolium, Dicroidium zuberi, Dicroidium odontopteroides*; reproductive organs fragments: *Pteruchus* sp. and *Umkomasia* sp.; and as a representative of Equisetales, *Neocalamites* sp. (Fig. 5).

Thus, the preliminary taxonomic analysis of fossil plants from the Estância dos Montes outcrop shows the presence of the following *taxa*:

Division Spermatophyta
Class Pteridospermopsida
Order Corystospermales
Family Corystospermaceae

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Genus *Dicroidium* Gothan 1912

Dicroidium lancifolium (Morris) Gothan 1912 (Fig. 5A).
Referred materials: UFSM12259

One specimen showed observable diagnostic morphological characteristics corresponding to species *Dicroidium lancifolium*, highlighting the presence of pinnate fronds, lanceolate leaflets with a broad base and acute apex, opposite leaflets at the base of the frond becoming alternate from the median to the apical part, entire margin, allopteroid venation, as described Gottan (1912) and visualized in the UFSM12259 specimen (Fig. 5A). This same species was recorded from the Triassic deposits of the Passo das Tropas by Guerra-Sommer and Klepzig (2000).

Division Spermatophyta
Class Pteridospermopsida
Order Corystospermales
Family Corystospermaceae
Genus *Dicroidium* Gothan 1912.

Dicroidium zuberi (Szajnocha) Archangelsky 1968 (Fig. 5B).

Referred materials: UFSM12276, UFSM12222, UFSM12232, UFSM12252, UFSM12260, UFSM12250, UFSM12258, UFSM12164, UFSM12165, UFSM12165, UFSM12165, UFSM12260, UFSM12252, UFSM12173, UFSM12281, UFSM12271, UFSM12220, UFSM12166, UFSM12221, UFSM12208, UFSM12284, UFSM12282.

There were a total of 22 specimens that showed observable diagnostic morphological characteristics corresponding to species *Dicroidium zuberi*, highlighting the presence of bipinnate fronds, equidimensional rhomboid pinnules with obtuse apex, slightly lobed margin, subopposed secondary rachis becoming alternate in the median part to the apex, odontopteroid venation (Archangelsky 1968) and visualized in the UFSM12222 specimen (Fig. 5B). This same species was recorded from the Triassic deposits of the Passo das Tropas by Guerra-Sommer et al. (1999b).

Division Spermatophyta
Class Pteridospermopsida
Order Corystospermales
Family Corystospermaceae
Genus *Dicroidium* Gothan 1912.

Dicroidium odontopteroides (Morris) Gothan 1912 (Fig. 5D)

Referred materials: UFSM12175, UFSM12244, UFSM12277, UFSM12224, UFSM12163, UFSM12215, UFSM12207, UFSM12262, UFSM12209, UFSM12176, UFSM12256, UFSM12242, UFSM12242, UFSM12167, UFSM12174, UFSM12170, UFSM12171, UFSM12224.

There were a total of 18 specimens that showed observable diagnostic morphological characteristics corresponding to species *Dicroidium odontopteroides*, highlighting the presence of fronds are pinnate, base pinnae wider than long, pinnae opposite to subopposite, apex rounded, margin entire, odontopteroid venation, as described Gothan (1912), and visualized in the UFSM12163 specimen (Fig. 5D). This same species was recorded from the Triassic deposits of the Passo das Tropas outcrop by Bortoluzzi (1985), Guerra-Sommer et al. (1999b) and Da Rosa et al. (2013).

Division Spermatophyta
Class Pteridospermopsida
Order Corystospermales
Family Corystospermaceae
Genus *Pteruchus* Thomas 1933

Pteruchus sp. (Fig. 5E)
Referred materials: UFSM12266, UFSM12246.

Two specimens showed observable diagnostic morphological characteristics corresponding to *Pteruchus* sp, the pollen organs consisting of naked axes with short microsporophylls, arranged in a subopposite to alternating pattern. Corystosperm pollen organs are assigned to the genus (Taylor and Taylor, 2009). Due to the scarcity of specific diagnostic elements, it was only possible to identify these specimens to genus level. UFSM12266 specimen (Fig. 5E). This same genus was recorded from the Triassic deposits of the Passo das Tropas by Pinto (1956), Bortoluzzi and Barberena (1967) and Guerra-Sommer et al. (1999b).

