AMEGHINIANA

A GONDWANAN PALEONTOLOGICAL JOURNAL

UPPER PENNSYLVANIAN AGE OF THE LOWER TALCHIR FORMATION IN THE WARDHA BASIN, CENTRAL INDIA, BASED ON GUIDE PALYNOMORPHS PRESENT IN RADIOMETRICALLY-DATED PALYNOZONATIONS IN SOUTH AMERICA, AFRICA, AND AUSTRALIA

PAULINE S. KAVALI[1]
ANIRBAN ROY[2]
MERCEDES DI PASQUO[3]
GUNDIGA P. GURUMURTHY[1]
GAURAV SHARMA[4]
AJIT KUMAR[5]

[1]Birbal Sahni Institute of Palaeosciences, 53 University Road Lucknow, 226 007 Uttar Pradesh State, India.
[2]Department of Botany K.J. Somaiya College of Science and Commerce, University of Bombay, Mumbai, 400077 Maharashtra State, India.
[3]Laboratorio de Palinoestratigrafía y Paleobotánica, CICYTTP- Pcia. E. R.-UADER (Centro de Investigaciones Científicas y Transferencia de Tecnología a la Producción-Entre Ríos-Universidad Autónoma de Entre Ríos), CONICET (Consejo Nacional de Investigaciones Científicas y Tecnológicas), España 149, E3105BWA Diamante, Entre Ríos, Argentina.
[4]Regional Institute- IV, Central Mine Planning and Design Institute Limited, Jaripatka, Nagpur, 440014 Maharashtra State, India.
[5]Mapp Drilling and Exploration Private Limited, Hyderabad, 500051 Telangana State, India.

Submitted: January 5th, 2021 - **Accepted:** March 29th, 2021 - **Published:** August 31st, 2021

To cite this article: Pauline S. Kavali, Anirban Roy, Mercedes Di Pasquo, Gundiga P. Gurumurthy, Gaurav Sharma, & Ajit Kumar (2021). Upper Pennsylvanian age of the Lower Talchir Formation in the Wardha Basin, Central India, based on guide palynomorphs present in radiometrically- dated palynozonations in South America, Africa, and Australia . *Ameghiniana 58*(4), 318–344.

To link to this article: http://dx.doi.org/10.5710/AMGH.29.03.2021.3423

ARTICLES AMEGHINIANA - 2021 - Volume 58 (4): 318–344

ISSN 0002-7014

UPPER PENNSYLVANIAN AGE OF THE LOWER TALCHIR FORMATION IN THE WARDHA BASIN, CENTRAL INDIA, BASED ON GUIDE PALYNOMORPHS PRESENT IN RADIOMETRICALLY-DATED PALYNOZONATIONS IN SOUTH AMERICA, AFRICA, AND AUSTRALIA

PAULINE S. KAVALI[1], ANIRBAN ROY[2], MERCEDES DI PASQUO[3], GUNDIGA P. GURUMURTHY[1], GAURAV SHARMA[4], AND AJIT KUMAR[5]

[1]Birbal Sahni Institute of Palaeosciences, 53 University Road Lucknow, 226 007 Uttar Pradesh State, India. *kpauline_sabina@bsip.res.in*; *gurumurthygp@bsip.res.in*

[2]Department of Botany K.J. Somaiya College of Science and Commerce, University of Bombay, Mumbai, 400077 Maharashtra State, India. *anirbanroy247@gmail.com*

[3]Laboratorio de Palinoestratigrafía y Paleobotánica, CICYTTP- Pcia. E. R.-UADER (Centro de Investigaciones Científicas y Transferencia de Tecnología a la Producción-Entre Ríos-Universidad Autónoma de Entre Ríos), CONICET (Consejo Nacional de Investigaciones Científicas y Tecnológicas), España 149, E3105BWA Diamante, Entre Ríos, Argentina. *medipa@cicyttp.org.ar*

[4]Regional Institute- IV, Central Mine Planning and Design Institute Limited, Jaripatka, Nagpur, 440014 Maharashtra State, India. *gaurav.cmpdi@gmail.com*

[5]Mapp Drilling and Exploration Private Limited, Hyderabad, 500051 Telangana State, India. *ajit0501kumar@gmail.com*

Abstract. The age of the Talchir Formation corresponding to the lower part of the Gondwana (Permo–Carboniferous) Sequence in India is revised in the light of palynostratigraphic data associated with radiometric dating generated in Gondwana. New data was generated from seven samples of the Talchir Formation obtained from Well 131, located in the Penganga area of Wardha Valley Coalfield (Maharashtra State, central India). Two assemblages were demarcated based on the stratigraphic distribution of 63 species of spores (23 taxa), pollen grains (35 taxa), and phytoplankton. Palynoassociation I recognized in the two basal samples yielded few *Punctatisporites* spores and monosaccate pollen grains. Palynoassociation II is demarcated in the overlying three samples characterized by spores and pollen grains that are more diversified and abundant than in the other two samples. Several taxa (*Concavissimisporites grumulus*, *Converrucosisporites confluens*, *Cyclogranisporites gondwanensis*, *Verrucosisporites andersonii*, *Latusipollenites quadrisaccatus*, *Marsupipollenites striatus*, *Pakhapites fusus*, *Striatoabieites multistriatus*, *Vittatina subsaccata*, *Vittatina vittifera*) are shared with palynozones radiometrically constrained to the latest Pennsylvanian–early Cisuralian in Argentina, Brazil, Africa, and Australia. Therefore, we propose a Kasimovian to Ghezelian–Asselian age for the palynoassociations I and II of the Talchir Formation and a correlation with the *Potonieisporites neglectus* and *Plicatipollenites gondwanensis* Zones of Tiwari & Tripathi, respectively. This approach significantly improves the stratigraphic correlations of the Indian palynozones in Gondwana.

Key words. Carboniferous–Permian. Talchir Formation. India. Palynostratigraphy. Radiometric data. Global correlation.

Resumen. PENNSYLVANIANO SUPERIOR, NUEVA EDAD DE LA FORMACIÓN TALCHIR EN LA CUENCA WARDHA, INDIA CENTRAL, BASADA EN PALINOMORFOS GUÍA PRESENTES EN PALINOZONACIONES RADIOMÉTRICAMENTE DATADAS EN AMÉRICA DEL SUR, ÁFRICA Y AUSTRALIA. La edad de Formación Talchir correspondiente a la parte inferior de la Secuencia Gondwana (Permo–Carbonífero) en India es revisada a la luz de datos palinoestratigráficos asociados a dataciones radiométricas generados en Gondwana. Nuevos datos de siete muestras de la Formación Talchir del Pozo 131 ubicado en el área de Penganga en Wardha Valley Coalfield (Estado de Maharashtra, India central) son generados en este estudio. Dos asociaciones se diferencian con base en la distribución estratigráfica de 63 especies de esporas (23 taxones), granos de polen (35 taxones) y fitoplancton. La Palinoasociación I se reconoció en las dos muestras basales y brindó escasas esporas de *Punctatisporites* y granos de polen monosaccado. La Palinoasociación II se caracteriza en sus tres primeras muestras por esporas y granos de polen más diversificados y abundantes que en las otras dos muestras. En ella aparecen varios taxones (*Concavissimisporites grumulus*, *Converrucosisporites confluens*, *Cyclogranisporites gondwanensis*, *Verrucosisporites andersonii*, *Latusipollenites quadrisaccatus*, *Marsupipollenites striatus*, *Pakhapites fusus*, *Striatoabieites multistriatus*, *Vittatina subsaccata*, *Vittatina vittifera*) documentados en palinozonaciones del Pennsylvaniano–Cisuraliano de Argentina, Brasil, África y Australia. Por ello, proponemos una edad Kasimoviano a Ghezeliano–Asseliano para las palinoasociaciones I y II de la Formación Talchir, y una correlación con las Zonas *Potonieisporites neglectus* y *Plicatipollenites gondwanensis* de Tiwari & Tripathi respectivamente. Este enfoque mejora significativamente las correlaciones estratigráficas de las palinozonas de India en Gondwana.

Palabras clave. Carbonífero–Pérmico. Formación Talchir. India. Palinoestratigrafía. Datos radiométricos. Correlación global.

 AMGHB2-0002-7014/12$00.00+.50

Chronostratigraphic correlations of upper Paleozoic successions in Gondwana are predominantly based on palynofloras bearing common palynospecies and especially taking into account those with similar stratigraphic ranges (cosmopolitan) documented across Gondwana. Although, it is proved that first occurrences of many species (**FAD**) are not synchronous reflecting potential paleogeographic patterns of plant migration (*e.g.*, Truswell, 1980; Backhouse, 1991; Lindström, 1995a, 1995b; Playford & Dino, 2000a, 2000b; Stephenson *et al.*, 2003; di Pasquo, 2003, 2009; Souza, 2006; Stephenson, 2008; Vergel, 2008; Modie & Le Hérissé, 2009; di Pasquo *et al.*, 2010, 2015, 2016; Beri *et al.*, 2011; Césari *et al.*, 2011; Barbolini *et al.*, 2016, 2018; Valdez *et al.*, 2020). Moreover, most of the Carboniferous and Permian palynomorphs and plant macrofossils are endemic to Gondwana, preventing the correlation with the International Time Scale (Gradstein *et al.*, 2012; Ogg *et al.*, 2016), which is calibrated using fossils that are not recorded in Gondwanan biotas. For instance, series and stages of the Permian System are named after marine successions standardized with calibrated biotas belonging to the Urals (lower Permian Cisuralian Series, including the Asselian, Sakmarian, Artinskian, and Kungurian stages), southwestern USA (middle Permian Guadalupian Series, including Roadian, Wordian, and Capitanian stages) and southern China (upper Permian Lopingian Series, including the Wuchiapingian and Changhsingian stages). This chronostratigraphic scheme has the approval of the Permian subcommission of the International Commission on Stratigraphy (Jin *et al.*, 1997; Waterhouse, 1997; Archbold, 1999). This schememakes difficult correlations with the vast bulk of Gondwana due to the lack or infrequent records of marine groups such as foraminifers, conodonts, and ammonoids of the tropical marine international stratotypes (Metcalfe *et al.*, 2017; Henderson, 2018). Late Paleozoic sequences of western Australia and northern Amazonas and Parnaíba basins of Brazil bearing the richest marine faunas (Picarelli *et al.*, 1991; Archbold, 1999; Metcalfe & Sone, 2008) offer the best opportunity to correlate with some precision to those international marine stratotypes, but are absent or extremely rare in most sequences of southern Gondwana. Nevertheless, correlations between farther regions in Gondwana are still possible due to the existence of index taxa having confident FADs, enhanced by absolute dates when interbedded igneous rocks are available in the successions (*e.g.*, Bangert *et al.*, 1999; Santos *et al.*, 2006; Guerra-Sommer *et al.*, 2008; Stephenson, 2009; Gulbranson *et al.*, 2010; Césari *et al.*, 2011; Mori *et al.*, 2012; di Pasquo *et al.*, 2015; Barbolini *et al.*, 2016, 2018; Griffis *et al.*, 2019; Valdez *et al.*, 2020).

