Gaea
Journal of Geoscience
9(1):37-46, jan/jun 2016
Unisinos - doi: 10.4013/gaea.2016.91.03

In-situ Late Triassic fossil conifer woods from the fluvial channel deposits of the Soturno River (Caturrita Formation, Rio Grande do Sul, Brazil)

Alexandra Crisafulli
Facultad de Ciencias Exactas y Naturales y Agrimensura, Universidad Nacional del Nordeste y CECOAL-CONICET. Ruta Provincial 5, km 2,5 – 3400, Corrientes, Argentina. alexandracrisafulli@yahoo.com.ar

Rafael Herbst
Instituto Superior de Correlación Geológica-CONICET. Las Piedras 201 7º/B, 4000 San Miguel de Tucumán, Argentina. rafa.herbst36@gmail.com

Tânia Lindner Dutra
Universidade do Vale do Rio dos Sinos. Programa de Pós-Graduação em Geologia. Av. Unisinos, 950, Cristo Rei, 93022-750, São Leopoldo, RS, Brasil. dutratl@gmail.com

ABSTRACT

Three new fossil gymnosperm woods are described from a new outcrop exposed on the margins of the Soturno River, State of Rio Grande do Sul, eastward located in relation to other well-known petrified forests from São Pedro do Sul and Mata, in South Brazil. The interest of their study lays on the *in situ* condition of the woods and its inclusion in the fluvial deposits of the Caturrita Formation, at Faxinal do Soturno County, from where such kind of fossil material were known only recently. The analysis allows to assign it to the conifers *Agathoxylon africanum* (Bamford) Kurzawe and Merlotti, *Megaporoxylon kaokense* Kräusel and *Chapmanoxylon* sp. cf. *C. jamuriense* Pant and Singh. Previously known mainly from Permian localities of Gondwana (Namibia, India and South America), and with few Triassic representatives, the field relations and stratigraphic context suggest a Late Triassic age and a life around low sinuosity river systems under the influence of climatic seasonal dry conditions.

Keywords: fossil woods, *Agathoxylon, Megaporoxylon, Chapmanoxylon,* Late Triassic, Brazil.

RESUMO

LENHOS *IN SITU* DE CONÍFERAS DO TRIÁSSICO SUPERIOR, EM DEPÓSITOS DE CANAIS FLUVIAIS DA FORMAÇÃO CATURRITA, FAXINAL DO SOTURNO, RIO GRANDE DO SUL, BRASIL. Três novos registros de lenhos gimnospérmicos são descritos para níveis da Formação Caturrita. O material lenhoso foi identificado em uma exposição às margens do Rio Soturno, em Faxinal do Soturno, Rio Grande do Sul, em áreas a leste daquelas tradicionalmente conhecidas pela presença de lenhos petrificados no sul do Brasil (São Pedro do Sul e Mata). O interesse em seu estudo, além de ampliar o conhecimento sobre este tipo de fóssil no sul do Brasil, provém de sua ocorrência *in situ* em depósitos representativos de canais fluviais da Formação Caturrita para esse novo setor, e onde outras ocorrências similares foram recentemente identificadas. O estudo indica a preservação de formas relacionadas às coníferas *Agathoxylon africanum* (Bamford) Kurzawe e Merlotti, *Megaporoxylon kaokense* Kräusel e *Chapmanoxylon* sp. cf. *C. jamuriense* Pant e Singh, com amplo registro no Permiano de outras localidades do Gondwana (Namíbia, América do Sul e Índia), e de mais rara ocorrência no Triássico. As relações faciológicas e estratigráficas dos níveis estudados para o Brasil sugerem uma idade no final do Triássico e seu crescimento em um contexto de rios de baixa sinuosidade e corpos lacustres associados, sob um clima sujeito a estações periódicas de seca.

Palavras-chave: lenhos, *Agathoxylon, Megaporoxylon, Chapmanoxylon,* Triássico Superior, Brasil.

INTRODUCTION

The Caturrita Formation is the uppermost unit of the Rosário do Sul Group in the Mesozoic succession of the Paraná Basin, southern Brazil (Andreis *et al.*, 1980). Their levels are exposed along a west-eastern belt in the central part of the State of Rio Grande do Sul (Figures 1A-C). Assigned to the Upper Triassic (Andreis *et al.*, 1980; Faccini, 2000; Zerfass *et al.*, 2003), the recent findings of large theropod footprints, evolved Spinicaudata and reproductive and vegetative remains of bennettites suggest that the upper part of the Caturrita Formation could be Early Jurassic in age (Wilberger, 2009; Silva *et al.*, 2012; Barboni and Dutra, 2013; Rohn *et al.*, 2014). Notwithstanding, tetrapod assemblages tend to maintain a Carnian-Norian (Schultz *et al.*, 2000; Langer *et al.*, 2007) or Rhaetian (Abdala and Ribeiro, 2010) age to this unit. Taking the tectonism into account that results in block dislodgments, only recently better understood (Da Rosa and Faccini, 2005; Faccini, 2007; Zerfass *et al.*, 2004), it calls the attention to the necessity of more detailed geological and paleontological works to define the position and correlation among these deposits.

Big fossil woods, also usually assigned to the Upper Triassic, are rather common in the central and western areas of Rio Grande do Sul (São Pedro do Sul and Mata), both as reworked logs included in Pleistocene-Holocene sediments – and more rarely –, in *in situ* condition (Faccini, 2000; Pires and Guerra-Sommer, 2004). In previous works, they have been loosely included as *Araucarioxylon* sp. (Minello, 1993; Guerra Sommer and Cazzulo-Klepzig, 2000). At present and after lengthy discussions, most of the *Araucaria*-like secondary xylems from Mesozoic levels for most of the Gondwana, have been included in the genus *Agathoxylon* Hartig, an epithet with nomenclatural priority (Philippe, 1995; Bamford and Philippe, 2011; Rößler *et al.,* 2014).

In the previous known fossil wood materials identified to the South Brazilian Triassic, is also *Rhexoxylon brasiliensis* Herbst and Lutz, a typical Triassic pteridosperm; however uncertain about its source level (Herbst and Lutz, 1988). The Ginkgophyta is represented by *Baieroxylon cicatricum* Prasad and Lele, identified in the Santa Maria Formation (Bardola *et al.*, 2009). To the Caturrita Formation *Sommerxylon spiralosus*, assigned to the Taxaceae (Pires and Guerra-Sommer, 2004) and *Kaokoxylon zalesskyi* (Sahni) Maheshwari, a well preserved conifer wood (Crisafulli and Dutra, 2009), were identified in the São Luis quarry, not far (1,5 km at North) from the Soturno river area of the present study (Figure 1D). The herein described fossil woods were found in an outcrop on the terraces of Soturno River, exposing small-scale cross-bedded sandstones covered by conglomerate deposits of probable Pleistocene age (Figures 2A-B). The woods are horizontally and bi-directionally orientated in relation to the beds, the biggest up to 30 cm diameter and variably between 50 cm to 1 m long (Figures 2C-D).