Division Spermatophyta
Class Pteridospermopsida
Order Corystospermales
Family Corystospermaceae
Genus Umkomasia sp. Thomas 1933

Umkomasia sp. (Fig. 5G)
Referred materials: UFSM12251

There were thirty specimens that showed observable diagnostic morphological characteristics corresponding to *Umkomasia* sp, highlighting the presence of ovulate cupules, uni-ovulate, recurved and isolated, roundly shaped with wrinkled surface. Due to the scarcity of specific diagnostic elements, it was only possible to identify these specimens to genus level. This same genus was recorded from the Triassic deposits of the Espuma outcrop by Barboni and Dutra (2015).

Division Pteridophyta
Class Sphenopsida
Order Equisetales
Family Apocalamitaceae
Genus *Neocalamites* T. Halle 1908

Neocalamites sp. (Fig. 5C)
Referred materials: UFSM12274.

Only one specimen showed morphological characteristics associated with *Neocalamites* sp. with fragments of thallus with continuous striae, preserved as impression, secondary thalli and leaves not preserved. Due to the scarcity of specific diagnostic elements, it was only possible to identify this specimen to genus level. This same genus was recorded from the Triassic deposits of the Passo das Tropas by Guerra-Sommer et al (1999b) and Da Rosa et al. (2013).

It was possible to make a taxonomic identification of 61 specimens to at least genus level from the Estancia dos Montes outcrop, it. The other specimens (64 in total) represent fragments plant fossils with poorly preserved or inconsistent morphological characteristics, making their identification unfeasible. The paleontological material presented here represents only the first studies carried out on fossils from this new fossiliferous locality. Therefore, a detailed

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paleofloristic composition of the Estancia dos Montes outcrop will be presented elsewhere shortly, as well as associated paleoecological and paleoenvironmental information.

6. Discussion

6.1. Stratigraphy

The Estância dos Montes outcrop is a new outcrop, as explained before, consisting of a sedimentary section composed of a 2 m thick bed of cross-bedded, medium sandstones below a 50 cm thick laminated or massive, reddish to purple mudstone. Leaf imprints can be found all over the fine-grained lithology, but preferentially when they are covered with a purple coloration. This outcrop may not resist the urbanization of the residential area, thus its description and interpretation, as well as correlation with nearby outcrops is urgent.

The Sarandi unit of the Passo das Tropas Member at the studied area is constituted by the Estância dos Montes, "Espuma", the Passo das Tropas and the remaining outcrops of the never described type section. Here we provide a simplified correlation of these outcrops, aiming to construct its paleoenvironmental reconstruction (Fig. 6).

Medium-grained lithologies may have constituted the original outcrop, as they can be hardly seen in the margins of the road, although covered with vegetation. It is difficult to consider it in a geological section, but here we consider them as part of the channel complex of a meandering system. This interpretation corroborates the stratigraphic characterization of Faccini et al. (2003) and the petrographic analysis of Garcia et al. (2003). An unpublished geophysical analysis in the area, with ground penetrating radar (GPR) by the Universidade do Vale do Rio dos Sinos (UNISINOS) team, also stands for channel seams with interbedded floodplain deposits Garcia et al. (2003).

The remaining outcrop is an abandoned sand quarry, in which a N-S wall reveals fine sandstones in decimeter thick beds that end in millimeter thick mudstone beds, in a sigmoidal shape ("epsilon structures"), interpreted as lateral accretion of a meandering system. Lateral to these lithologies, but stratigraphically above them, there is a laterally restricted, circa 10 m wide, lens of purple mudstones finely interbedded with fine sandstones, interpreted as a lacustrine deposit of an abandoned channel.

The "Espuma" outcrop shows multiple millimetric mudstone layers, embedded in medium sandstones. These lithologies may represent a more extensive lacustrine deposition in an abandoned channel. The Estância dos Montes outcrop also records the same lithologies, representing the same environment.

In the proposed simplified geological section (Fig. 6), the studied outcrops stand for small and lateral variations of a meandering fluvial system, with its channel and lateral accretion deposits, cross cutting the floodplain and abandoned channels.

6.2. Fossil remains

The results found align with the estimates presented in the studies of Bortoluzzi et al. (1985), indicating a significant abundance of *D. zuberi*, followed by *D. odontopteroides*, whereas *D. lancifolium* has limited sampling. It's worth noting the substantial sampling of *Umkomasias* Thomas 1933 found in this outcrop. Accordingly, Da Rosa et al. (2009) suggested that the presence of more developed limb pinnae and the occasional occurrence of reduced limb pinnae are part of a floodplain taphoflora resulting from a river system alternating between xerophilic and humid environments.