In most of the Indian Permian, with a few exceptions (Tiwari & Tripathi, 1992), palynological zones are defined using the dominance datum of taxa (*e.g.*, Aggarwal & Jha, 2013) at generic level, which prevents accurate comparisons and correlations with FAD zonal schemes elsewhere in Gondwana. Additionally, a taxonomic revision of illustrated and listed endemic species of the Permian successions in India (*e.g.*, Tiwari & Tripathi, 1992; Aggarwal & Jha, 2013, and their references) is required as previously highlighted in several publications (Truswell, 1980; Stephenson, 2008; Modie & Le Hérissé, 2009; di Pasquo *et al.*, 2015, 2021; Barbolini *et al.*, 2018). In the case of those taxa that are not illustrated, a revision of samples of their respective works or the development of new studies to identify Pennsylvanian and Permian guide species is mandatory (see Murthy *et al.*, 2020; di Pasquo *et al.*, 2021). Murthy *et al.* (2020) obtained a palynoassemblage attributed to the *Potonieisporites neglectus* Zone of Tiwari & Tripathi (1992) from the Lower Talchir Formation that appears below the *Plicatipollenites gondwanensis* Assemblage Zone bearing diagnostic Permian spores/pollen grains. An undoubted late Carboniferous age is assigned to this basal Talchir Formation by Murthy *et al.* (2020), confirming the interpretation of Mukhopadhyay *et al.* (2010) and few previous studies (Casshyap & Qidwai, 1974; De, 1979; Raja Rao, 1982, 1983, 1987). The early Permian age given by other researchers due to the absence of characteristic late Carboniferous fossils or palynofloras likely by erosion or non-deposition of older strata (Tiwari & Tripathi, 1988, 1992; Venkatachala & Tiwari, 1988; Tiwari, 1996; Vijaya, 1996; Jha *et al.*, 2018) is discarded. Therefore, despite the current lack of absolute dates from the late Paleozoic Indian basins, more accurate palynotaxonomic studies are mandatory to attempt more accurate comparisons and correlations with other palynofloras across Gondwana. We present the results of the palynologic study of core samples from the Talchir Formation at Penganga in Wardha Basin, Maharashtra State, Central India (Fig. 1). The age of the assemblages is based on the recognition of diagnostic species and correlations established with palynozones radiometrically

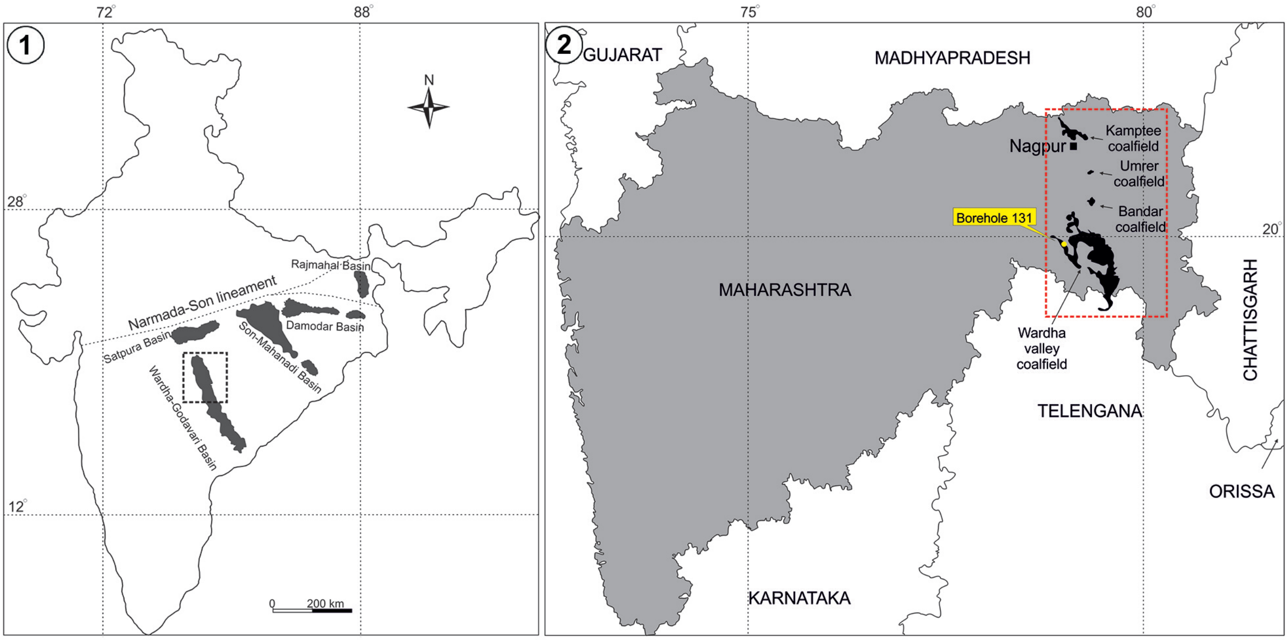

Figure 1. 1, Map showing the Gondwana basins in India (after Geological Survey of India). **2,** Map of Maharashtra State showing the coalfields in the Wardha Basin and the location of Borehole 131 of the present study (after Kavali *et al.*, 2016).

constrained elsewhere in Gondwana. A better age constraint is ongoing for this unit in other basins of India based on the present work.

PREVIOUS WORKS

A review of the voluminous literature from different Gondwana basins of India reveals that palynological studies of the Talchir Formation are relatively scarce compared to the plethora of data generated from the overlying coal-bearing lower Permian Barakar and upper Permian Raniganj formations (and its equivalents Kamthi and Bijori) due to the extensive coal mining activity (Mukhopadhyay *et al.*, 2010). Another possible factor is the scarcity of drill cores of the Talchir sediments available for scientific studies because the exuberant costs prevent the continuity of the drilling below the last coal-bearing sediments just over that unit. However, few palynological works were possible in cases where Talchir sediments were unexpectedly intersected in faulted horizons in due course of drilling. Few studies were also carried out on outcrops.

A literature survey of the palynological works from Talchir sediments of the Wardha Basin is relatively less and requires further studies. Many palynologic studies were carried out in the lower Permian Barakar and upper Permian Kamthi formations (Agashe & Chitnis, 1970, 1972a, 1972b; Anand-Prakash & Khare, 1974; Bharadwaj & Anand-Prakash, 1974; Agashe *et al.*, 1981; Sarate, 1985; Bhattacharrya, 1997; Kumar & Jha, 2000; Jha *et al.*, 2007; Sabina *et al.*, 2007; Shivanna *et al.*, 2008, 2011, 2014; Kalkar *et al.*, 2010; Kavali *et al.*, 2010, 2016; Jha *et al.*, 2011; Murthy & Sarate, 2016; Sarate *et al.*, 2016, 2017; Murthy *et al.*, 2017, 2019). Other studies were on megaspores (Agashe, 1979; Tewari *et al.*, 2004; Murthy *et al.*, 2017) and macrofloras (Bunbury, 1861; Feistmantel, 1881; Chitnis & Vagyani, 1979; Varadpande, 1977a, 1977b; Chandra & Prasad, 1981; Raja Rao, 1982; Tewari & Rajanikanth, 2001; Singh *et al.*, 2005; Tewari, 2007, 2008). Fewer studies concern seeds (Sundaram & Nandi, 1984; Tewari, 2007; Tewari *et al.*, 2012) and gymnospermous woods (Agashe & Prasad, 1989; Agashe & Kumar, 1996, 2001; Agashe, 2001; Agarwal *et al.*, 2007).

Hitherto there is only one published palynological study from the Talchir deposits of the Wardha Basin by Lele (1979). He discovered for the first time a definite basal Talchir microflora from the Penganga river section, close to the glacial pavement near Irai, on the east bank of the Penganga river about 1.6 km to the south of its confluence with the Wardha river. There, the Talchir Formation lies unconformably on the limestones of the Precambrian Penganga Formation, the surface of which exposes the classical Penganga Pavement with grooves and striations studied by Smith (1963), who established it as unequivocal evidence of the late Paleozoic Gondwana glaciation (**LPIA**). The palynoassemblage recovered from the basal Talchir Formation contains 70% acritarchs and 30% miospores dominated by radial monosaccate pollen grains, notably of the genera *Potonieisporites*, *Cannanoropolis*, and *Plicatipollenites*.

Our work is the second palynofloral report from the Talchir Formation of Wardha Basin, and a taxonomic updated list of the species provided by Lele (1979) is included, along with a discussion on its age.

GEOLOGY OF THE AREA

The Gondwana deposits in India are exposed and spread over an enormous extent of 50,000 km^2 and collectively represent about 6,000 m of strata (Mukhopadhyay *et al.*, 2010). The Gondwana basins of Peninsular India show certain specific characteristics in terms of their distribution pattern and mode of evolution. These occur as conspicuous rectilinear belts of basins of failed rift origin (Acharyya, 2000). These basins were embryonic in dimension during the initial stage of Gondwana deposition (*i.e.*, during the Talchir Period), where sedimentation commenced with deposition of glacial and glaciogene fluvio-lacustrine sediments. Evidently, the growth of these deposits continued through a regional tensional regime, in which the basins were characterized by extensional faulting parallel to the rift trend creating half-grabens that formed different sub-basins within the master basin belt (Acharyya, 2000; Tewari & Mahejima, 2010). The evolution and pattern of these Permo–Cretaceous sedimentary basins along particular linear belts are genetically related to the ancient seismo-tectono-thermal activity belts, which particularly became active during the late Paleozoic. The development of basins fits with the structural geometry of the basement modeled by distensional events that resulted in rectilinear distribution patterns (Chakraborthy, 1999). The Indian shield constitutes a multi-cratonic mosaic of several Precambrian crustal blocks assembled together along prominent tectonic joints and mobile belts through the incidence of recurrent tectono-thermal events from Archaean to Late Proterozoic (Chakraborthy, 1999). Four major belts along which these basins are distributed, viz., (a) Satpura-Son-Damodar belt (E–W), (b) Godavari-Wardha belt (NNW–SSE), (c) Mahanadi belt (NNW–SSE), and (d) Rajmahal-Birbhum belt (N–S) (Fig. 1.1).

The Wardha Basin holds a premier position in India for having a considerable share of reserve of thermal grades non-coking coal for catering to the demand of coal in the western part of the country. The late Paleozoic Gondwana outcrops in the Wardha Basin are concentrated in the north-eastern parts of the Maharashtra State, bordering the states of Madhya Pradesh and Telangana (Fig. 1.2). There are several coalfields identified in the Wardha Basin and are concentrated in the districts of Nagpur (Umred Colliery, Sillewara Colliery, Kamptee Colliery, Bina, and Ghatrohan), Chandrapur (Wardha Valley, Ghugus, Ballarpur, Hindustan Lalpeth Colliery, Rajura, Tilwasa, and Sasi Colliery) and Wardha (Majri, Warora, Bandar) (Agashe & Chitnis, 1970; Raja Rao, 1987).

The Wardha Valley Coalfield is located in the southeastern part of Maharashtra State in the districts of Yavatmal and Chandrapur. An area of 4,000 km^2 is estimated, between 19° 30′ and 20° 27′ N, and 78° 50′ and 79° 49′ E (Raja Rao, 1987). The NNW–SSE axis corresponds to the strike of the coal-bearing successions and is around 100 km long with a maximum width of about 80 km. The extension of this coalfield in north-northwest direction beneath the Deccan Trap is not discarded. A south-south eastward continuation of the Wardha Valley Coalfield in Godavari Valley Coalfield of the Telangana State (previously included in Andhra Pradesh State) is considered. The area comprises Precambrian and late Paleozoic Gondwana successions and Deccan Trap rocks covered with black soil and alluvium. The lithostratigraphic sequence in the Wardha Valley Coalfield is given in Figure 2. The general slope of the area is towards the south and drained mainly by the Wardha, Penganga, and Erai rivers. North-eastern area is drained by the Erai river and its tributaries, whereas the southern part of the area is drained by Penganga flowing along the south boundary of the coalfield.

The regional structure of the Wardha Valley Coalfield is a broad anticline plunging towards NNW. Both, the western and eastern limbs of this anticline have been proved to be coal-bearing. The western limb dips westerly, whereas the eastern limb dips easterly. The Gondwana sedimentation in Wardha Valley Coalfield has taken place in NW–SE trending

Age	Formation	Lithology
upper Permian to lower Triassic	Kamthi	Yellow to brown fine to coarse grained sandstones, shale and variegated clays
- - - - - - - - - - - - UNCONFORMITY - - - - - - - - - - - -		
middle Permian	Motur	Medium to fine to grained variegated sandstones, variegated clays and shale
lower Permian	Barakar	Grey to white fine to coarse grained sandstones, thin clay bands, shale, intercalation of shale & sandstone, sandy shale, shaly sandstone, carbonaceous shale, shaly coal and coal.
upper Carboniferous to lower Permian	Talchir	Green shale, grey shale, siltstones and sandstones
- - - - - - - - - - - - UNCONFORMITY - - - - - - - - - - - -		
Precambrian	Vindhyan Formation	Limestone

Figure 2. Lithostratigraphic succession in the Wardha Valley Coalfield (unpublished report of Central Mine Planning and Design Institute Limited).

rift basins separated by Vindhyans. Deccan Trap/Lameta and Kamthi formations unconformably overlie the Motur and coal-bearing Barakar formations, preventing the coal seams outcrop on the surface. NW–SE trending normal faults are major structural features of Wardha Valley Coalfield. These strike faults have caused the repetition of strata in many parts of the coalfield. As a result, the coal seams have occurred at shallow depths in many areas of the Wardha Valley Coalfield, opening additional possibilities of opencast mining in this coalfield.

The coalfield has elliptically aligned coal prospects within the Barakar Formation around the core of Talchir Formation, which occupies its central part. The Gondwana deposits boundary toward the east is delineated by the exposures of Archaean rocks. The intervening area between the faults outlines of coal-bearing deposits towards the northeast, southwest, and southeast is occupied by the Vindhyan Formation, whereas in its central part is the Talchir Formation. The Deccan Trap covers the Gondwana sediments towards the west and north. Strata of the Lameta Formation are available in patches towards the north. The coal-bearing Barakar Formation is exposed only in the western part of the coalfield in isolated patches covered by the overlying Kamthi Formation.