GEOLOGICAL SETTING

Andreis *et al.* (1980) formally established the Caturrita Formation as an independent unit in the Triassic deposits

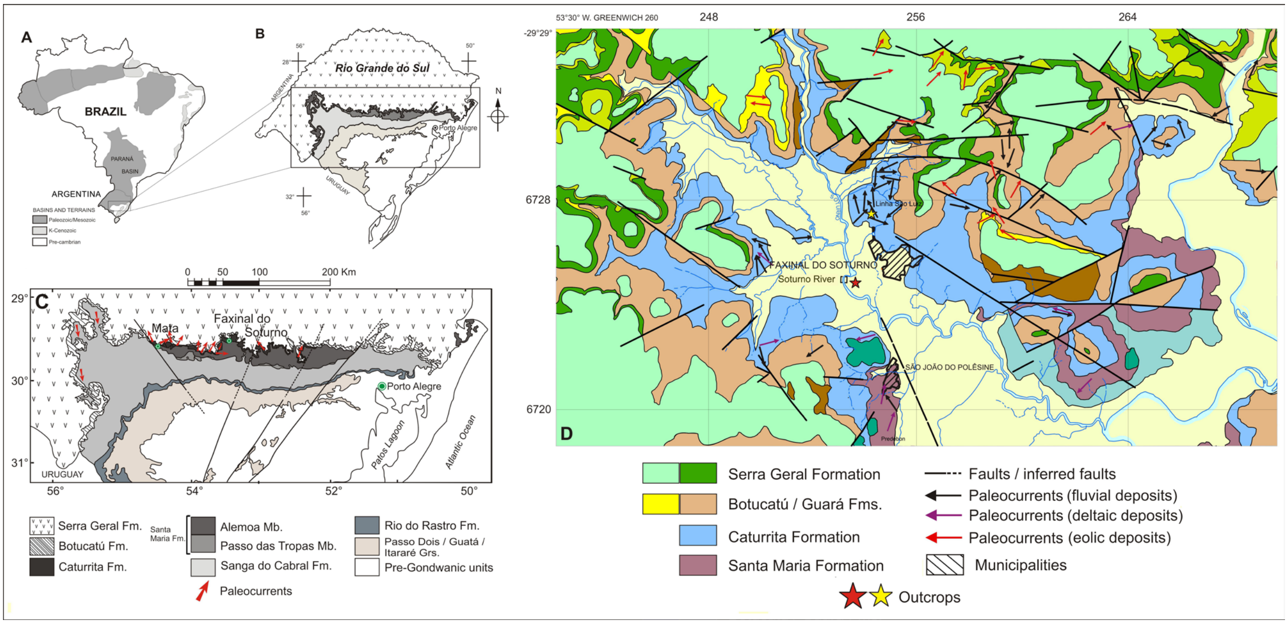

Figure 1. Study area. **A.** Map of Brazil with location and age of the main sedimentary basins; **B.** State of Rio Grande do Sul (RS) and the central East-Western belt where outcrops the Permian-Mesozoic rocks (from Faccini, 2007); **C.** Central Depression of RS. Geological context and areas exposing the Caturrita Formation deposits (modified from Faccini, 2007); **D.** Detail of Agudo geological map (leaf SH.22-V-C-V) from Zerfass (2007) and the location of the Soturno River (red star) and São Luis outcrops (yellow star). Structural features based in Da-Rosa and Faccini (2005).

Figure 2. A. General aspect of the exposition at the Soturno river (right margin); **B.** Detail of the through cross-bedded sandstones; **C.** Transversal section of the fossil wood related to *Agathoxylon africanum* (Bamford) Kurzawe & Merlotti (ULVG 10780), orthogonally positioned in relation to paleo-dune foresets; **D.** Horizontally disposed fossil wood of *Megaporoxylon kaokense* Kräusel (ULVG 10723), aligned in relation to the dune foresets. Scale (hammer size) is 20 cm long.

from the Paraná Basin (Rosário do Sul Group). In terms of Sequence Stratigraphy, it represents a coarsening-upward third order sequence formed in a high stand systems tract (Zerfass *et al*., 2004). The Caturrita Formation facies indicates an association of fine lacustrine and deltaic deposits of a broader low sinuosity river channels system, represented by massive and stratified sandstones (horizontal and trough-cross bedded). The whole succession reveals a progressive reduction of accommodation space, with the shallowing of lacustrine basins and its progressive replacement by fluvial systems (Faccini, 2007). To Zerfass *et al.* (2003, 2005), it marks one of the cyclic variations in base levels (1-3 Ma, in extent) probably induced by tectonic (or climatic) events and documented in an independent rift basin (Santa Maria Basin) formed in the southern part of the Paraná Basin. The Caturrita Formation deposits (~Santa Maria 3 Sequence of Zerfass *et al*., 2004) includes two phases with distinct deposits and fossil assemblages. The youngest (Arenito Mata, from Faccini, 2007, or Mata Sequence of Horn *et al*., 2014), was considered Rhaetian in age and is characterized by fluvial psefitic (intraformational conglomerates) and psamitic deposits containing the big fossil woods (90-100 cm in diameter) of the "*Araucarioxylon*" Flora (*Agathoxylon* sensu Rößler *et al*., 2014). The older deposits show fluvial sandstones with few lacustrine/alluvial plain intercalations, which outcrops at the easternmost areas (Faxinal do Soturno and Candelaria regions). Langer *et al.* (2010) proposed a Norian age to this succession based in its diversified assemblage of post-Ischigualastian dinosaurs (*Guaibasaurus candelariensis* Bonaparte, Ferigolo and Ribeiro and *Unaysaurus tolentinoi* Leal *et al.,* 2004) and small "ictidosaurian" cynodonts (Bonaparte *et al*., 1999; Leal *et al*., 2004). Together with other tetrapods, they were assigned to the *Riograndia Assemblage Zone* (Langer *et al*., 2007; Abdala and Ribeiro 2010; Horn *et al*., 2014). Ferigolo (2000) has proposed a possible Early Jurassic age to this upper faunal succession; however, most researchers agree with a Norian-Rhaetian age to the faunal content of the Caturrita Formation (Schultz *et al.,* 2000; Bonaparte *et al.,* 2001; Leal *et al.,* 2004; Langer *et al.,* 2010).

In the São Luis outcrop (Figure 3A), the tetrapod remains occur in the massive sandstones from the basal-middle part of the section (Bonaparte *et al*., 1999, 2003; Langer *et al.,* 2007). Upwards gives place to the mudstones containing the Taxaceae fossil wood and bennettites flora herein mentioned, Rhaetian or early Jurassic in age (Barboni and Dutra, 2013).The section ends with crevasse splay deposits containing dinosaur ichnites (Silva *et al*., 2012). The fossil content allows inferring a correlation with those from the Upper Triassic-Lower Jurassic rift basins from South Africa and Argentina (Andreis *et al*., 1980; Bordy *et al*., 2004; Zerfass *et al*., 2004; Da Rosa and Faccini, 2005; Veevers, 2005; Barredo *et al*., 2012).

The field work and the detailed geological map from Zerfass (2007, see Figure 1D) allow us to propose a probable correlation between the levels containing the fossil woods herein described and the basal levels of São Luis section (Figures 3A-B). However, this inference still needs to be proven, due to the restrict exposition at Rio Soturno and its recover by Quaternary deposits, which prevents more precise field relations. This assumption has support today only by the similar facies, geographical proximity and a common location in a probable less disturbed block. The three distinct levels of paleosoils identified in the São Luis section, the basal one with *in situ* thick root systems that suggests an arboreal vegetation (Barboni and Dutra, 2013, Figure 4.1) stands up for this inference.