The genus *Dicroidium* stands out as the predominant representative of the Triassic taphofloras around the world. According to the classification of Petriella (1981), *Dicroidium* Gothan 1912 belongs to the order Corystospermales, division Pteridospermophyta, a clade composed of extinct land plants, popularly called "seed ferns". *Dicroidium* can be found in the Gondwana territories: Antarctica, Australia, Arabian Peninsula, Índia, Southern Africa, South America (Fig 7.).

For this genus, the main morphological characteristic consists of the presence of a forked frond, often unipinnate, bipinnate or tripinnate, with a delta-shaped leaf contour with an inverted base. The pinnae are generally bifurcated into two straight or slightly curved rachis with a variable angle and are supported by the petiole, which has a straight shape. In addition, the pinnae can have their apex with a very acute to obtuse shape and entire or divided leaf margins, venetian odontopteroid or alopteroid (Guerra-Sommer et al. 1999).

During the Permian, the genus *Dicroidium* already inhabited small parts of Gondwana, and shared territory with the main floristic representative of this period, *Glossopteris* Flora (Kerp et al. 2006). At the end of the Permian, the planet went through the largest mass extinction event, massively extinguishing marine organisms and strongly affecting terrestrial life. In this event, records of *Glossopteris* disappeared, however, *Dicroidium* persisted, resisting even after such an environmental imbalance (Kerp et al. 2006). After the decline of the *Glossopteris* Flora, the niches became vacant, enabling the expansion of *Dicroidium* and migration through Gondwana, which populated the territory during the Triassic for around 50 million years (Mays and McLoughlin 2019).

The Lower Triassic is marked by the recovery of fauna and flora after the Permo-Triassic extinction, while later periods are characterized by the warming of the planet, the Greenhouse effect (Guerra-Sommer and Cazzulo-Klepzig 2007). The high temperature on the continents with the combination of intense rainfall events led to the migration and colonization of *Dicroidium* across Gondwana (Kerp et al. 2006). Concomitantly, the intense rains from the Carnian event led to an increase in the diversity of shapes and an increase in the abundance of species of the genus *Dicroidium* during the Middle Triassic and Late Triassic (Bomfleur and Kerp 2010).

Therefore, the discovery of a new outcrop, such as the Estância dos Montes outcrop, which contains fossiliferous material related to the *Dicroidium* Flora, is a new and valuable opportunity to obtain more information about the Triassic ecosystems of Gondwana and also to obtain data that will help to understand the factors that led to the evolution and subsequent extinction of this flora.

Furthermore, when considering the entire Brazilian territory, the Triassic deposits, especially at the Passo das Tropas Member, appear in the southern region of Brazil in a well represented way. As previously mentioned, unfortunately the poor management of paleontological heritage and adequate inspection regulations for the protection of these

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deposits throughout history in Brazil and also in Rio Grande do Sul state, a large part of the locations that contained deposits with *Dicroidium* Flora were completely destroyed, which further reinforces the importance of the new discovery and the potential for paleontological studies of global importance of this new outcrop in the territory Brazilian.

7. Conclusions

Based on the data presented here, it is possible to state that:

A new outcrop with fossil leaf imprints belonging to the *Dicroidium* Flora, Estancia dos Montes outcrop, is described for the municipality of Santa Maria, state of Rio Grande do Sul/Brazil.

The presence of *Dicroidium lancifolium, Dicroidium zuberi, Dicroidium odontopteroides*, *Neocalamites* sp., *Pteruchus* sp., *Umkomasia* sp. and seed was diagnosed in this new fossiliferous locality.

The Triassic deposits of southern Brazil, especially in the Santa Maria region, hold important paleontological records of the *Dicroidium* Flora, which require protection and/or conservation measures.

The Passo da Tropas Member holds a unique and important record of the *Dicroidium* Flora in southern Brazil, and although it has been explored by different authors over time, it has potential for new studies, especially paleoenvironmental and paleoecological ones.