MATERIALS AND METHODS

Nine core samples were collected from Borehole 131 drilled in Penganga area of Wardha Valley Coalfield in Wardha Basin, Central India. The borehole lies between 19° 49′ 4.43″ N and 79° 8′ 3.59″ E (Fig. 1.2). The depth of the borehole is 66 m, and the Talchir Formation comprises grey greenish shales and siltstones that lie over the limestones of the Precambrian Vindhyan basement and overlain by the sandstones of the Barakar Formation (Fig. 3). Samples were processed applying Hydrochloric acid (HCl) 10% and Hydrofluoric acid (HF) 40%, washed with distilled water, sieved through a 10 μm mesh, and slides prepared with +10 residues and Canada balsam. The residues were divided into two sets, and one was oxidized with Nitric acid (HNO_3) 40% for two hours and Potassium hydroxide (KOH) 10% applied for two minutes (see di Pasquo *et al.*, 2021). Quali-quantitative (200 palynomorphs per sample) examination was performed using a Leica DM 2500 light microscope, and pictures of specimens were captured with a Leica DFC290 camera using LAS V4.6 software. Materials were processed at the laboratory of the Birbal Sahni Institute of Palaeosciences (**BSIP**) and housed under the acronyms BSIP 16598–16630. Figured specimens are indicated by the respective acronym followed by the number of the slide and the England Finder coordinate.

RESULTS

Characteristics of the palynoassemblages

The basal grey shale samples, S.1 and S.2, lying over the limestones of the Precambrian Vindhyan basement at a depth of 66 and 64 m, contain poorer assemblages and are the least diversified, represented by monosaccate grains. The overlying greenish shale samples, S.3–S.5, between the depth-interval of 62–57 m, contain the most diversified and best-preserved palynomorphs. The samples S.6–S.7 from the siltstones of the Talchir Formation were poor in their yield. The sandstone samples, S.8 and S.9, of the overlying Barakar Formation were unproductive. The relative frequency and vertical distribution of 63 species composed of spores (23 taxa), pollen grains (35 taxa), and phytoplankton support the definition of two assemblages (Tab. 1), and significant forms are illustrated (Figs. 4–7). The analysis of the chrono-biostratigraphic documentation of spores and pollen grains reveals diagnostic species that allow us to establish correlations addressed in discussion (Fig. 8; Tab. 2).

Palynoassemblage I

It is recognized in the basal-most grey shale sample S.1 at 66 m and S.2 at 64 m depth (Fig. 3), characterized by poorly diverse spores of pteridophytes (*Punctatisporites gretensis*) and cordaitean and coniferalean monosaccate pollen species of *Cannanoropollis*, *Plicatipollenites*, and *Potonieisporites* (Tab. 1).

Palynoassemblage II

The overlying greenish shale samples between the depth intervals of 62 m (S.3)–57 m (S.5) yielded abundant and diversified palynomorphs fairly well preserved. The first appearance of several Permian marker taxa such as the trilete spore *Concavissimisporites grumulus*, *Converrucosisporites confluens*, *Verrucosisporites andersonii* (Pteridophyta), and gymnospermous pollen grains *Latusipollenites quadrisaccatus*, *Pakhapites fusus*, *Striatoabieites multistriatus*, *Vittatina subsaccata*, and *Vittatina vittifera* is documented. Frequent or dominant species of *Plicatipolenites*, *Cannanoropollis*, and *Potonieisporites*, as well as other groups of pollen grains widely distributed in Gondwana, mainly with Pennsylvanian–

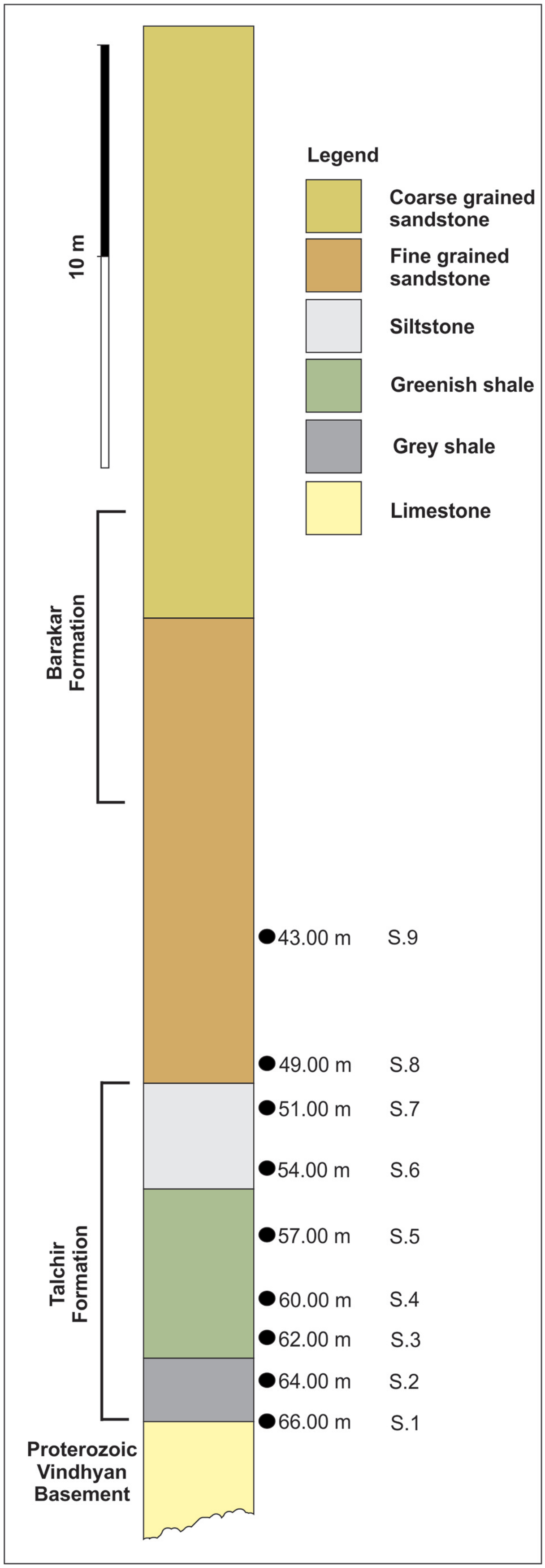

Figure 3. Lithology of Borehole 131 showing the position of samples studied.

TABLE 1. Distribution of taxa and demarcation of Palynoassemblage I and Palynoassemblage II of Talchir Formation in Borehole 131, Wharda Basin.

Taxa	**Assemblage**							
	I				II			*Lele (1979)
Spores / Samples	1	2	3	4	5	6	7	
Brevitriletes cornutus (Balme & Hennelly, 1956) Backhouse, 1991			P	P	P			
Calamospora hartungiana Schopf in Schopf, Wilson & Bentall, 1944			F	F	A			
Calamospora landiana Balme, 1970			F	F	F		X	
Calamospora liquida Kosanke, 1950			F	F	F		X	
Concavissimisporites grumulus Foster, 1979					P			
Converrucosisporites micronodosus (Balme & Hennelly, 1956) Playford & Dino, 2002			F	P	P			
Converrucosisporites confluens (Archangelsky & Gamerro, 1979) Playford & Dino, 2002			P					
Convolutispora ordonensis Archangelsky & Gamerro, 1979			P					
Cristatisporites conatus (Lele & Makada, 1972) comb. nov.					P		X	
Cristatisporites pseudozonatus (Lele & Makada, 1972) Jones & Truswell, 1992			P		P			
Cristatisporites sp.					P		X	
Cyclogranisporites gondwanensis Bharadwaj & Salujha, 1964							X	
Granulatisporites austroamericanus Archangelsky & Gamerro, 1979 (closely similar to ***Microbaculispora tentula*** Tiwari, 1965)			P			X		
Grossusporites sp.			P					
Horriditriletes gondwanensis (Tiwari & Moiz, 1971) Foster, 1975			P	P	P			
Horriditriletes ramosus (Balme & Hennelly, 1956) Bharadwaj & Salujha, 1964			F		P			
Horriditriletes uruguaiensis (Marques-Toigo, 1974) Archangelsky & Gamerro, 1979			P					
Leiotriletes directus Balme & Hennelly, 1956			P	P	F			
Leiotriletes virkkii Tiwari, 1965			F	F	F			
Lophotriletes rectus Bharadwaj & Salujha, 1964					P			
Punctatisporites gretensis Balme & Hennelly, 1956	X	X	F	F	A		X	sp.
Verrucosisporites verrucosus (Ibrahim, 1932) Ibrahim, 1933			P	P				
Verrucosisporites andersonii (Anderson, 1977) Backhouse, 1988			P	P				
Pollen grains / Samples	1	2	3	4	5	6	7	*Lele (1979)
Caheniasaccites flavatus (Bose & Kar, 1966) Azcuy & di Pasquo, 2000						P		X
Cannanaropollis densus (Lele, 1964) Bose & Maheshwari, 1968		X	F	P	P	X		X
Cannanaropollis janakii Potonié & Sah, 1960	X	X	F	F	P	X	X	X
Cannanaropollis mehtae (Lele, 1964) Bose & Maheshwari, 1968	X	X	F					
Cannanaropollis triangularis (Mehta, 1944) Bose & Maheshwari, 1968	X		P					
Cannanaropollis trigonalis (Bose & Maheshwari, 1966) Bose & Maheshwari, 1968			P		P			
Costatascyclus crenatus (Felix & Burbridge, 1967) Urban, 1971			P					
Cycadopites cymbatus (Balme & Hennelly, 1956) Segroves, 1970	X	X	A	A	F		X	
Divarisaccus lelei Venkatachala & Kar, 1966			P	P				
Illinites talchirensis (Lele & Makada, 1972) Azcuy, di Pasquo & Ampuero, 2002					P			

TABLE 1. Continuation.

Taxa	Assemblage							
Pollen grains / Samples	1	2	3	4	5	6	7	*Lele (1979)
Latusipollenites quadrisaccatus Marques-Toigo, 1974			P		P			
Limitisporites rectus Leschik, 1956							X	
Limitisporites hexagonalis Bose & Maheshwari, 1968					P		X	
Lunatisporites noviaulensis Foster, 1979						X		
Lunatisporites varisectus Archangelsky & Gamerro, 1979			P					
Marsupipollenites striatus (Balme & Hennelly, 1956) Foster, 1975			P	P				
Marsupipollenites triradiatus Balme & Hennelly, 1956			F	A	A		X	
Pakahpites fusus (Bose & Kar, 1966) Menéndez ,1971			P					
Plicatipollenites gondwanensis (Balme & Hennelly, 1956) Lele, 1964	X	X	F	F	F	X	X	X
Plicatipollenites malabarensis (Potonié & Sah, 1960) Foster, 1979			A	A	F	X		X
Plicatipollenites trigonalis Lele, 1964	X	X	F	A	F	X	X	X
Potonieisporites barrelis Tiwari, 1965		X			P			X
Potonieisporites congoensis Bose & Maheshwari, 1968	X			P	P			
Potonieisporites densus Maheshwari, 1967		X						X
Potonieisporites lelei Maheshwari, 1967	X	X	F		P	X	X	X
Potonieisporites magnus Lele & Karim, 1971					P			
Potonieisporites neglectus Potonié & Lele, 1961	X	X	P					X
Potonieisporites novicus (Bharadwaj, 1954) Poort & Veld, 1997		X		P	P	X		
Protohaploxypinus latissimus (Luber in Luber & Waltz, 1941) Samoilovich, 1953			P					
Protohaploxypinus limpidus (Balme & Hennelly, 1956) Balme & Playford, 1967			P	F	P			
Protohaploxypinus perfectus (Naumova, 1939) Samoilovich, 1953			P		P			
Scheuringipollenites maximus (Hart, 1960) Tiwari, 1973							X	
Striatoabieites multistriatus Foster, 1979			P		P			
Vittatina subsaccata Samoilovich, 1953					P			
Vittatina vittifera (Luber in Luber & Waltz, 1941) Samoilovich, 1953					P			
Algae / Samples	1	2	3	4	5	6	7	*Lele (1979)
Botryococcus braunii Kützing, 1849	X	X	A	A	F		X	X
Brazilea scissa (Balme & Hennelly, 1956) Foster, 1975			P		P			
Cymatiosphaera gondwanensis (Tiwari, 1965) Backhouse, 1991			P		P			
Tetraporina punctata (Tiwari & Navale, 1968) Kar & Bose, 1976			P		P			

The frequency of species expressed as: X= presence (not counted in the samples at the depths of 66 m, 64 m, 54 m, 51 m), P (present)= < 2.5 %, F (frequent)= 2.5–7 %, A (abundant)= > 7 %). * For synonymy of species illustrated by Lele (1979) proposed herein see in the text under taxonomy.