MATERIAL AND METHODS

The silicified decorticated trunks, without signs of mechanical distortion, were prepared according to standard procedures, i.e., with the elaboration of thin sections of the polished three surfaces (transversal, longitudinal tangential and radial), mounted in Canada Balsam, and observed and described in their anatomic details with optical microscopy in transmitted light. The terminology used for microscopical descriptions is that from IAWA (2004). The anatomical features were measured following the biometric values from García Esteban *et al.* (2002, 2003). A minimum of 25 measurements were made quoting the median and, in parentheses, minimum and maximum values. Specimens are housed under the acronym ULVG at the Paleontological Laboratory (LaViGæa) of the Post-Graduate Program in Geology of the Vale do Rio dos Sinos University (Unisinos). The original wood specimens were maintained in the outcrop under the supervision of CAPPA (Center of Support to Paleontological Research) from the Quarta Colonia Valley.

SYSTEMATIC DESCRIPTIONS

Division Tracheophyta Sinnott 1935 ex Cavalier-Smith 1998
Class Spermatopsida Serbert & Rothwell 1995
Order Coniferales Engler 1897
Family *incertae sedis*
Genus *Agathoxylon* Hartig 1848

Type species: *Agathoxylon cordaianum* Hartig 1848

Agathoxylon africanum (Bamford) Kurzawe & Merlotti 2010
Figures 2C; 4A-E

Synonymy

1999 *Araucarioxylon africanum* Bamford, *Paleontologia Africana*, 34, Figures 17-20, tab. 2
2000 *Araucarioxylon africanum* Bamford, *Journal of South African Earth Sciences,* **31**(1):123, Figures 2 a-d
2010 *Agathoxylon africanum* (Bamford) Kurzawe & Merlotti 2010, *Pesquisas em Geociências,* **37**(1):43

Material: ULVG 10780 and slides 10780a-c

Description: Silicified wood, 30-45 cm in diameter (Figure 2C), picnoxylic secondary wood with well-marked gradual growth rings. Latewood is not more than five cells wide. Tracheids are quadrangular and hexagonal, mainly in earlywood transversal section, with an average of 39 μm (17-60 μm) in tangential diameter and an average of 41 μm (24-63 μm) in radial diameter. An average of nine tracheids (7-10) separate rays. Abundant dark and fungoid elements are present. Bulliform cells are also observed (Figures 4A-B). In longitudinal radial section, pits are hexagonal and biseriate, alternate, some opposite; some big ones, uniseriate, contiguous, and variable from 12-17 μm in diameter are also present on radial tracheidal walls (Figure 4C). Cross-fields have 2-6 oculiporous pits. In tangential longitudinal section, rays are homogeneous, uniseriate and very low (1), and some with 2–15 cells, few are partially biseriate and there are six rays per mm^2 (Figures 4D-E).

Remarks: The hexagonal, biseriate, alternate and some opposite, uniseriate, contiguous pits, present on radial tracheidal walls, are clearly indicative of this species, as described by Bamford (1999) from the Upper Permian Normandien Formation (three localities) in South Africa. Bamford (2000) also recorded the species from the Huab Formation in Namibia and proposed that the species could reach up to the Jurassic, which was also confirmed by findings in the same unit made by Crisafulli and Herbst (2010).

Genus *Megaporoxylon* (Kräusel, 1956) emend. Maheshwari, 1972

Type species *Megaporoxylon kaokense* Kräusel, 1956

Megaporoxylon kaokense Kräusel, 1956
Figures 2D; 4F; 5A-D; 6A

Synonymy

1956 *Megaporoxylon kaokense* Kräusel, *Senckenbergiana Lethaea,* **37**(5/6):421, pl. 6, Figures 22-24.

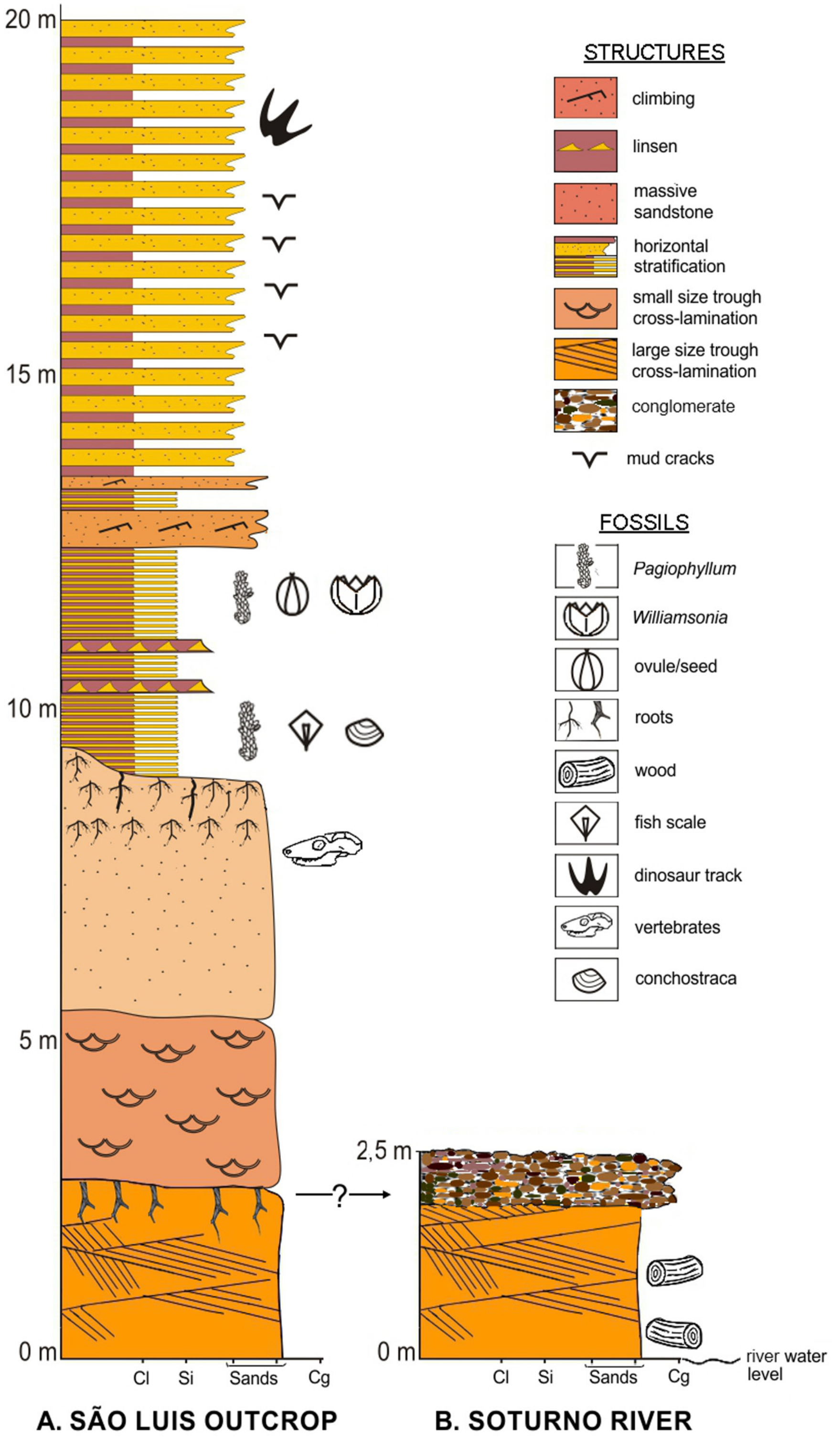

Figure 3. Geological sections at Faxinal do Soturno surroundings. **A.** São Luis outcrop (modified from Barboni and Dutra, 2013); **B.** Soturno River outcrop, and the fluvial sandstones that contain the partially preserved fossil woods. Similar sands with large through-cross lamination characterize the Soturno River terraces and the basal part of São Luis section.