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Authorship credits

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C - Data Interpretation/ Validation **D** - Writing
E - Review/Editing **F** - Supervision/Project administration

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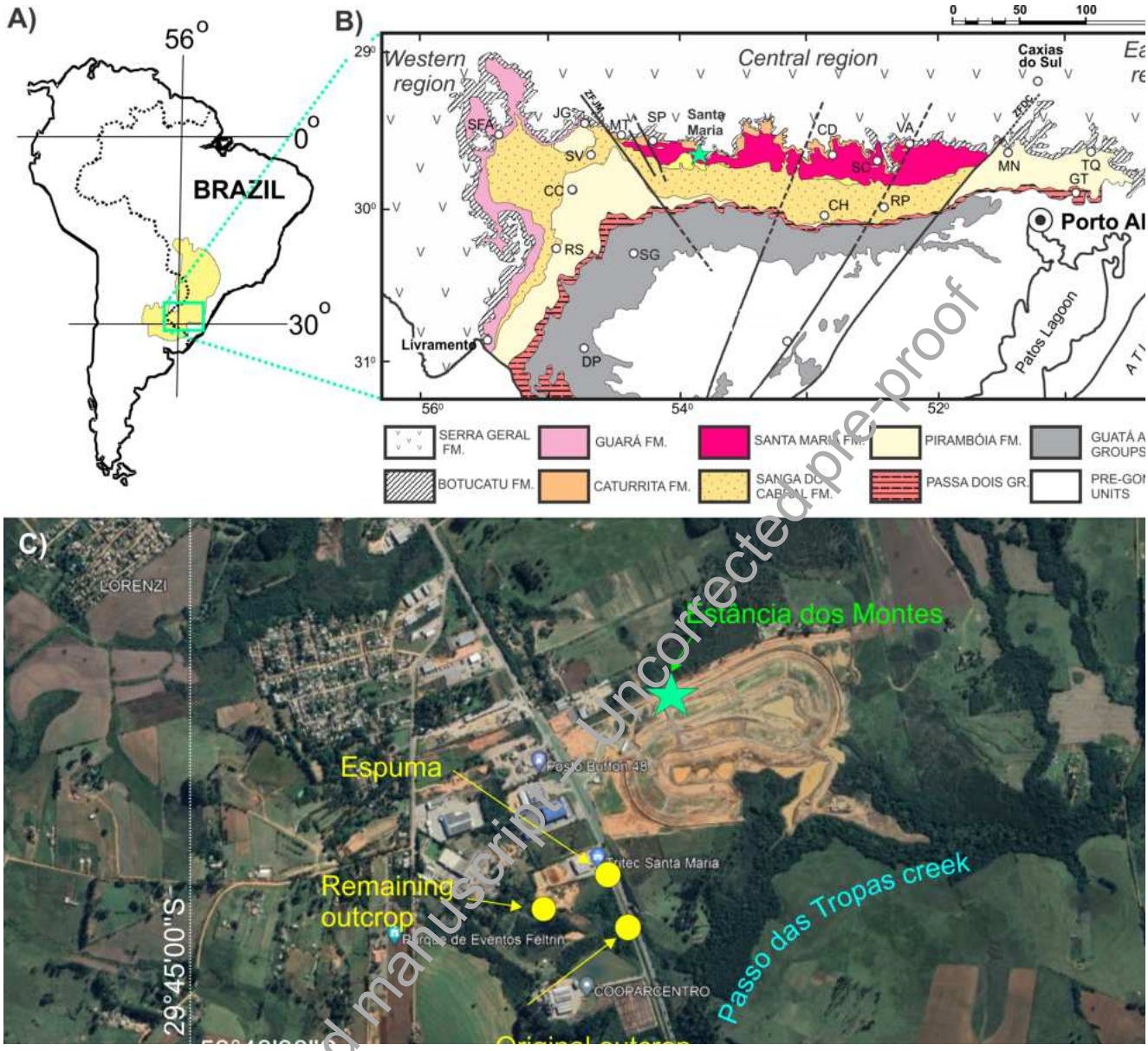

FIGURE 1. Location of studied outcrops. A) Paraná Basin (in yellow), in the context of South America. B) Simplified geological map of the central region of the state of Rio Grande do Sul, focusing on Mesozoic lithologies. C) Satellite image with location of the outcrops mentioned in the text (image taken from Google Earth Pro). Modified from Da Rosa (2015).