Permian ranges, include *Marsupipollenites triradiatus*, *Marsupipollenites striatus* (Pteridospermophyta), *Cycadopites cymbatus* (Cycadophyta/Ginkgophyta). Among spores, sphenophytes (*Calamospora hartungiana*, *Calamospora landiana*, *Calamospora liquida*), pteridophytes (*Brevitriletes cornutus*, *Convolutispora ordonensis*, *Converrucosisporites micronodosus*, *Horriditriletes ramosus*, *Horriditriletes uruguayensis*, *Horriditriletes gondwanensis*, *Punctatisporites gretensis*, *Leiotriletes directus*, *Leiotriletes virkkii*) and few lycophytes (*Cristatisporites pseudozonatus*, *Cristatisporites conatus*) are present.

SYSTEMATIC PALEONTOLOGY

Suprasubturma LAMINATITRILETES
Smith & Butterworth, 1967
Subturma ZONOLAMINATITRILETES
Smith & Butterworth, 1967
Infraturma CINGULICAVATI
Smith & Butterworth, 1967

Genus ***Cristatisporites*** (Potonié & Kremp, 1954)
Butterworth, Jansonius, Smith & Staplin, 1964

Type species. *Cristatisporites indignabundus* Loose in Potonié & Kremp, 1954. Pennsylvanian of Germany.

Cristatisporites conatus
(Lele & Makada, 1972) comb. nov.

Basionym. *Jayantisporites conatus* Lele & Makada, 1972.
Remarks. The general morphology is similar to *Cristatisporites menendezii* (Menéndez & Azcuy, 1972) Playford, 1978 emend. Césari, 1986 and *Cristatisporites stellatus* (Azcuy, 1975) Gutiérrez & Limarino, 2001, although it differs in having a narrower incomplete cingulizone composed of cristate ornamentation. *Cristatisporites pseudozonatus* (Lele & Makada, 1972) Jones & Truswell, 1992 is characterized by a larger and denser cristate ornamentation. Backhouse (1988) considered *Cristatisporites inconstans* Archangelsky & Gamerro, 1979 a junior synonym of the latter taxon, whereas we agree with other authors that maintain both species separated based on minor differences of their ornamentation and completeness of cingulizones (see Jones & Truswell, 1992; Césari *et al*., 2019; Backhouse & Mory, 2020).

On the other hand, we propose a re-assignment of the illustrated species from Talchir Formation published by Lele (1979) as follows: *Callumispora uniformis* (Tiwari, 1968) Lele & Chandra, 1977 (Lele, 1979, pl. 1.1) = *Punctatisporites gracilis* Anderson, 1977; *Plicatipollenites indicus* Lele, 1964 (Lele, 1979, pl. 1.2), and *Potonieisporites crassus* Lele & Chandra, 1977 (Lele, 1979, pl. 1.5) = *Plicatipollenites malabarensis* (Potonié & Sah, 1960) Foster, 1975; *Plicatipollenites densus* Lele, 1964 (Lele, 1979, pl. 1.4) = *Plicatipollenites gondwanensis* (Balme & Hennelly, 1956) Lele, 1964; *Potonieisporites crassus* Lele & Chandra, 1977 (Lele, 1979, pl. 1.6) = *Potonieisporites densus* Maheshwari, 1967; *Potonieisporites jayantensis* Lele & Karim, 1972 (Lele, 1979, pl. 1.7) = *Potonieisporites barrelis* Tiwari, 1965 (see Azcuy & di Pasquo, 2000); *Parasaccites densicorpus* Lele, 1964 (Lele, 1979, pl. 1.10–1.11) and *Parasaccites densus* Maheshwari, 1967 (Lele, 1979, pl. 1.12) = *Cannanoropollis densus* (Lele, 1964) Bose & Maheshwari, 1968; *Parasaccites korbaensis* Bharadwaj & Tiwari, 1964 (Lele, 1979, pl. 1.13), *Parasaccites diffusus* Tiwari, 1965 (Lele, 1979, pl. 1.14); and *Parasaccites fimbriatus* Maheshwari, 1969 (Lele, 1979, pl. 1.15) = *Cannanoropollis janakii* Potonié & Sah, 1960 (see Azcuy & di Pasquo, 2000); *Caheniasaccites densus* Lele & Karim, 1972 (Lele, 1979, pl. 1.16) = *Caheniasaccites flavatus* Bose & Kar, 1966 (see Azcuy & di Pasquo, 2000); *Gondwanopollis densus* Lele & Chandra, 1977 (Lele, 1979, pl. 1.17) = *Potonieisporites lelei* Maheshwari, 1967 (see Tab. 1). The specimen cf. *Crescentipollenites* (Lele, 1979, pl. 1.18) would fit in *Lunatisporites* sp. based on the description of the striated cappa.

DISCUSSION

Age of the assemblages

Most of the Gondwana palynostratigraphic works published in India applied the palynozonation scheme proposed by Tiwari and Tripathi (1992). They have demarcated three palynozones in the basal Talchir Formation: *Potonieisporites neglectus*, *Plicatipollenites gondwanensis*, and *Cannanoropollis janakii* (=*Parasaccites korbaensis*) in stratigraphic order constrained to the early Permian based on the general dominance of monosaccates and the associated occurrence of the marine *Eurydesma* fauna. Murthy *et al.* (2020) revised the age of these palynozones based on a critical analysis of the composition of these assemblage zones, their reference

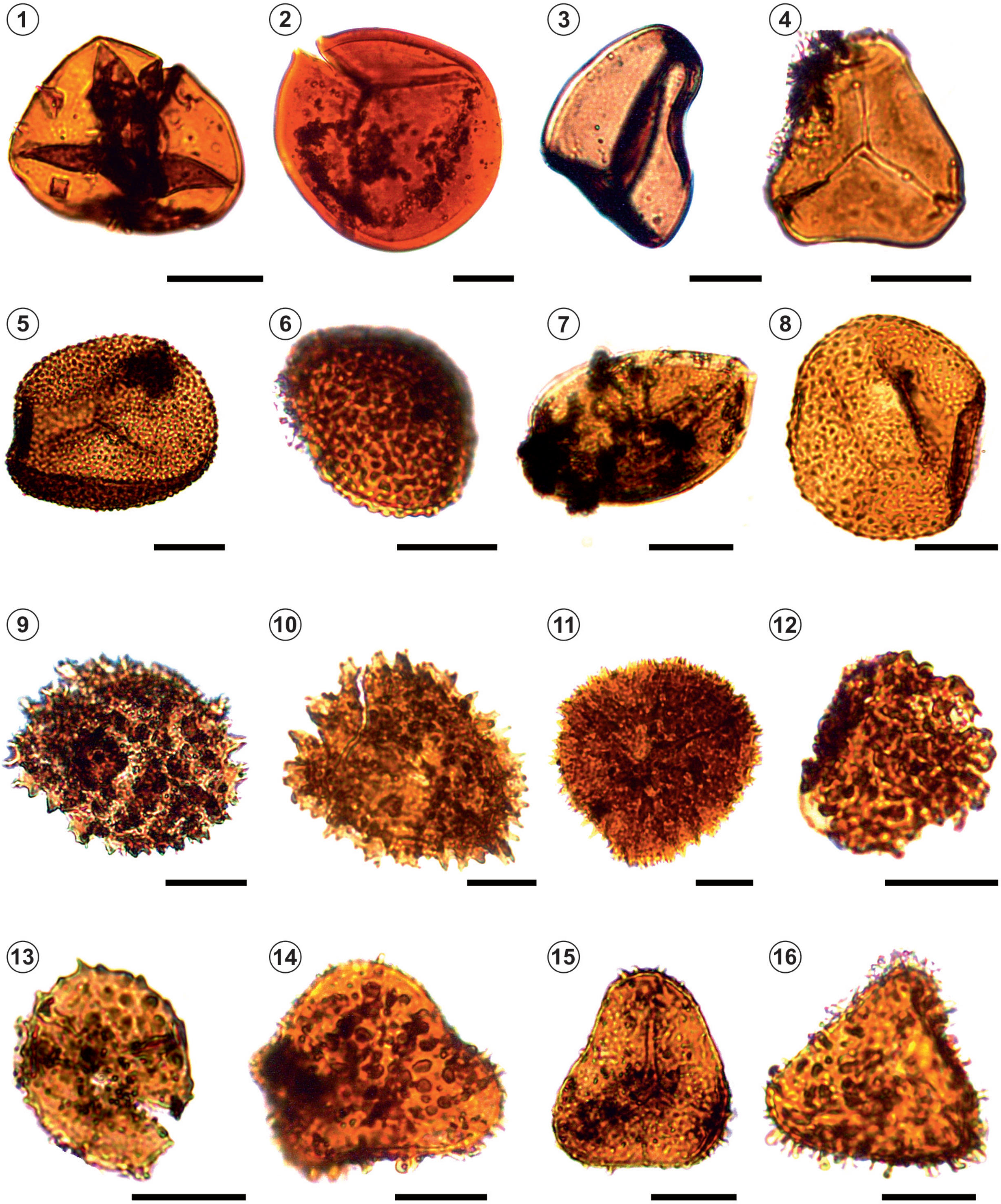

Figure 4. 1, ***Calamospora landiana*** Balme, 1970, **BSIP** 16620, EF: M.45; **2,** ***Punctatisporites gretensis*** Balme & Hennelly, 1956, **BSIP** 16604, EF: J.49; **3,** ***Leiotriletes directus*** Balme & Hennelly, 1956, **BSIP** 16605, EF: P.52; **4,** ***Leiotriletes virkkii*** Tiwari, 1965, **BSIP** 16612, EF: L.34; **5,** ***Cyclogranisporites gondwanensis*** Bharadwaj & Salujha, 1964, **BSIP** 16628, EF: K.57; **6,** ***Verrucosisporites verrucosus*** (Ibrahim, 1932) Ibrahim, 1933, **BSIP** 16618, EF: J.43.4; **7,** ***Grossusporites*** sp., **BSIP** 16620, EF: X.35; **8,** ***Verrucosisporites andersonii*** (Anderson, 1977) Backhouse, 1988, **BSIP** 16598, EF: G.53.3; **9,** ***Cristatisporites conatus*** (Lele & Makada, 1972) comb. nov., **BSIP** 16626, EF: V.50; **10,** ***Cristatisporites pseudozonatus*** (Lele & Makada, 1972) Jones & Truswell, 1992, **BSIP** 16615, EF: T.46.4; **11,** ***Cristatisporites*** sp., **BSIP** 16625, EF: O.44.2; **12,** ***Convolutispora ordonensis*** Archangelsky & Gamerro, 1979, **BSIP** 16612, EF: V.50; **13,** ***Brevitriletes cornutus*** (Balme & Hennelly, 1956) Backhouse, 1991, **BSIP** 16618, EF: W.51; **14,** ***Horriditriletes ramosus*** (Balme & Hennelly, 1956) Bharadwaj & Salujha, 1964, **BSIP** 16604, EF: H.67; **15,** ***Horriditriletes gondwanensis*** (Tiwari & Moiz, 1971) Foster, 1975, **BSIP** 16624, EF: M.28.1; **16,** ***Horriditriletes uruguayensis*** (Marques-Toigo, 1974) Archangelsky & Gamerro, 1979, **BSIP** 16618, EF: W.41.3. Scale bars equal 20 μm.