1961 *Megaporoxylon kaokense* Kräusel 1956, *in*: Kräusel, Maithy & Maheshwari, *The Paleobotanist,* **1**(1-2):102, Figures 21a, 21d. (September 1962).

1972 *Megaporoxylon kaokense* Kräusel 1956, *in*: Maheshwari, *Paleontographica B,* 138:12

Material: ULVG 10723 and slides 10723a-c

Description. Silicified decorticated fossil wood with about 150 cm long and 20 cm diameter (Figure 2D). Central, circular, solid, heterogeneous pith, over 1 cm in diameter, composed of parenchymatic, circular and polygonal cells often broader than high, with dark contents, few sclerenchymatic ovoidal cells and some secretory cells. Parenchymatic cells are 80–100 µm in radial diameter and 60-90 µm in tangential one. Protoxylem endarch has wedge shaped projections. Protoxylem tracheids are ovoid, flattened, like the metaxylem tracheids, but smaller (Figures 5A-B). Picnoxylic secondary xylem with marked growth rings; average 9 tracheids separate raddi (Figure 5C) and shearing zones (*sensu* Erasmus, 1976). Secondary tracheids have an average of tangential diameter of 40 µm (30-67 µm) and 45 µm (37-60 µm) of radial diameter. Tracheidal radial walls are uniseriate, rarely with biseriate pits. Cross-fields show one simple large oval pit with 13 mm in diameter; scarce cross fields with two pits (Figures 5D and 6A). Radial system is homogeneous. Rays are uniseriate1-8 cells high (Figure 4F).

Remarks. We agree with Maheshwari's (1972) emendation of *Megaporoxylon*, which includes woods with homogeneous and heterogeneous piths, and one, sometimes two, large pits in cross-fields in the secondary xylem in this taxon. Such type of woods was identified in Kaokoveld, Namibia, and in the Alan Nunatak, Antarctica (Maheshwari, 1972). Pits in the cross-fields are very characteristic of this species and allow assigning the Soturno River woods to the species. At generic level, *Megaporoxylon* has been compared with *Phyllocladoxylon* Gothan and *Circoporoxylon* Kräusel, as they share

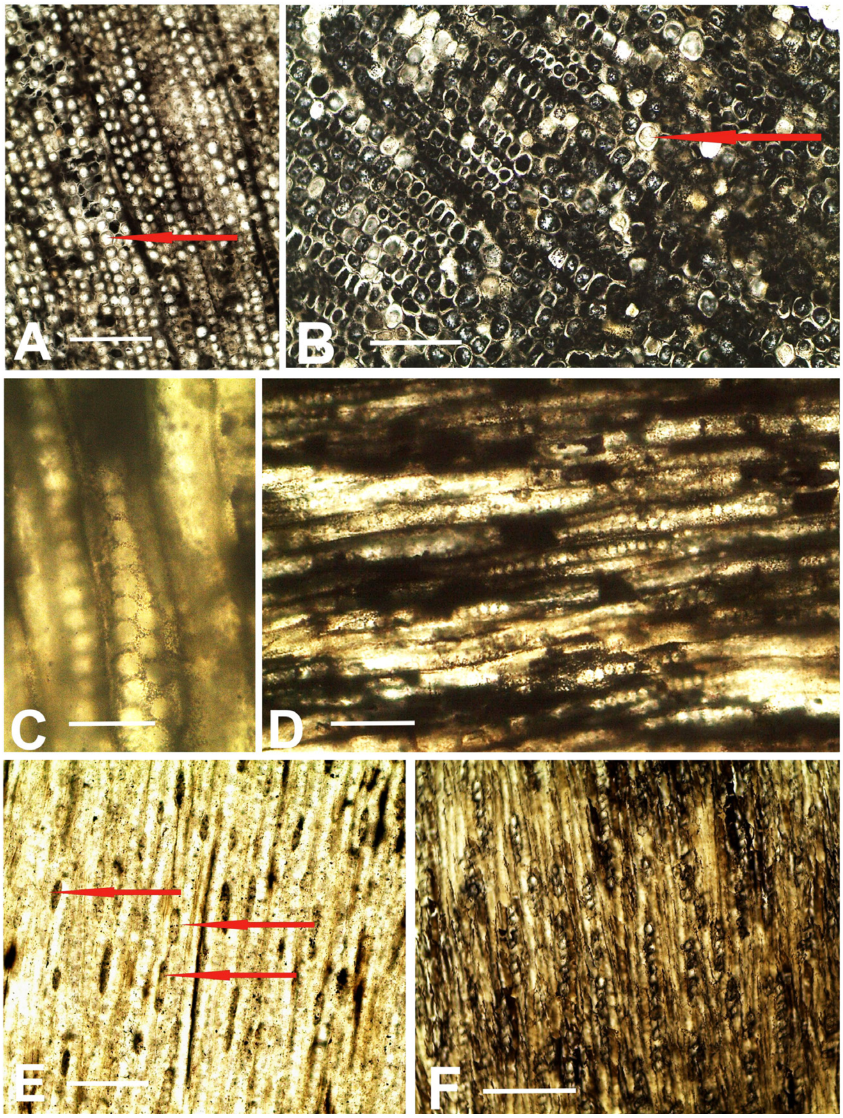

Figure 4. A-E. *Agathoxylon africanum*, secondary xylem. **A-B**. Transverse section (ULVG 10780 and slides 10780a). Arrows in A indicate the tracheid of early secondary xylem and in B, bulliform cell; **C-D.** Longitudinal radial section of wood with uniseriate and biseriate pits on the tracheid walls (ULVG 10780 and slides 10780b); **E.** Longitudinal tangential section showing the distribution and frequency of rays (ULVG 10780 and slides 10780c.). The upper arrow indicates a biseriate ray, the others, uniseriate rays; **F.** *Megaporoxylon kaokense*, secondary xylem. Longitudinal tangential section showing the uniseriate rays (ULVG 10723 and slide 10723c). Scale bars: A=360 µm; B=200 µm; C-D=60 µm; E=130 µm; F=100 µm.

similarities in pits of their cross-fields. *M. kaokense* is also comparable with *Mesembrioxylon woburnense* (Stopes) Seward 1919, from the Cretaceous of Namaqualand (Bamford and Corbett, 1995) by the single, rounded to oval pits in the cross-fields, and pits on the tracheidal walls. However, none of these genera has piths. The generic name *Megaporoxylon* is preferred over the above-mentioned ones, as those genera lack information of their piths, which is not the case of *Megaporoxylon*. On the other hand, the pits on the radial tracheidal walls of the secondary xylem in the species described here are similar to those of *Agathoxylon allani* (Kräusel) Crisafulli and Herbst, a taxon found in the Tres Islas Formation of Uruguay (Crisafulli *et al*., 2009), and the Carapacha Formation, in Argentina (Crisafulli *et al.,* 2000), both of Permian age. The presence of the pith excludes its incorporation to *Agathoxylon*.