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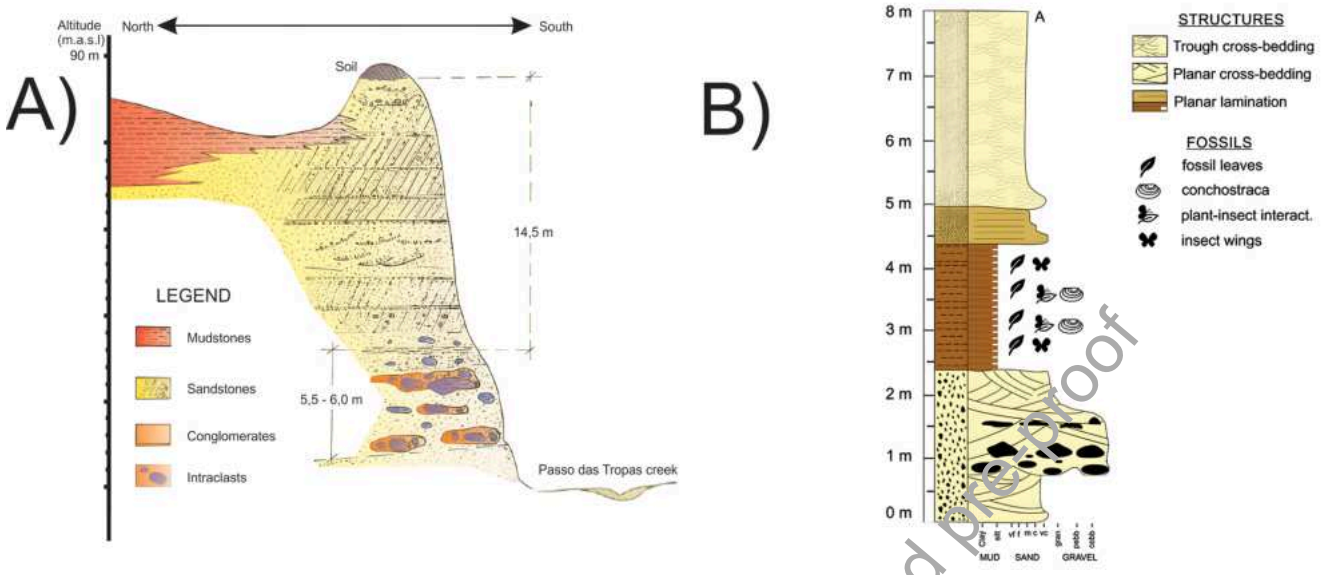

FIGURE 2.Geological profiles of the (A) Passo das Tropas area (redrawn from Bortoluzzi, 1974); and (B) the "Espuma" outcrop (adapted from Barboni & Dutra 2015).