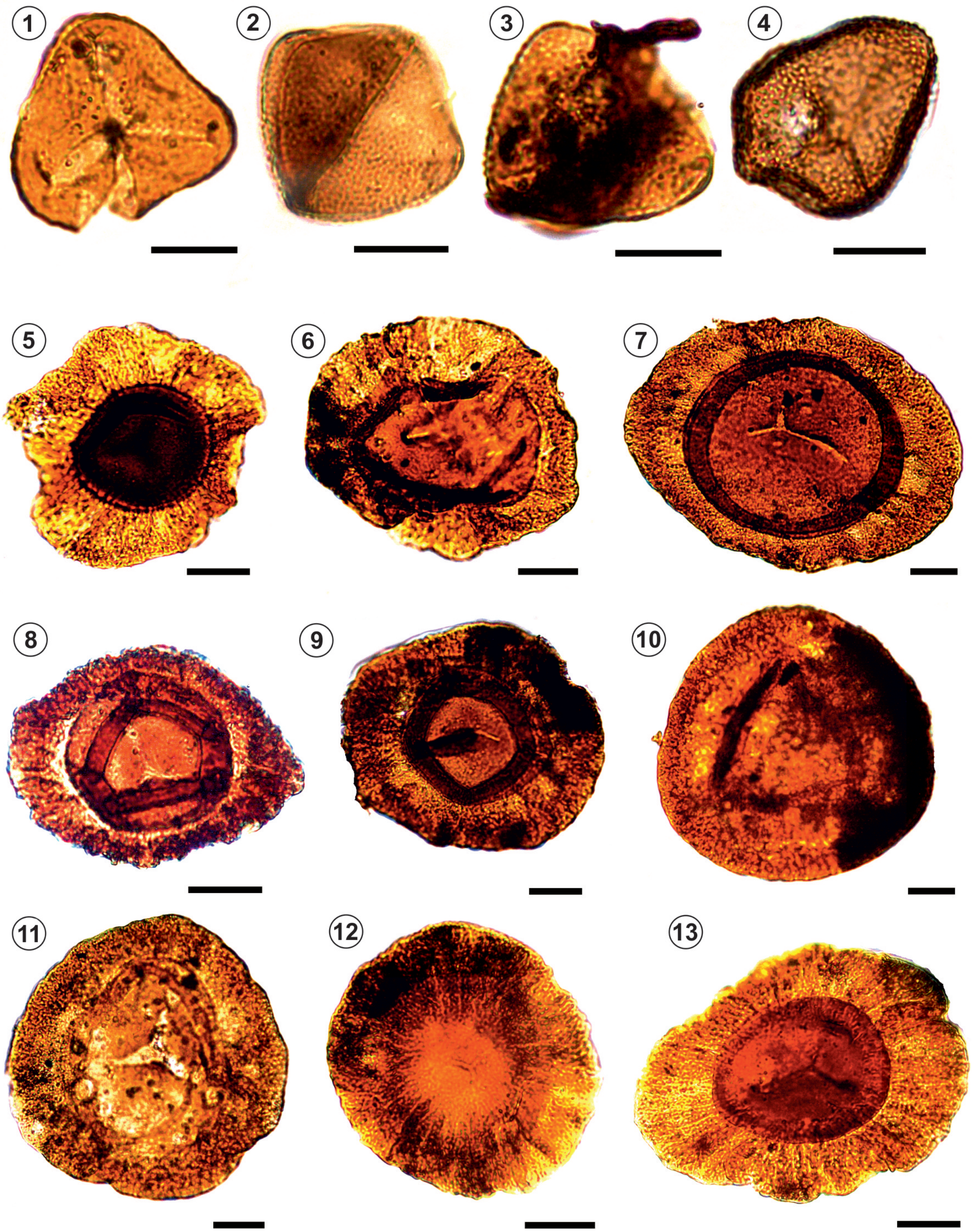

Figure 5. 1, ***Granulatisporites austroamericanus*** Archangelsky & Gamerro, 1979, **BSIP** 16629, EF: X.45.2; **2–3,** ***Pseudoreticulatispora confluens*** (Archangelsky & Gamerro, 1979) Backhouse, 1991, **2, BSIP** 16620, EF: K.51, **3, BSIP** 16620, EF: X.34.1; **4,** ***Converrucosisporites micronodosus*** (Balme & Hennelly, 1956) Playford & Dino, 2002, **BSIP** 16611, EF: Q.35.1; **5,** ***Cannanaropollis densus*** (Lele, 1964) Bose & Maheshwari, 1968, **BSIP** 16598, EF: E.43.1; **6, 8–9,** ***Plicatipollenites gondwanensis*** (Balme & Hennelly, 1956) Lele, 1964, **6, BSIP** 16598, EF: N.52.1, **8, BSIP** 16600, EF: P.48.1, **9, BSIP** 16600, EF: W.34.1; **7,** ***Plicatipollenites malabarensis*** (Potonié & Sah, 1960) Foster, 1979, **BSIP** 16599, EF: Q.30.4; **10–11,** ***Plicatipollenites trigonalis*** Lele, 1964, **10, BSIP** 16602, EF: F.11, **11, BSIP** 16601, EF: E.48; **12,** ***Cannanaropollis janakii*** Potonié & Sah, 1960, **BSIP** 16603, EF: G.64; **13,** ***Costatascyclus crenatus*** (Felix & Burbridge, 1967) Urban, 1971, **BSIP** 16604, EF: W.46. Scale bars equal 20 μm.

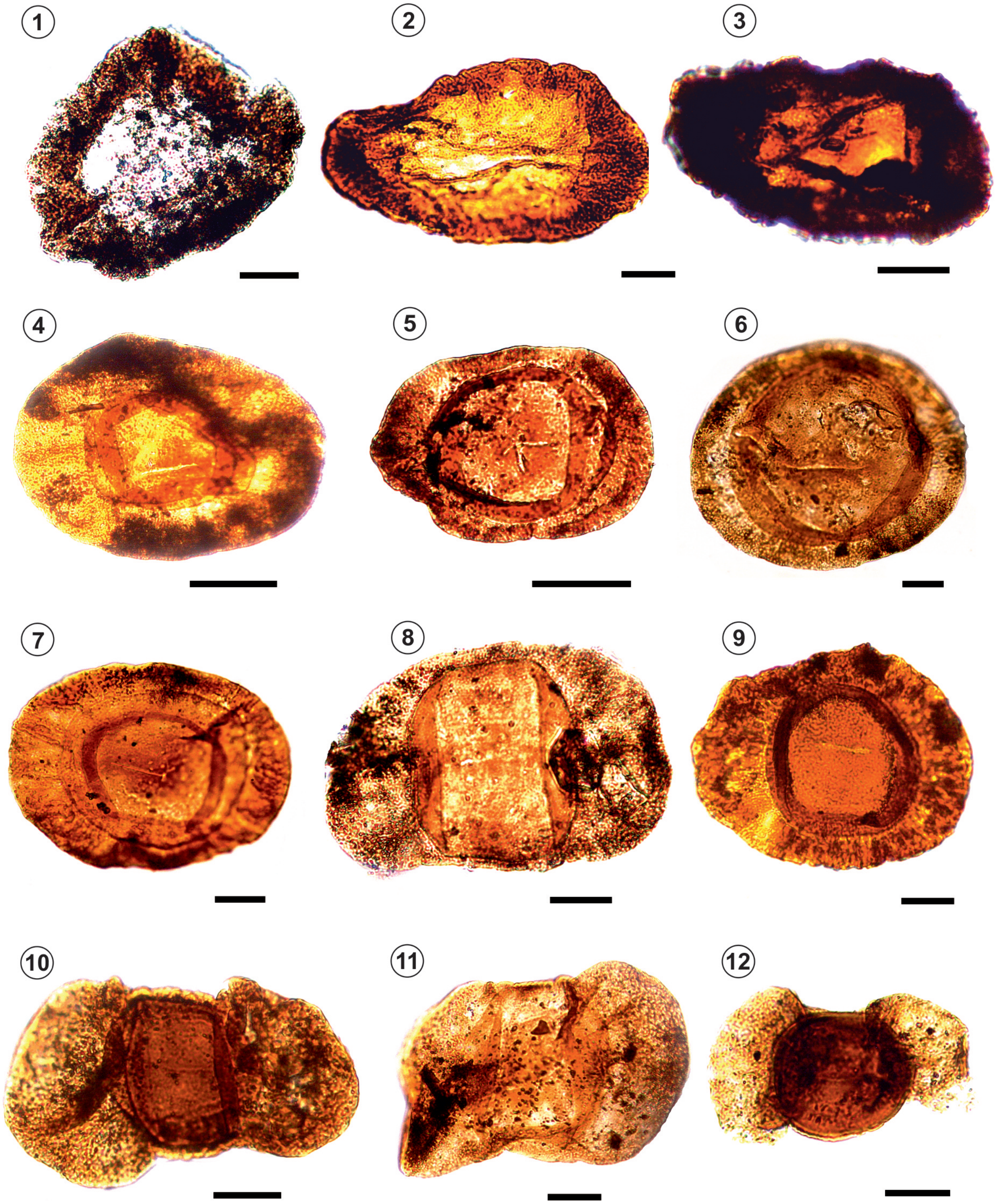

Figure 6. 1, ***Cannanaropollis triangularis*** (Mehta, 1944) Bose & Maheshwari, 1968, **BSIP** 16605, EF: X.51; **2,** ***Divarisaccus lelei*** Venkatachala & Kar, 1966, **BSIP** 16603, EF: G.10; **3,** ***Latusipollenites quadrisaccatus*** Marques-Toigo, 1974, **BSIP** 16608, EF: X.64; **4,** ***Potonieisporites densus*** Maheshwari, 1967, **BSIP** 16609, EF: S.40; **5–6,** ***Potonieisporites novicus*** (Bharadwaj, 1954) Poort & Veld, 1997, **5, BSIP** 16600, EF: P.48.1, **6, BSIP** 16609, EF: W.59; **7,** ***Potonieisporites congoensis*** Bose & Maheshwari, 1968, **BSIP** 16609, EF: M.53.4; **8,** ***Potonieisporites barrelis*** Tiwari, 1965, **BSIP** 16610, EF: L.71.4; **9,** ***Potonieisporites lelei*** Maheshwari, 1967, **BSIP** 16602, EF: W.50.2; **10,** ***Potonieisporites lelei*** transitional to ***Limitisporites hexagonalis***, **BSIP** 16609, EF: T.61.1; **11,** ***Limitisporites hexagonalis*** Bose & Maheshwari, 1968, **BSIP** 16609, EF: Y.61.1; **12,** ***Caheniasaccites flavatus*** (Bose & Kar, 1966) Azcuy & di Pasquo, 2000, **BSIP** 16604, EF: U.34.2. Scale bars equal 20 μm (**1–6**, **9–12**), 50 μm (**7–8**).