Genus *Chapmanoxylon* Pant & Singh, 1987

Type species *Chapmanoxylon raniganjensis* Pant & Singh, 1987

Chapmanoxylon sp. cf. *C. jamuriense* Pant & Singh, 1987

Figures 5E-F; 6B-C

Material: ULVG 8682 and slides a-c

Description: Silicified decorticated wood with homogeneous parenchymatic pith;

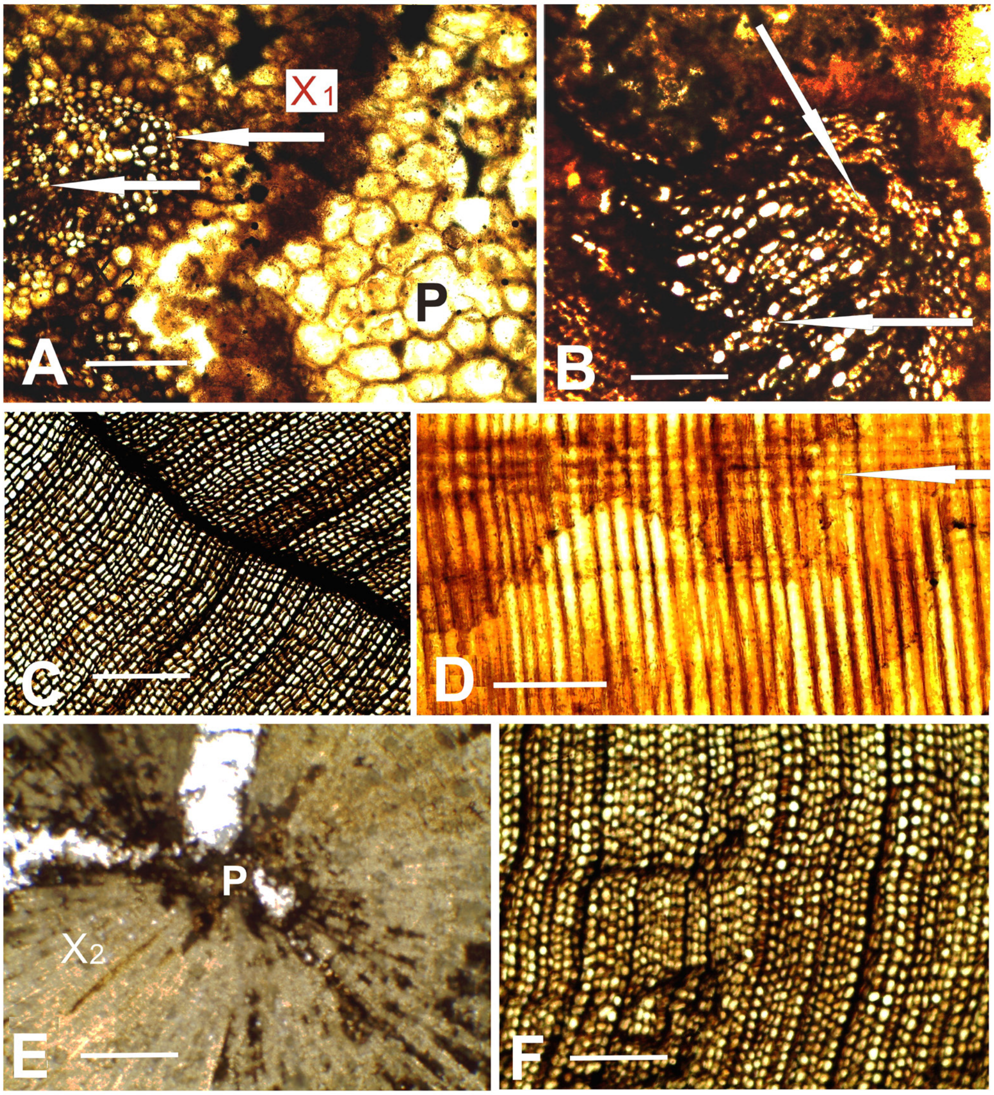

Figure 5. A-C. *Megaporoxylon kaokense*, transverse section of wood (ULVG 10723 and slide 10723*a*). **A.** The pith (P), primary xylem (X1) and the secondary xylem (arrows); **B.** Detail of the wedge shaped projection of primary xylem (upper arrow) and the tracheids of the secondary xylem (lower arrow); **C.** Growth rings; **D.** *Megaporoxylon kaokense*, longitudinal radial section of the secondary xylem (slide 10723b) showing single and simple pit in the cross-fields. **E-F.** *Chapmanoxylon* cf. C. *jamuriense*, transversal section of the wood (ULVG 8682 and slide 8682a). **E.** The pit (P) and secondary xylem (X2); **F.** tracheids of secondary xylem. Scale bars: A=190 µm; B=100 µm; C=980 µm; D=400 µm; E=500 µm; F=300 µm.

primary xylem difficult to observe; secondary xylem without growth rings but with shearing zones (*sensu* Erasmus 1976) (Figures 5E-F). Parenchymatic cells are circular to ovoidal. They have an average of 5 (7-4) tracheids separate rays. Secondary xylem tracheids are 60 µm (50-75 µm) in radial diameter and 45 µm (38-70 µm) in tangential diameter. In radial section, it is possible to observe fungi and abundant resin plates on the secondary xylem. On the tracheid, radial walls are uniseriate, spaced pits; a few of them are biseriate, contiguous, circular and separate. Cross-fields have three oval pits, 7,5 µm in diameter, areoles are not preserved. In tangential section, rays are uniseriate, in average three cells high (Figure 6B). A small percentage of uniseriate, partially biseriate, up to 12 cells high are also present (Figure 6C).

Remarks. Although this specimen can be assigned to *Chapmanoxylon* by its typical homogeneous parenchymatic pith, being one of the few Permian genera with this characteristic (see discussion in Crisafulli and Herbst, 2008, and Crisafulli *et al.,* 2009), the cellular preservation is not good enough to include it in a definite species. Comparisons with other species of the genus show some similarities with *C. jamuriense* Pant & Singh (Pant and Singh, 1987) in its uniseriate and biseriate pits, although not with the hexagonal ones of the species. Rays are also lower than those of *C. jamuriense*. With *C. daintreii* (Chapman) Pant & Singh shares the characters