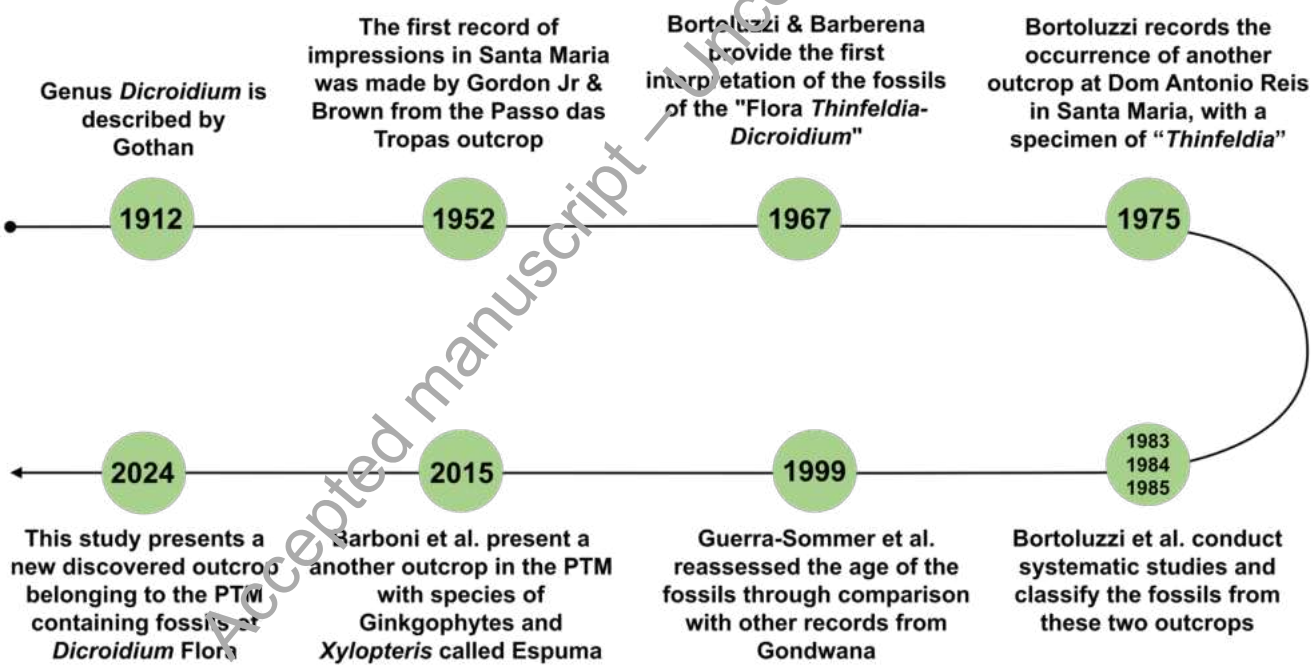

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FIGURE 3.Timeline referring to publications and paleontological findings about the Dicroidium Flora in the Passo das Tropas Member in Santa Maria, RS.

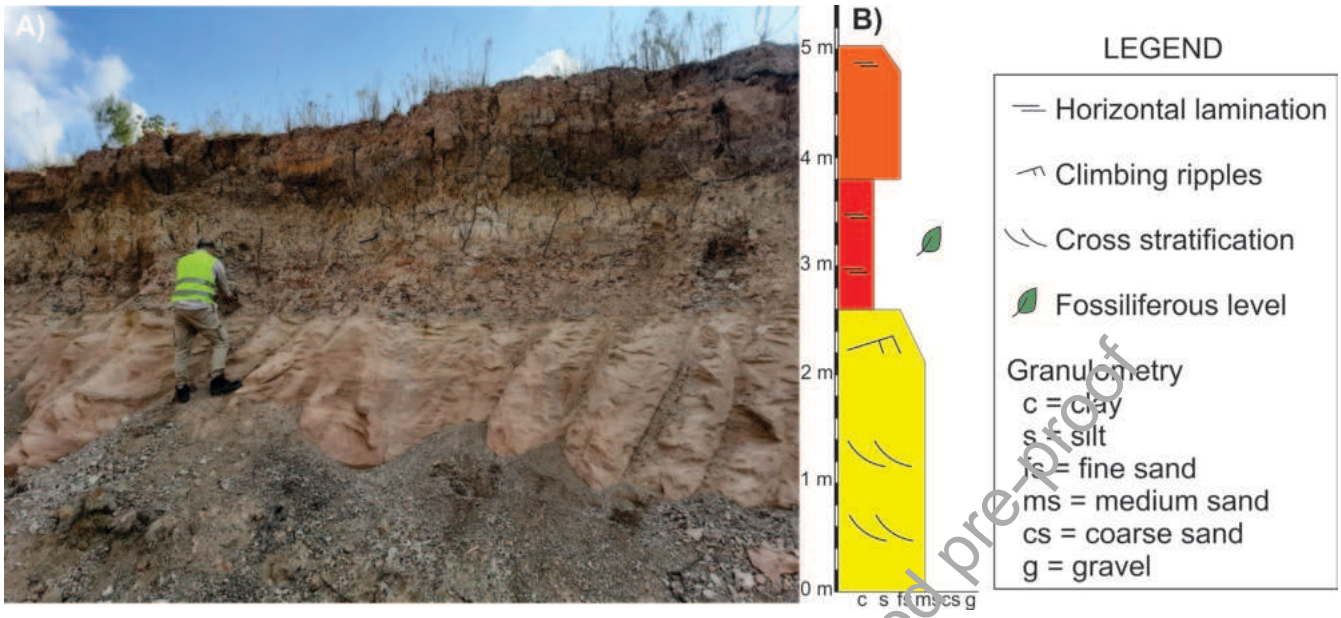

FIGURE 4.Estância dos Montes outcrop. (A) General view of the artificial exposure; (B) Geological profile, with indication of the fossiliferous level.