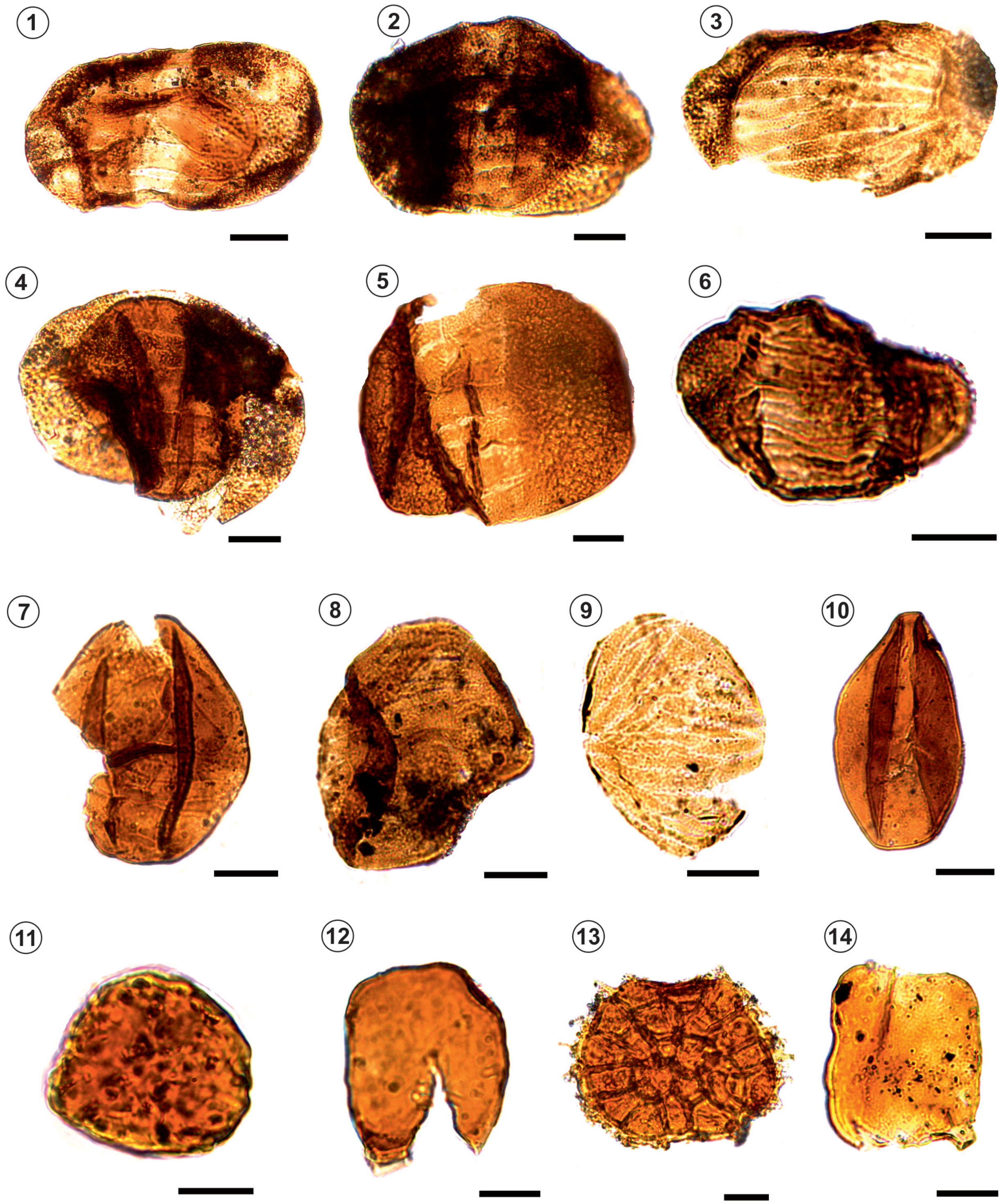

Figure 7. 1, ***Illinites talchirensis*** (Lele & Makada, 1972) Azcuy, di Pasquo, & Ampuero, 2002, **BSIP** 16604, EF: M.63.2; **2,** ***Protohaploxypinus perfectus*** (Naumova, 1939) Samoilovich, 1953, **BSIP** 16611, EF: J.54; **3,** ***Vittatina subsaccata*** Samoilovich, 1953, **BSIP** 16603, EF: S.69.3; **4,** ***Lunatisporites variesectus*** Archangelsky & Gamerro, 1979, **BSIP** 16611, EF: J.54; **5,** ***Lunatisporites noviaulensis*** Foster, 1979, **BSIP** 16602, EF: R.39; **6,** ***Striatoabietites multistriatus*** Foster, 1979, **BSIP** 16613, EF: P.50.4; **7,** ***Pakahpites fusus*** (Bose & Kar, 1966) Menéndez, 1971, **BSIP** 16614, EF, Q.47; **8,** ***Vittatina vittifera*** (Luber in Luber & Waltz, 1941) Samoilovich, 1953, **BSIP** 16615, U.31; **9,** ***Marsupipollenites striatus*** (Balme & Hennelly, 1956) Foster, 1975, **BSIP** 16616, EF: E.35.4; **10,** ***Marsupipollenites triradiatus*** Balme & Hennelly, 1956, **BSIP** 16609, EF: Q.49.3; **11,** ***Botryococcus braunii*** Kützing, 1849, **BSIP** 16626, EF: U.38.1; **12,** ***Brasilea scissa*** (Balme & Hennelly, 1956) Foster, 1975, **BSIP** 16609, EF: S.32; **13,** ***Cymatiosphaera gondwanensis*** (Tiwari, 1965) Backhouse, 1991, **BSIP** 16601, EF: U.49; **14,** ***Tetraporina punctata*** (Tiwari & Navale, 1968) Kar & Bose, 1976, **BSIP** 16599, EF: N.58.1. Scale bars equal 20 μm.

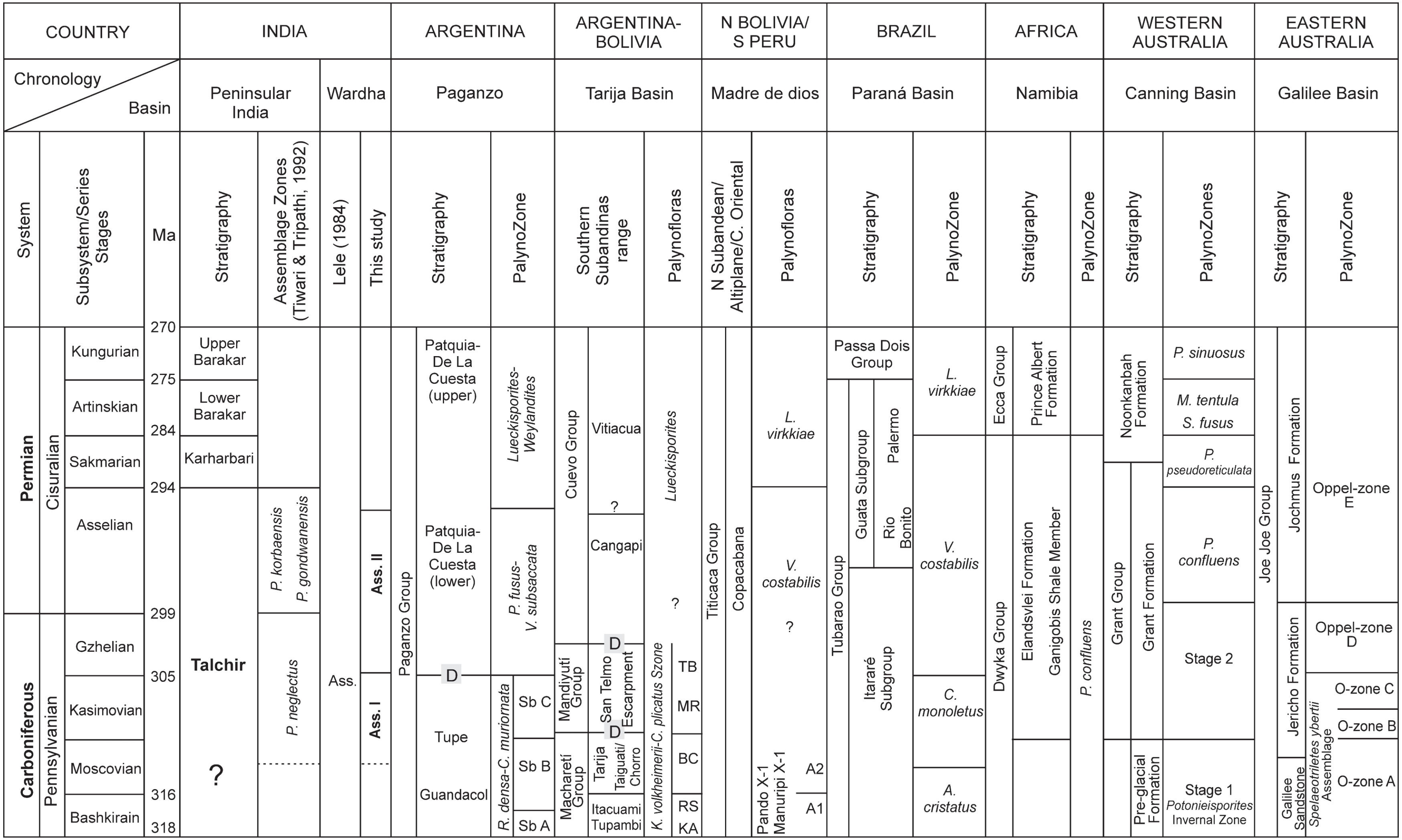

Figure 8. Age proposed for the Palynoassemblages I and II of the present study based on correlation with selected biostratigraphic schemes radiometrically constrained across Gondwana. References: Argentina-Paganzo Basin (Césari & Gutiérrez, 2001; di Pasquo *et al.*, 2010; Césari *et al.*, 2013; Césari & Chiesa, 2017; Valdez *et al.*, 2020). Bolivia, Tarija Basin (di Pasquo, 2003; di Pasquo *et al.*, 2017); Madre de Dios (di Pasquo *et al.*, 2015, 2019). Brazil, Paraná Basin (Mori *et al.*, 2012; Souza *et al.*, 2021). Uruguay, Paraná Basin (Beri *et al.*, 2011). Africa (Stephenson, 2009). Western Australia, Canning Basin (Foster & Waterhouse, 1988; Backhouse & Mory, 2020). Eastern Australia, Galilee Basin (Jones & Truswell, 1992; Backhouse & Mory, 2020). Abbreviations: **AC,** *Striatoabieites anaverrucosus-Staurosaccites cordubensis*; **BC,** *Dictyotriletes bireticulatus-Cristatisporites chacoparanensis*; **FM,** Fraile Muerto Member of Melo Formation; **IS,** *Cristatisporites inconstans-Vittatina subsaccata*; **KA,** *Crassispora kosankei-Cystoptychus azcuyi*; **Mg,** Mangrullo Member of Melo Formation; **MR,** *Converrucosisporites micronodosus-Reticulatisporites reticulatus*; **RS,** *Raistrickia radiosa-Apiculatisporis spinulistratus*; **TB,** *Marsupipollenites triradiatus-Lundbladispora braziliensis*.

TABLE 2. Biostratigraphic distribution of spores and pollen grain species across Gondwana addressed in the present study.

Taxa / Basins	DAMODAR-RAJMAHAL (India)			PAGANZO (Argentina)				TARIJA (Bolivia)			MADRE DE DIOS (Bolivia)		PARANÁ (Brazil)			PARANÁ (Uruguay)	NAMIBIA (Africa)	CANNING (Western Australia)		GALILEE (Eastern Australia)		
Samples	Pn	Pg	Pk	DMa	DMb	DMc	FS	KA-RS	BC	MR-TB	A1/A2	Vc	Ac	Cm	Vc	IS	Cc	Va-Mt	Pc	OpZ C	OpZ D	OpZ E
Spores																						
Brevitriletes cornutus					X	X	X								X	X	X		X			
Calamospora hartungiana				X	X	X	X	X	X	X			X	X	X	X						
Calamospora landiana												X										
Calamospora liquida			X		X	X	X			X	X		X	X	X							
Concavissimisporites grumulus																						
Converrucosisporites micronodosus										X					X	X			X			
Converrucosisporites confluens							X			X					X	X			X			
Convolutispora ordonensis				X	X	X	X			X	X			X	X	X						
Cristatisporites conatus		X	X																			
Cristatisporites pseudozonatus		X	X															X	X	X	X	
Cristatisporites sp.																						
Cyclogranisporites gondwanensis															X	X						
Granulatisporites austroamericanus		X		X	X	X	X			X					X	X						
Grossusporites sp.																						
Horriditriletes gondwanensis															X							
Horriditriletes ramosus							X							X	X	X	X				X	X
Horriditriletes uruguaiensis				X	X	X	X							X	X	X	X					
Leiotriletes directus				X	X	X	X		X	X		X			X	X	X					
Leiotriletes virkkii						X	X									X						
Lophotriletes rectus															X	X						
Punctatisporites gretensis		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X
Verrucosisporites verrucosus									X	X						X						
Verrucosisporites andersonii					X	X	X			X						X		X	X			
Pollen grains																						
Caheniasaccites flavatus		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Cannanaropollis densus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
Cannanaropollis janakii	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Cannanaropollis mehtae	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X						
Cannanaropollis triangularis	X	X		X	X	X	X	X	X	X	X	X	X	X	X							
Cannanaropollis trigonalis				X	X	X	X	X	X	X	X	X	X	X	X							
Costatascyclus crenatus	X			X	X		X	X			X		X			X						
Cycadopites cymbatus							X					X					X		X			

TABLE 2. Continuation.

Taxa \ Basins	DAMODAR-RAJMAHAL (India)			PAGANZO (Argentina)				TARIJA (Bolivia)			MADRE DE DIOS (Bolivia)		PARANÁ (Brazil)			PARANÁ (Uruguay)	NAMIBIA (Africa)	CANNING (Western Australia)		GALILEE (Eastern Australia)		
Samples	Pn	Pg	Pk	DMa	DMb	DMc	FS	KA-RS	BC	MR-TB	A1/A2	Vc	Ac	Cm	Vc	IS	Cc	Va-Mt	Pc	OpZ C	OpZ D	OpZ E
Divarisaccus lelei	X	X	X																			
Illinites talchirensis		X	X																			
Latusipollenites quadrisaccatus							X								X	X						
Limitisporites rectus		X		X	X	X	X			X		X		X	X	X						
Limitisporites hexagonalis		X		X	X	X	X			X		X		X	X	X						
Lunatisporites noviaulensis							X									X						
Lunatisporites varisectus		X					X								X	X						
Marsupipollenites striatus							X					X			X	X			X			
Marsupipollenites triradiatus							X			X	X	X			X	X						
Pakahpites fusus							X					X			X	X	X					
Plicatipollenites gondwanensis	X	X	X	X	X	X	X		X	X		X			X	X				X	X	
Plicatipollenites malabarensis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
Plicatipollenites trigonalis	X	X	X	X	X	X	X	X	X	X	X				X	X		X	X			
Potonieisporites barrelis	X	X	X	X	X	X	X	X	X	X	X	X			X	X						
Potonieisporites congoensis	X	X	X	X	X	X	X	X	X	X	X				X	X						
Potonieisporites densus	X	X	X	X	X	X	X	X	X	X	X	X			X	X						
Potonieisporites lelei	X	X	X	X	X	X	X	X	X	X	X				X	X						
Potonieisporites magnus	X	X	X	X	X	X	X	X	X	X	X	X			X	X						
Potonieisporites neglectus	X	X	X	X	X	X	X	X	X	X	X	X			X	X						
Potonieisporites novicus	X	X		X	X	X	X	X	X	X	X				X	X		X	X	X	X	X
Protohaploxypinus latissimus		X	X				X															
Protohaploxypinus limpidus			X		X	X	X					X			X	X	X		X			
Protohaploxypinus perfectus							X								X	X						
Scheuringipollenites maximus		X	X		X	X	X				X			X	X	X						
Striatoabieites multistriatus							X								X	X	X					
Vittatina subsaccata							X								X	X						
Vittatina vittifera							X					X			X	X						