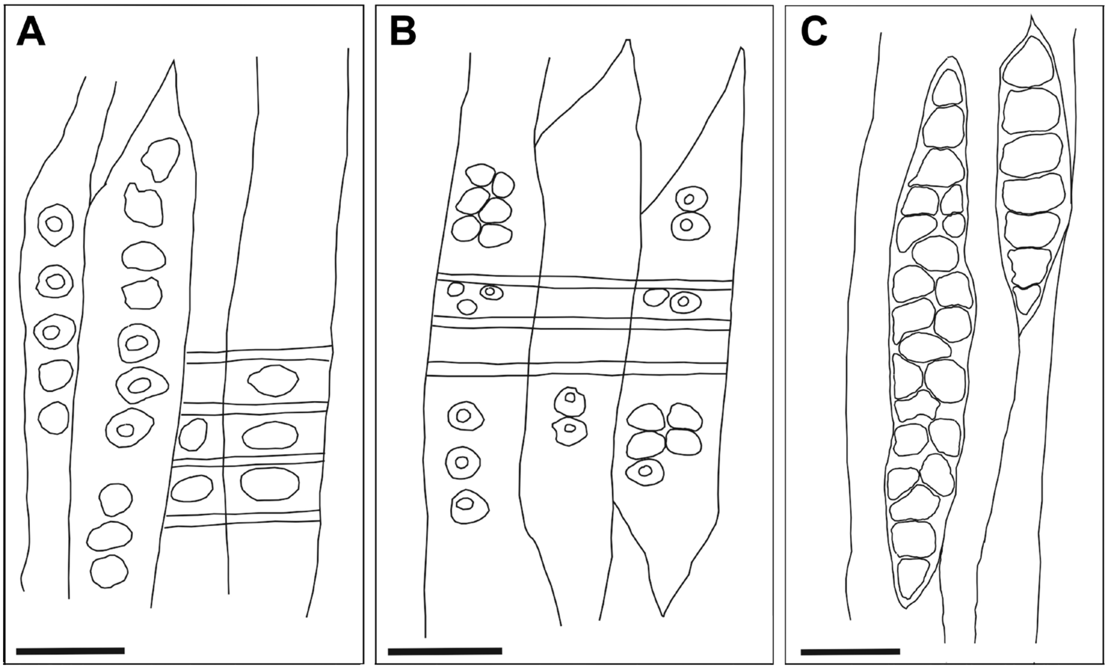

Figure 6. A. *Megaporoxylon kaokense*, sketch of the pits on the longitudinal radial tracheid walls and in the cross-fields (ULVG 10723 and slide b); **B-C.** *Chapmanoxylon* sp. cf. C. *jamuriense* (ULVG 8682 and slide 8682b). **B.** A sketch of the radial pits on the longitudinal radial tracheidal walls and cross-fields; **C.** Longitudinal tangential section, showing secondary rays (ULVG 8682 and slide 8682c). Scale bars: A=30 μm; B=60 μm; C=50 μm.

of the cross-fields, but there are fewer pits in amount. Apart from India, *C. jamuriense* is also found in Permian strata of Solca, Argentina (Crisafulli and Herbst, 2008) and Uruguay (Crisafulli *et al.*, 2009).

GENERAL COMMENTS

Both *A. africanum* and *M. kaokense* have been found in the so-called Permo–Triassic sediments of South Africa and Namibia (Kräusel, 1956; Bamford, 1999, 2000; Crisafulli and Herbst, 2010), but none of them can be useful for age inferences, as they have rather long biochrons. A similar broad age characterizes the *in situ* fossil woods from the Caturrita Formation, *e.g. Kaokoxylon zalesskyi*, from Faxinal do Soturno (Crisafulli and Dutra, 2009), and *Lobatoxylon kaokense* Kräusel (Crisafulli *et al.,* 2012), from the Piscina outcrop, close to São Pedro do Sul City, Brazil. *Kaokoxylon* related taxa*,* albeit with other species*,* have been recently found in Jurassic sediments of Patagonia (Gnaedinger and Cúneo, 2009; Zavattieri and Gnaedinger, 2012).

Megaporoxylon has Carboniferous representatives in Namibia (Bangert, 2000), and is recorded in the Triassic (*in* Kräusel, quoted by Bangert, 2000). Thus, none of all these taxa is useful for precise age dating and the studied xyloflora tends to be kept limited to the Triassic. However, the lack of any typical Triassic elements (e.g. *Rhexoxylon* woods) and the presence of evolved bennettites and *Spinicaudata* faunas, associated to woods of Taxaceae, in the not too distant San Luis outcrop, could suggests a Rhaetian or even an initial Jurassic age to the upper part of the Caturrita Formation, as already proposed by Barboni and Dutra (2013).

Taphonomically, the relatively well-preserved conditions and the bidirectional orientation of the fossil logs seems to show a flora that grew in proximal sites (exposed sand bars or uplands) that had its wood logs transported to the depositional areas in times of more rough waters of the river channels. This conditions support the idea of seasonal wet climate to the inner Gondwana areas during the lower Mesozoic, proposed by the paleoclimatological data (Frakes *et al.*, 1992; Parrish, 1993; Royer, 2006; Golonka, 2007).

ACKNOWLEDGMENTS

The authors wish to thank CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico, Procs. 401780/2010-4; 401854/2010-8) and FAPERGS (Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul, Proc. 1010122) for their financial support to the field works and MHGEO (Geological Museum) and LaViGæa (Earth and Life History Laboratory) of the PPGEO-Unisinos, for the assistance and facilities provided. This paper is a partial result of the Project PI 2010 – F 015 from the Secretaría General de Ciencia y Técnica, Universidad Nacional del Nordeste, Corrientes, Argentina. We deeply thank the anonymous reviewers for their valuable suggestions, which allowed to improve the original manuscript.

REFERENCES

]ABDALA, F.; RIBEIRO, A.M. 2010. Distribution and diversity patterns of Triassic cynodonts (Therapsida, Cynodontia) in Gondwana. *Paleogeography, Paleoclimatology, Paleoecology*, **286**:202-217. http://dx.doi.org/10.1016/j.palaeo.2010.01.011

ANDREIS, R.R.; BOSSI, G.E.; MONTARDO, D.K. 1980. O Grupo Rosário do Sul (Triássico) no Rio Grande do Sul. *In*: Congresso Brasileiro de Geologia, 31, Balneário Camboriú, *Anais*... **2**:659-673.

BAMFORD, M. 1999. Permo-Triassic fossil woods from the South African Karoo Basin. *Paleontologia Africana*, **34**:25-40.

BAMFORD, M. 2000. Fossil wood of Karoo age deposits in South Africa and Namibia as an aid to biostratigraphical correlation. *Journal of African Earth Sciences*, **31**(1):119-132. http://dx.doi.org/10.1016/S0899-5362(00)00077-4

BAMFORD, M.; CORBETT, I. 1995. More fossil wood from the Namaqualand coast, South Africa; onshore material. *Paleontologia Africana*, **32**:67-74

BAMFORD, M.K.; PHILIPPE, M. 2001. Jurassic-Early Cretaceous Gondwanan homoxylous woods: a nomenclatural revision of the genera with taxonomic notes. Review of Palaeobotany and Palynology, **113**:287-297. http://dx.doi.org/10.1016/S0034-6667(00)00065-8

BAMFORD, M.K.; PHILIPPE, M. 2011. Jurassic–Early Cretaceous Gondwanan homoxylous woods: a nomenclatural revision of the genera with taxonomic notes. *Review of Palaeobotany and Palynology*, **113**:287-297. http://dx.doi.org/10.1016/S0034-6667(00)00065-8

BANGERT, B. 2000. *Tephrostratigraphy, petrography, geochemistry, age and fossil record of the Ganigobis Shale Member and associated glaciomarine deposits of the Dwyka Group, Late Carboniferous, southern Africa*. Dissertation zur Erlangung des naturwissenschaftlichen Doktorgrades der Bayerischen Julius-Maximilians-Universität Würzburg, 260 p.