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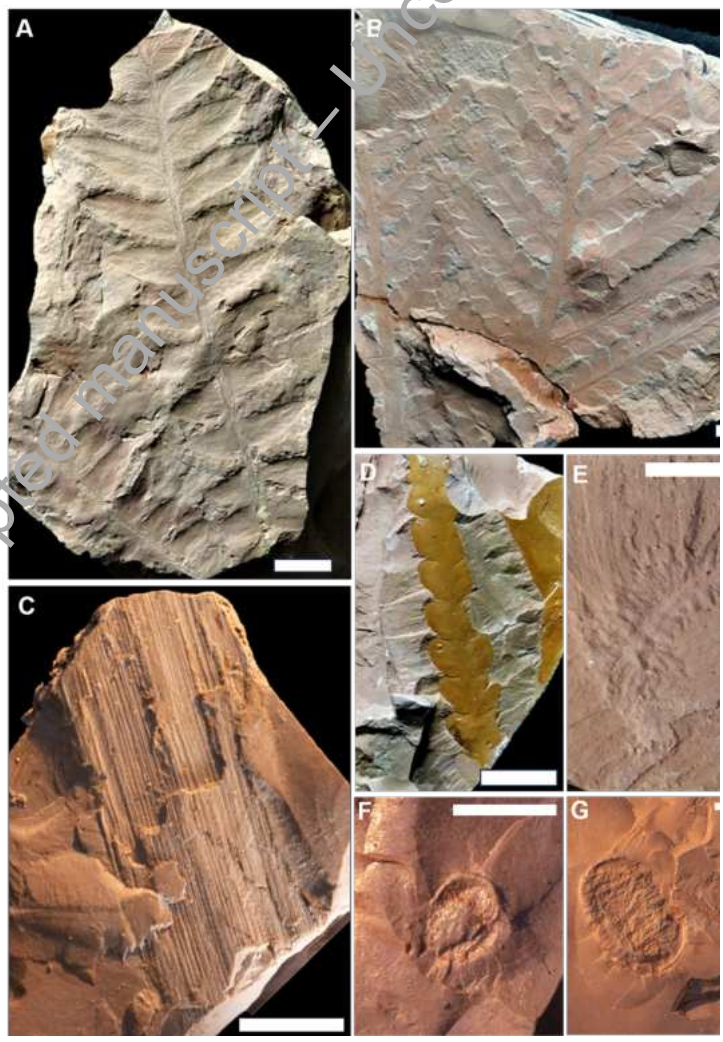

FIGURE 5. Floristic elements belonging to the *Dicroidium* Flora collected in Estância dos Montes outcrop. A) *Dicroidium lancifolium*; B) *Dicroidium zuberi*; C) *Neocalamites* sp.; D) *Dicroidium odontopteroides*; E) *Pteruchus* sp.; F) Seed; G) *Umkomasia* sp. Scale 1 cm.