Abbreviations: **Pn,** *Potonieisporites neglectus*; **Pg,** *Plicatipollenites gondwanensis*; **Pk,** *Parasaccites korbaensis*; **DM,** *Raistrickia densa-Convolutispora muriornata*; **FS,** *Pakhapites fusus-Vittatina subsaccata*; **KA,** *Crassispora kosankei-Cystoptychus azcuyi*; **RS,** *Raistrickia radiosa-Apiculatisporis spinulistratus*; **BC,** *Dictyotriletes bireticulatus-Cristatisporites chacoparanensis*; **MR,** *Converrucosisporites micronodosus-Reticulatisporites reticulatus*; **TB,** *Marsupipollenites triradiatus-Lundbladispora braziliensis*; **Vc,** *Vittatina costabilis*; **Ac,** *Ahrenisisporites cristatus*; **Cm,** *Crucisaccites monoletus*; **IS,** *Cristatisporites inconstans-Vittatina subsaccata*; **Cc, Pc,** *Converrucosisporites* (= *Pseudoreticulatisporites*) *confluens*; **Va,** *Vallatisporites arcuatus*; **Mt,** *Microbaculispora tentula*. See also Figure 8. References: Damodar-Rajmahal basins (India): Tiwari and Tripathi (1992); Murthy *et al.* (2020). Paganzo Basin (Argentina): Césari and Gutiérrez (2001); di Pasquo *et al.* (2010); Césari *et al.* (2013); Césari and Chiesa (2017); Valdez *et al.* (2020). Tarija Basin (Bolivia): di Pasquo (2003); di Pasquo *et al.* (2017). Madre de Dios (Bolivia): di Pasquo *et al.* (2015, 2019). Paraná Basin (Brazil): Mori *et al.* (2012); Souza *et al.* (2021). Paraná Basin (Uruguay): Beri *et al.* (2011). Namibia (Africa): Stephenson (2009). Canning Basin (Western Australia): Foster and Waterhouse (1988); Backhouse and Mory (2020). Galilee Basin (Eastern Australia): Jones and Truswell (1992); Backhouse and Mory (2020).

horizons and corresponding lithofacies, and associated fossils (see Murthy *et al.*, 2020, tab. 3) and proposed a correlation with radiometrically constrained similar assemblages across Gondwana. They established for the first time, a late Pennsylvanian age to the oldest *Potonieisporites neglectus* Assemblage Zone of Tiwari & Tripathi (1992) based on the absence of species with earliest Permian's FAD and the first occurrence of Glossopteridales in association with the overlying palynozones in the Damodar-Rajmahal Basins (Fig. 1.1). A Pennsylvanian age is also affirmed by global occurrence of the constituent elements of the palynozone in congruence with radiometrically constrained palynozones of South America and elsewhere in Gondwana (see di Pasquo *et al.*, 2015; Valdez *et al.*, 2020 and references therein).

The overlying *Plicatipollenites gondwanensis* Assemblage Zone from the siltstones above younger boulder beds was attributed to the early Cisuralian by Murthy *et al.* (2020) based on the first appearance of Permian marker taxa, reinforced by associated *Eurydesma* assemblage fauna (Lele & Makada, 1972). Currently, despite some taxonomic revision of species yet required, several palynozones across Gondwana, calibrated with radiometric data from interbedded igneous rocks, support or improve the stratigraphic ranges of Pennsylvanian/Permian diagnostic taxa that are present in the *P. gondwanensis* Zone (Fig. 8; Tab. 1).

Hitherto, Lele (1979) reported a palynoflora from the siltstone and clasts associated with the basal boulder beds of the Talchir Formation that unconformably overlie the Proterozoic Penganga limestones and dolomites near Irai in Maharahtra State, Central India (Wardha Basin, Fig. 1). He recorded for the first time a definite basal Talchir microflora dominated by phytoplanktonic species (70%), few trilete spores of *Punctatisporites* and monosaccate pollen species of the genera *Potonieisporites* (12%), *Cannanoropollis* (9.5%), *Plicatipollenites* (4.5%), *Caheniasaccites* (2.5%) and poorly preserved bisaccate pollen grains (striate?) (Tab. 1). Interestingly, while other researchers assigned this unit to the early Permian (*e.g.*, Tiwari & Tripathi, 1992; Tiwari, 1999), Lele (1979) had correlated this assemblage with the late Pennsylvanian Stage 1 of Australia (Kemp *et al.*, 1977). Smith (1963) attributed a glacial origin to the Talchir boulder beds at Irai resting on striated pavements and pointed out its equivalence with other late Carboniferous Gondwanan glacial units.

The present study is the second palynofloral report of the Talchir Formation in the Wardha Basin. The older Palynoassemblage I (**PI**) of our study is tentatively correlated with that of Lele (1979) based on their compositional similarities despite the different kinds of phytoplankton in the present assemblage (Tab. 1). Lele (1979) did not find any equivalent assemblage with our Palynoassemblage II (**PII**). More accurate correlations between the two lower palynozones of the Talchir Formation across Gondwana are addressed below (Fig. 8).

Correlation with other basins in India

Despite the plethora of palynodata generated from the Indian Gondwana basins, unfortunately, most of the assemblages of the Talchir Formation cannot be correlated with our results and other Gondwanan palynoassemblages as they are mostly dated using dominance and sub-dominance of species instead of using chronometric tie species. Besides, some works do not provide a robust lithostratigraphic framework, which undermines the essence of biostratigraphic correlation. We have confined our correlation with the recent work of Murthy *et al.* (2020) from Rajmahal Basin, who applied chronometric tie species (FADs and chronostratigraphic ranges of species) in regional correlations of their assemblages. Hence, our Palynoassemblage I from the basal Talchir Formation correlates with the older Palynoassemblage I of Murthy *et al.* (2020) and the assemblage of Lele (1979), sharing palynological features like the dominance of monosaccate pollen species of the genera *Cannanaropollis*, *Plicatipollenites*, and *Potonieisporites* and the absence of typical Permian marker taxa. The Palynoassemblage II of the present study correlates with the younger assemblage from the Rajmahal Basin (Murthy *et al.*, 2020), characterized by more diversified pollen and spore species recording the first appearance of taxa such as *Cristatisporites pseudozonatus*, *C. conatus*, and *Lunatisporites variesectus*. However, the present assemblage documents the first appearance of several other taxa such as *Converrucosisporites confluens*, *Latusipollenites quadrisaccatus*, *Marsupipollenites striatus*, *Pakhapites fusus*, *Striatoabieites multistriatus* (Tab. 2), documented in the latest Pennsylvanian–Asselian palynozones in Gondwana as further discussed.

Comparison and correlation with radiometrically constrained assemblages from Gondwana Palynoassemblage I

Palynological associations documented across Gondwana since the Bashkirian are dominated by long-ranged monosaccate pollen grains with the absence of Permian markers like in the Palynoassemblage I of the present study. A comparison with radiometrically constrained palynoassemblages is addressed below to attempt correlations (Fig. 8; Tab. 2).

Argentina. The Carboniferous and Permian fossiliferous sequences of central-western Argentina (Paganzo, Río Blanco, Calingasta-Uspallata, and San Rafael Basins) contain abundant plant remains, palynomorphs, and invertebrates. The late Pennsylvanian biostratigraphic framework in Argentina referred to the *Raistrickia densa-Convolutispora muriornata* (**DMZ**) Assemblage Biozone is recognized in the Guandacol and Tupe formations of the Paganzo Basin and their stratigraphic equivalents, Jejenes, Lagares, and Agua Colorada formations, from different localities of San Juan and La Rioja provinces (Césari & Gutiérrez, 2001). Subzone A (**DMa**) of DMZ is characterized by the first record of monosaccate pollen genera *Plicatipollenites* and *Potonieisporites* and the absence of bisaccate striated pollen grains. The ^{206}Pb/^{238}U 319.57±0.09 Ma and 318.79±0.10 Ma ages of Gulbranson *et al.* (2010) from post-glacial transgressive facies of the Guandacol Formation was confirmed (320±3 Ma) by Valdez *et al.* (2020), who added an age of 326±3 Ma late Serpukhovian–Bashkirian to the Subzone A from basal glacial deposits (Pre-MTD1/Cycle 0 at Sierra de Maz).

Subzone B (**DMb**) of the DMZ is characterised by the presence of diverse monosaccate pollen and scarce taeniate pollen usually *Protohaploxypinus limpidus* (Césari, 1986; Césari & Gutiérrez, 2001; di Pasquo *et al.*, 2010). Subzone C (**DMc**) of the DMZ is similar in composition to DMb, composed of brackish and marine palynomorphs, especially acritarchs that constitute 70% of the assemblage, in association with monosaccate pollen grains lacking Permian markers (Gutiérrez & Limarino, 2006). Isotopic ages were obtained from different stratigraphic units in western Argentina, constraining these two zones mainly to the late Bashkirian/Moscovian–Kasimovian (Lech, 2002; Césari *et al.*, 2007, 2011, 2019; Gulbranson *et al.*, 2010). Despite PI shares only long-ranged monosaccate pollen grains with the DMc, the absence of Asselian diagnostic species that appear in the conformably overlying PII (c. 4 m above) would support their correlation.

Brazil. The upper Paleozoic deposits of the Tubarão and Passa Dois groups in Paraná Basin of Brazil are well-represented by marine and continental environments with evidence of the interglacial and post-glacial events (Holz *et al.*, 2010). Souza (2006) proposed the Pennsylvanian *Ahrensisporites cristatus* Interval Zone (**AcZ**) for the basal portion of the Itararé Subgroup and the overlying *Crucisaccites monoletus* Interval Zone (**CmZ**) ranging approximately from the top of its lower portion to the middle portion of the unit. Souza *et al.* (2021) constrained these zones to the late Bashkirian to Kasimovian. Cingulizonate, apiculate, and laevigate spores, and monosaccate pollen grains with radial and bilateral symmetry are dominant in both assemblages. Common constituents include *Cristatisporites* spp., *Vallatisporites* spp., *Punctatisporites gretensis*, *Calamospora* spp., *Apiculatisporis variornatus*, *Horriditriletes* spp., *Reticulatisporites* spp., *Spelaeotriletes ybertii*. Species of *Scheuringipollenites*, *Cycadopites*, *Limitisporites*, and *Protohaploxypinus* are also present in low frequencies (*i.e.*, lesser than 10% of the total assemblages). The *Vittatina costabilis* Interval Zone (**VcZ**) is mainly recorded from the upper Itararé Subgroup and the Rio Bonito Formation of the Passa Dois Group.

The lowermost glacial levels identified in the eastern area of the Brazilian Itararé Group is correlated to the *Ahrensisporites cristatus* Zone in the glacigenic rocks of the subsurface Lagoa Azul Formation (Souza, 2006; Holz *et al.*, 2010; Rosa *et al.*, 2019) and the DMa of the Guandacol Formation (Pérez Loinaze *et al.*, 2010; Valdez *et al.*, 2020). As in Argentina, Brazilian macrofloral species like *Nothorhacopteris argentinica* and *Botrychiopsis weissiana* characterized this interval with the absence of glossopterids (Bernardes-de-Oliveira *et al.*, 2016). Despite the poorly diversified composition of our Palynoassemblage I, common species, along with its stratigraphic position close to the PII, allowed the correlation with the CmZ.

Bolivia. The Pennsylvanian–Permian Copacabana Formation in the Madre de Dios Basin is a biostratigraphically well-characterized succession (200–800 meters) dominated by fossiliferous carbonates and intercalated siliciclastic facies in some intervals. Thin ash beds along this unit are numerous in different localities and in the core from the Mobil-Oxy Manuripi X-1 exploration well in northern Bolivia nearby

Pando X-1 cores (di Pasquo *et al.*, 2019 and references therein). U-Pb zircon age determination carried out in fractured siliceous green tuffaceous interval at depths of 882.4–883.2 meters yielded the average $_{206}$Pb/U$_{238}$ CA-ID-TIMS age of 316.0±0.4 Ma supporting a Bashkirian through Middle Moscovian age for calcareous foraminifera, conodonts, and palynomorphs (A1 and A2 palynofloras in Table 2) documented (Hamilton *et al.*, 2016; di Pasquo *et al.*, 2016, 2019). In southern Bolivia and northern Argentina, the Pennsylvanian *K. volkheimeri-C. azcuyi* (**Kv-Ca**) Superzone, divided into five First Appearance Interval Zones (Fig. 8), is documented in the Macharetí and Mandiyutí groups of the Tarija Basin (di Pasquo, 2003; di Pasquo *et al.*, 2017 and references therein). Long-ranged *Punctatisporites gretensis* and monosaccate pollen grains are shared between PI and the Pennsylvanian assemblages of Bolivia, and along with the stratigraphic position of the PI, a correlation with the MR–TB Zones is established.