BARBONI, R.; DUTRA, T.L. 2013. New "flower" and leaves of bennettites from Southern Brazil and their implication in the age of the lower Mesozoic deposits. *Ameghiniana*, **50**(1):14-32. http://dx.doi.org/10.5710/AMGH.28.11.2012.444

BARDOLA, T.P.; SCHMIDT, I.D.; GUERRA SOMMER, M.; SCHULTZ, C.L. 2009. Lenhos de Ginkgophyta em florestas petrificadas no Triássico Superior do Rio Grande do Sul, Brasil. *Revista Brasileira de Paleontologia*, **12**:139-148. http://dx.doi.org/10.4072/rbp.2009.2.04

BARREDO, S.; CHEMALE, F.; MARSICANO, C.; ÁVILA, J.N.; OTTONE, E.G.; RAMOS, V.A. 2012. Tectono-sequence stratigraphy and U–Pb zircon ages of the Rincón Blanco depocenter, northern Cuyo Rift, Argentina. *Gondwana Research*, **21**:624-636. http://dx.doi.org/10.1016/j.gr.2011.05.016

BONAPARTE, J.F.; FERIGOLO, J.; RIBEIRO, A.M. 1999. A New Early Late Triassic saurischian dinosaur from Rio Grande do Sul State, Brazil. *In:* Proceedings of the Second Gondwanan Dinosaur Symposium, Tokyo, *National Science Museum Monographs,* **15**:89-109. http://dx.doi.org/10.1111/1475-4983.00194

BONAPARTE, J.F.; FERIGOLO, J.; RIBEIRO, A.M. 2001. A primitive Late Triassic "Ictidosaur" from Rio Grande do Sul, Brazil. *Palaeontology*, **44**(4):623-635.

BONAPARTE, J.F.; MARTINELLI, A.G.; SCHULTZ, C.L.; RUBERT, R. 2003. The sister group of mammals: Small cynodonts from the Late Triassic of southern Brazil. *Revista Brasileira de Paleontologia,* **5**:5-27.

BORDY, E.M.; HANCOX, P.J.; RUBIDGE, B.S. 2004. A description of the sedimentology and paleontology of the Upper Triassic-Lower Jurassic Elliot Formation in Lesotho. *Palaeontologia Africana*, **40**:43-58.

CRISAFULLI, A.; DUTRA, T.L. 2009. *Kaokoxylon zalesskyi* (Sahni) Maheswari en los niveles superiores de la Secuencia Santa Maria 2 (Formación Caturrita), Cuenca de Paraná, Brasil. *Gaea - Journal of Geoscience*, **5**(2):61-69. http://dx.doi.org/10.4013/gaea.2009.52.02

CRISAFULLI, A.; HERBST, R. 2008. Maderas gimnospérmicas de la Formación Solca (Pérmico Inferior), provincia de La Rioja, Argentina. *Ameghiniana*, **45**(4):737-751.

CRISAFULLI, A.; HERBST, R. 2010. Revisión de algunas lignofloras pérmicas de Namibia, Africa. *In*: Congreso Argentino de Paleontologia y Bioestratigrafía, 10. *Resúmenes*, p. 151.

CRISAFULLI, A.; LUTZ, A.; MELCHOR, R. 2000. Maderas gimnospérmicas de la Formación Carapacha (Pérmico) provincia de La Pampa, Argentina. *Ameghiniana*, **37**:181-191.

CRISAFULLI, A.; HERBST, R.; MANZA STORTI, L. 2009. Maderas gimnospérmicas de la Formación Tres Islas (Pérmico Inferior) de Uruguay. *Gaea - Journal of Geoscience*, **5**(1):1-14. http://dx.doi.org/10.4013/gaea.2009.51.01

CRISAFULLI, A.; DUTRA, T.L.; HERBST, R. 2012. New fossil (*in situ*) wood from the Upper Triassic Caturrita Formation from São Pedro do Sul, Rio Grande do Sul, Brazil. *In:* Simposio Argentino de Paleobotánica y Palinología, 15, Corrientes. *Ameghiniana (Suplemento)*, **49**(4):R 112.

DA-ROSA, A.A.S.; FACCINI, U. 2005. Delimitação de blocos estruturais de diferentes escalas em sequências mesozoicas do Estado do Rio Grande do Sul: implicações bioestratigráficas. *Gaea - Journal of Geosciences*, **1**(1):16-23.

ERASMUS, T. 1976. On the anatomy of *Dadoxylon arberi* Seward, with some remarks on the phylogenetical tendencies of its tracheid pits. *Paleontologia Africana*, **19**:127-133.

FACCINI, U.F. 2000. *Estratigrafia do Permo–Triássico do Rio Grande do Sul: estilos deposicionais versus espaço de acomodação*. Porto Alegre, RS. Tese de Doutorado. Universidade Federal do Rio Grande do Sul, 353 p.

FACCINI, U.F. 2007. Tectonic and climatic induced changes in depositional styles of the Mesozoic sedimentary record of southern Paraná Basin, Brazil. *In*: R. IANNUZZI; D. BOARDMAN (eds.), Problems in Western Gondwana geology, workshop 1: South America - Africa correlations: du toit revisited, Gramado. *Extended abstracts*, p. 42-45.

FERIGOLO, J. 2000. Esfenodontídeos do Neotriássico?/Jurássico do Estado do Rio Grande do Sul, Brasil. *In:* M. HOLZ; L.F. DE ROS (eds.), *Paleontologia do Rio Grande do Sul.* Porto Alegre, Ed. UFRGS.

FRAKES, L.A.; FRANCIS, J.E.; SYKTUS, J.I. 1992. *Climate Modes of the Phanerozoic.* Cambridge, Cambridge University Press, 275 p. http://dx.doi.org/10.1017/CBO9780511628948

GARCÍA ESTEBAN, L.; DE PALACIOS, P.; GUINDEO CASASÚS, A.; LÁZARO DURÁN, I.; GONZÁLEZ FERNÁNDEZ, L.; RODRÍGUEZ SALVADOR, Y.; FERNÁNDEZ GARCÍA, S.; BOBADILLA MALDONADO, I.; CAMACHO ATALAYA, A. 2002. *Anatomía e identificación de maderas de coníferas a nivel de especies*. Madrid, Coedición Fundación Conde del Valle de Salazar, Ediciones Mundi-Prensa, 421 p.

GARCÍA ESTEBAN, L.; GUINDEO CASASÚS, A.; PEREZA ORAMAS, C.; DE PALACIOS, P. 2003. *La madera y su anatomía.* Madrid, Coedición Fundación Conde del Valle de Salazar, Ediciones Mundi Prensa, 327 p.

GNAEDINGER, S.C.; CÚNEO, R. 2009. Maderas de gimnospermas de la Formación Cañadón Asfalto, Chubut, Argentina. *In:* Simposio Argentino de Paleobotánica y Palinología, 16, *Resúmenes*… p. 49.

GOLONKA, J. 2007. Phanerozoic paleoenvironment and paleolithofacies maps: Mesozoic. *Geologia*, **33**(2):211-264.

GUERRA SOMMER, M.; CAZZULO-KLEPZIG, M. 2000. The Triassic taphoflora from Parana Basin, southern Brazil: an overview. *Revista Brasileira de Geologia*, **30**:481-485.

HERBST, R.; LUTZ, A.I. 1988. *Rhexoxylon brasiliensis* n. sp. (Corystospermaceae, Pteridospermales) from the upper Triassic Caturrita Formation - Brazil, with comments on biology and environment. *Mededelingen Rijks Geologische Dients,* **42**:21-31.