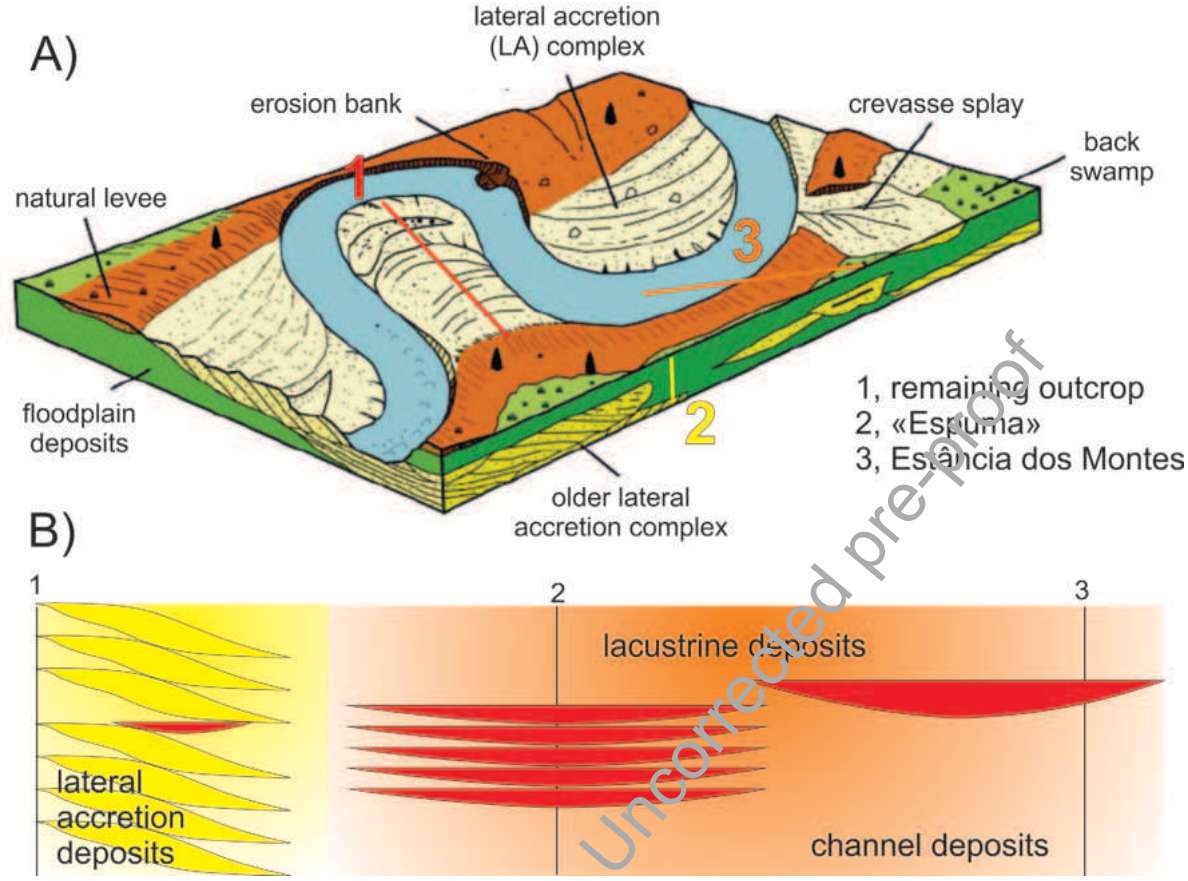

FIGURE 6. Paleoenvironmental reconstruction of the Sarandi unit of the Passo das Tropas Member. (A) Block diagram of a meandering river, with location of studied outcrops; (B) Simplified geological section and interpretation.

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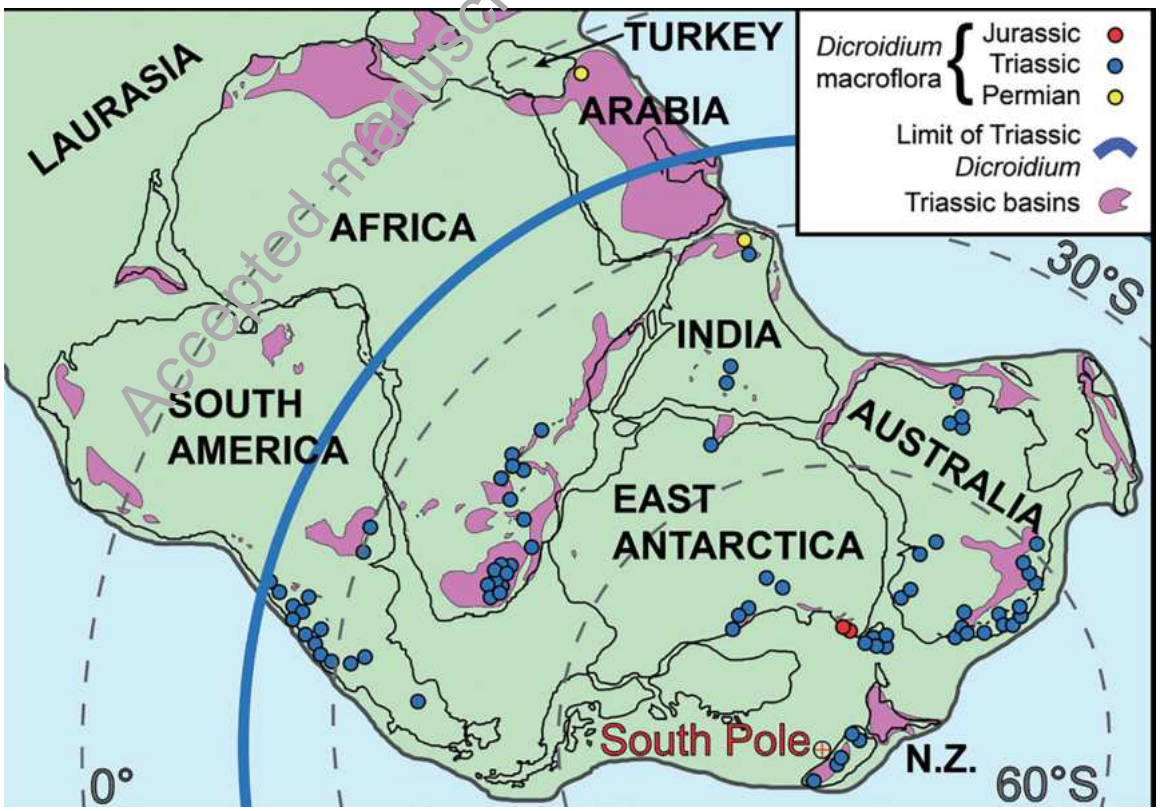

FIGURE 7. Distribution of the Dicroidium Flora around Gondwana (Mays and Mc Loughlin 2019).