HORN, B.L.D.; MELO, T.M.; SCHULTZ, C.L.; PHILIPP, R.P.; KLOSS, H.P.; GOLDBERG, K. 2014. A new third-order sequence stratigraphic framework applied to the Triassic of the Paraná Basin, Rio Grande do Sul, Brazil, based on structural, stratigraphic and paleontological data. *Journal of South American Earth Sciences*, **55**:123-132. http://dx.doi.org/10.1016/j.jsames.2014.07.007

INTERNATIONAL ASSOCIATION OF WOOD ANATOMISTS (IAWA). 2004. IAWA list of microscopic features for softwood identification. *IAWA Journal*, **25**(1):1-70. http://dx.doi.org/10.1163/22941932-90000349

KRÄUSEL, R. 1956. Der "Versteinerte Wald" im Kaokoveld, Südwest Africa. *Senkenbergiana Lethaea*, **37**(5/6):411-445.

KRÄUSEL, R.; MAITHY, P.K.; MAHESHWARI, H.K. 1962. Gymnospermous woods with primary structures from Gondwana rocks – a review. *The Palaeobotanist*, **10**(1-2):97-107.

KURZAWE, F.; MERLOTTI, S. 2010. O complexo *Dadoxylon-Araucarioxylon*, Carbonífero e Permiano do Gondwana: estudo taxonómico do gênero *Araucarioxylon*. *Pesquisas em Geociencias*, **37**(1):41-45.

LANGER, M.C.; BITTENCOURT, J.S.; SCHULTZ, C.L. 2007. The inclusivity and phylogenetic position of *Guaibasaurus candelariensis*:

a basal dinosaur from the Late Triassic of Brazil. *Journal of Vertebrate Paleontology*, **27**(Suppl. 3):103A-104A.
http://dx.doi.org/10.1111/j.1469-185X.2009.00094.x

LANGER, M.C.; EZCURRA, M.D.; BITTENCOURT, J.S.; NOVAS, F.E. 2010.The origin and early evolution of dinosaurs. *Biological Reviews*, **85**:55-110.

LEAL, L.A.; AZEVEDO, S.A.K.; KELLNER, A.W.A.; DA ROSA, A.A.S. 2004. A new early dinosaur (Sauropodomorpha) from the Caturrita Formation (Late Triassic), Parana Basin, Brazil. *Zootaxa*, **690**:1-24.

MAHESHWARI, H. 1972. Permian woods from Antarctica and revision of some Lower Gondwana wood taxa. *Paleontographica B*, **138**:1-43.

MINELLO, L.F. 1993. *As florestas petrificadas da região de São Pedro do Sul e Mata, RS: introdução ao estudo dos processos de fossilização e análise morfológica, legislação pertinente e análise do desenvolvimento da consciência preservacionista*. Porto Alegre, RS. Dissertação de Mestrado. Universidade Federal do Rio Grande do Sul, 484 p.

PANT, D.; SINGH, V. 1987. Xylotomy of some woods from Raniganj Formation (Permian), Raniganj Coal-field, India. *Paleontographica B*, **203**:1-82.

PARRISH, J.T. 1993. Climate of the Supercontinent Pangea. *The Journal of Geology*, **101**:215-233.
http://dx.doi.org/10.1086/648217

PHILIPPE, M. 1995. Bois fossiles du Jurassique de Franche-Comt (NE France). *Paleontographica B*, **236**:45-103.

PIRES, E.F.; GUERRA-SOMMER, M. 2004. A new taxon with taxacean affinity from Upper Triassic in southernmost Paraná Basin (Brazil). *Anais da Academia Brasileira de Ciências,* **76**:595-609.
http://dx.doi.org/10.1590/S0001-37652004000300013

RÖßLER, R.; PHILIPPE, M.; VAN KONIJNENBURG-VAN CITTERT, J.H.-A.; MCLOUGHLIN, S.; SAKALA, J.; ZIJLSTRA, G. 2014. Which name(s) should be used for Araucaria-like fossil wood? – Results of a poll. *Taxon,* **63**(1):177-184.
http://dx.doi.org/10.12705/631.7

ROHN, R.; DUTRA, T.L.; CABRAL, M.V.B. 2014. Conchostráceos como evidência de níveis jurássicos na Formação Caturrita, Faxinal do Soturno, Rio Grande do Sul, Brasil. *Geologia USP, Série Científica*, **14**(1):3-20.
http://dx.doi.org/10.5327/Z1519-874X201400010001

ROYER, D.L. 2006. CO2-forced climate thresholds during the Phanerozoic. *Geochimica et Cosmochimica Acta*, **70**:5665-5675.
http://dx.doi.org/10.1016/j.gca.2005.11.031

SCHULTZ, C.L.; SCHERER, C.M.S.; BARBERENA, M.C. 2000.Biostratigraphy of Southern Brazilian Middle-Upper Triassic. *Revista Brasileira de Geociências*, **30**:495-498.

SEWARD, A.C. 1919. *Fossil plants*. Cambridge, Cambridge University Press, vol. IV, 543 p.

SILVA, R.C.; BARBONI, R.; DUTRA, T.L.; GODOY, M.M.; BINOTTO, R.B. 2012. Footprints of large theropod dinosaurs and implications on the age of Triassic biotas from Southern Brazil. *Journal of South American Earth Sciences*, **39**:16-23.
http://dx.doi.org/10.1016/j.jsames.2012.06.017

VEEVERS, J.J. 2005. Updated Gondwana (Permian-Cretaceous) earth history of Australia. *Gondwana Research*, **9**:231-260.
http://dx.doi.org/10.1016/j.gr.2005.11.005

WILBERGER, T.P. 2009. Record of *Pagiophyllum* Heer in the Lower Mesozoic red beds of Paraná Basin, Southern Brazil, based in epidermal anatomy. *In*: Simpósio Argentino de Paleobotánica y Palinología, 14, Mar del Plata. *Boletín de Resumos*… p. 51.

ZAVATTIERI, A,M.; GNAEDINGER, S.C. 2012. Maderas de gimnospermas de la Formación El Freno (Jurásico Inferior), provincia de Mendoza, Argentina. *In*: Simposio Argentino de Paleobotánica y Palinología, 15, Corrientes. *Actas*... R120.

ZERFASS, H. 2007. *Geologia da Folha Agudo*, SH.22-V-C-V, escala 1:100.000. Serviço Geológico do Brasil – CPRM (CD-ROM). Disponível em: http://www.cprm.gov.br/publique/media/rel_agudo.pdf. Acesso em: 28/05/2016

ZERFASS, H.; CHEMALE JR. F.; SCHULTZ, C.L.; LAVINA, E. 2004. Tectonics and sedimentation in Southern South America during Triassic. *Sedimentary Geology*, **166**:265-292.
http://dx.doi.org/10.1016/j.sedgeo.2003.12.008

ZERFASS, H.; CHEMALE JR. F.; LAVINA, E. 2005. Tectonic control of the Triassic Santa Maria Supersequence of the Paraná Basin, southernmost Brazil, and its correlation to the Waterberg Basin, Namibia. *Gondwana Research*, **8**(2):163-176.
http://dx.doi.org/10.1016/S1342-937X(05)71115-1

ZERFASS, H.; LAVINA. E.; SCHULTZ, C.L.; GARCIA, A.J.V.; FACCINI, U.F.; CHEMALE Jr., F. 2003. Sequence stratigraphy of continental Triassic strata of Southermost Brazil: a contribution to southwestern Gondwana palaeogeography and palaeoclimate. *Sedimentary Geology*, **161**:85-105.
http://dx.doi.org/10.1016/S0037-0738(02)00397-4

Submitted on April 22, 2015
Accepted on November 17, 2015