Australia. Palynological studies in the Eastern Australian Joe Joe Group of the Galilee Basin by Jones & Truswell (1992) allowed the characterization of the Pennsylvanian (Bashkirian–Kasimovian) *Spelaeotriletes queenslandensis* (=*Grandispora queenslandensis sensu* Playford *et al.*, 2001) Superzone (equivalent to the *Spelaeotriletes ybertii* Assemblage of Powis 1984), subdivided into three Oppel-zones A–C followed by the Oppel-zones D (Kasimovian–Asselian) and E (Asselian). The basal Oppel-zone A (**OP A**) contains monosaccate pollen, without taeniate specimens, like the Subzone A of the Argentinian DM Zone and the correlative zones of South America depicted in Figure 8. Fielding *et al.* (2008) correlated the OP A with the glacial interval C2 of Australia. Roberts *et al.* (1995) reported for the *Levipustula levis* marine fauna a radiometric age of 321–323 Ma (SHRIMP zircon dating). This agrees with the inferred age of the Guandacol Formation glacial event of the Argentinian and coeval glacial-marine deposits (*i.e.*, Hoyada Verde Formation) bearing rich invertebrate assemblages mainly belonging to the *Levipustula* Zone (Césari *et al.*, 2007; Vergel *et al.*, 2015). The first striated pollen grains of the genus *Protohaploxypinus* along with *Cristatisporites pseudozonatus* are documented in the OP C, and *Horriditriletes ramosus* appears in the OP D, all persisting up to the OP E. These species recorded in our PII make a correlation of PI with any of these zones difficult to assert.

Palynoassemblage II

The qualitative composition of Palynoassemblage II compared with other radiometrically constrained assemblages to the Gzhelian–Asselian (Permo/Carboniferous boundary) across Gondwana is addressed, and correlations proposed (Fig. 8; Tab. 2).

Argentina. The *Pakhapites fusus-Vittatina subsaccata* (**FS**) palynological Zone defined by Césari and Gutiérrez (2001) was defined in the stratigraphic units originally referred to the Asselian–Sakmarian in western Argentina. The appearance of *Gangamopteris* megafloristic Zone coincides with the base of the FS Zone. An oldest age of 298–301 Ma dated the first appearance of glossopterid remains that appeared interbedded with basaltic horizons dated between K/Ar 293±6 Ma and 308±6 from the lower part of the La Colina Formation (Thompson & Mitchell, 1972; Limarino & Césari, 1984). Gutiérrez and Limarino (2006) proposed the Río del Peñón Formation at the Río Blanco area in northern Precordillera, as a potential stratotype for the boundary between the DM and FS Zones. Gulbranson *et al.* (2010) reported a ^{206}Pb/^{238}U age of 310.63±0.1 Ma obtained from fluvio-deltaic deposits of the middle part of this unit below the FS Zone. An increase of striate pollen grains, the first appearance of *Converrucosisporites confluens*, and species of *Vittatina* and *Pakhapites fusus*, *Latusipollenites quadrisaccatus*, *Marsupipollenites striatus*, *Striatoabieites multistriatus* characterized this zone (see also di Pasquo *et al.*, 2010; Césari *et al.*, 2013; Césari & Chiesa, 2017). These species shared with our Palynoassemblage II supporting their correlation (Fig. 8; Tab. 2).

Brazil and Uruguay. The *Crucisaccites monoletus* Interval Zone (**CmZ**) of Souza (2006) ranges approximately from the top of the lower portion to the middle portion of the Itararé Subgroup in the Paraná Basin of Brazil. The upper limit characterized by the appearance of *Illinites unicus* and the first species of the genus *Vittatina* marks the beginning of the VcZ. The VcZ is radiometrically constrained based on ID-TIMS U-Pb zircon ages ranging from 299±2.6 to 296±1.4 Ma from ton steins located in the middle section of the Rio Bonito Formation (see Mori *et al.*, 2012; Griffis *et al.*, 2018; Valdez *et al.*, 2019, 2020). Stephenson (2009) pointed out that the base of the *Vittatina costabilis* Interval Zone is older than the age of the base of the Rio Bonito Formation and may be approximated to the age of the first occurrence of

Converrucosisporites confluens in the Carboniferous/Permian boundary of Namibia (*i.e.*, 298.9+0.31/−0.15 Ma; Ramezani *et al.*, 2007). Recently, Souza *et al.* (2021) verified that VcZ is positioned between the Gzhelian and the Artinskian, based on radiometric ages obtained from levels containing spore-pollen associations assigned to this zone.

The San Gregorio up to the lower part of the Melo Formations (Frayle Muerto Member) in Uruguay are referred to the *Cristatisporites inconstans-Vittatina saccata* Assemblage Zone (**IS**) characterized by trilete spores and monosaccate pollen and, to a lesser extent by non-taeniate bisaccate, taeniate bisaccate, and plicate pollen grains (Beri *et al.*, 2011). The overlying *Striatoabieites anaverrucosus-Staurosaccites cordubensis* (**AC**) Assemblage Zone is constrained by radiometric datings from ashfall deposits of the Mangrullo Member of the Melo Formation that yielded U-Pb SHRIMP ages of 275.9±4.8 Ma and 269.8±4.7 Ma (Rocha-Campos *et al.*, in Beri *et al.*, 2011). Most the diagnostic species of Vc and AC Zones, such as *Converrucosisporites confluens*, *Pakhapites fusus*, *Latusipollenites quadrisaccatus*, *Marsupipollenites striatus*, *Striatoabieites multistriatus*, *Vittatina subsaccata*, among others, occurred in our Palynoassemblage II, supporting their correlation (Fig. 8; Tab. 2).

Bolivia. Two Cisuralian palynoassemblages were recorded in marine and transitional deposits of the Copacabana Formation at Apillapampa in central Bolivia (di Pasquo & Grader, 2012). First appearances of mainly cosmopolitan diagnostic taxa allowed the characterization of a lower assemblage assigned to the *Vittatina costabilis* Zone of Paraná Basin and the upper one that occurred in overlying marine and coal-bearing transitional intervals linked to the *Lueckisporites virkkiae* Zone. U-Pb geochronology (ID-TIMS of zircons) from the lowermost tuff sample of five interbedded tuffs analyzed provided an absolute age of 298.9±0.15 Ma (earliest Asselian) and the uppermost dated late Sakmarian (291.6 Ma±0.9 Ma). This interval confirmed previous microfossil (conodonts, fusulinids) ages and supports that the plant remains belonging to the *Glossopteris* Flora recorded in the Coal Member appeared in the late Sakmarian (di Pasquo *et al.*, 2015). A correlation is proposed herein between the present PII of the Talchir Formation and the lower VcZ (Fig. 8) based on their common pollen elements such as *Vittatina subsaccata*, *V. vittifera*, *Pakhapites fusus*, *Marsupipollenites striatus*, *Lunatisporites variesectus*, and several species of monosaccate pollen genera *Cannanoropollis*, *Potonieisporites*, *Plicatipollenites* among other taxa (Tab. 2).

Australia. The Palynoassemblage II of the present study shares some index taxa with the *Converrucosisporites confluens* Oppel Zone (=*Pseudoreticulatispora confluens*) recognized by Foster and Waterhouse (1988) in core intervals from the Calytrix No. 1 Borehole and in several boreholes by Backhouse and Mory (2020) in the Canning Basin of Australia. Those species are *Brevitriletes cornutus*, *C. confluens*, *Cycadopites cymbatus*, *Horriditriletes ramosus*, *Cristatisporites pseudozonatus*, *Marsupipollenites striatus*, *Protohaploxypinus limpidus*, *Striatoabieites multistriatus*, and monosaccate pollen grains. Instead, the species of *Vittatina* found in our PII were not in the Canning Basin (Backhouse & Mory, 2020).

Africa. The Palynoassemblage II shared with the *Converrucosisporites* (=*Pseudoreticulatispora*) *confluens* assemblage from Carboniferous–Permian Ganigobis shale Member (Dwyka Group) in Namibia (Stephenson, 2009) species such as *Horriditriletes ramosus*, *H. uruguaiensis*, *Cycadopites cymbatus*, *Brevitriletes cornutus*, *Vittatina*, and *Converrucosisporites confluens.* In this succession, Bangert *et al.* (1999) identified three sets of ash layers (termed I, II, and III). The upper ash layer of Set II (Ash Layer IIb at 25° 53′ 35″ S, 18° 00′ 51″ E, south of Ganigobis) gave a SHRIMP-based age from juvenile magmatic zircons of 302.0±3.0 Ma (Bangert, 2000) so placed it entirely within the Pennsylvanian, Gzhelian or Kasimovian. Bangert *et al.* (1999) also provided an age for other ash layers within the Ganigobis Shale Member of 299.2±3.2 Ma from a road cutting east of Ganigobis, near Tses. Both ages are still substantially older than the age corresponding to the lower limit of the range of the *Converrucosisporites confluens* Oppel Zone in Western Australia (approximately 295 Ma). Stephenson (2009) proposed that the age of the *Converrucosisporites confluens* Oppel Zone in Western Australia may range earlier than the mid–late Asselian previously established considering the radiometric dates from the Ganigobis Shale Member.

Barbolini *et al.* (2018) carried out a comprehensive review of previous palynological works in South Africa and identified biostratigraphically-restricted palynomorphs from the western, southern, and northeastern facies of the upper Dwyka (Asselian–Sakmarian K0 Zone) and Ecca Group (Artinskian–Lopingian K1–K11 Zones) in the Main

Karoo Basin. The chronostratigraphic framework of the Karoo successions was supported by isotopic dates (Barbolini *et al*., 2016). Several species are shared with the K1Z like the possible pan-Gondwanan Carboniferous–Permian index taxa *Pakhapites fusus* and *Vittatina*, among other spores (*Brevitriletes cornutus*, *Converrucosisporites micronodosus*, *Horriditriletes ramosus*, *Verrucosisporites andersonii*) and pollen grains (*Cannanoropollis methae*, *Cycadopites cymbatus*, *Marsupipollenites striatus*, *Plicatipollenites gondwanensis*, *Protohaploxypinus limpidus*, *Striatoabieites multistriatus*). A correlation of our PII with the K1Z is impeded due to their significant age difference.

CONCLUSIONS

The present work is significant because it is the second palynologic study of the Talchir Formation from Wardha Basin in India. Two palynoassemblages characterized by successive appearance of species and their biochron were compared and correlated with palynozones constrained by independent faunal dates and radiometric dates obtained across Gondwana. Quantitative abundance of genera is the conventional practice in Indian palynostratigraphic studies that may or may not be chronologically significant worldwide as it may reflect responses to specialized ecological conditions. Despite the absence of radiometric dates from the Indian Gondwana sequences, concerted efforts are being made to provide absolute dates in the near future. Meanwhile, Palynoassemblage I from the basal-most samples of the Borehole 131 from Penganga area is assigned to the oldest *Potonieisporites neglectus* Zone of Tiwari & Tripathi (1992) from the Indian Gondwana Sequence. The Palynoassemblage I composed of monosaccate pollen grains and few trilete spores long-ranged from Pennsylvanian to Permian is likely akin to the late Pennsylvanian by correlation to the radiometrically constrained late Serpukhovian–late Pennsylvanian DM Zone of central-western Argentina.

The Palynoassemblage II is constrained to the Carboniferous/Permian boundary by correlation with *Pakhapites fusus*-*Vittatina subsaccata* Zone of central-western Argentina, based on common diagnostic species of *Vittatina* and *Pakhapites* and *Converrucosisporites confluens*, among others. The relative age of the base of this zone is accurately assigned to the Kasimovian/Gzhelian based on $^{206}Pb/^{238}U$ age of 310.63±0.1 Ma obtained from the middle part of the Rio del Peñón Formation at the Rincón Blanco section in Mendoza Province of Argentina.

The lower limit is also consistent with the associated marine fauna correlatable with the *Tivertonia-Streptorhynchus* Zone of Sabattini *et al.* (1991) and the DMb and DMc of Tupe Formation (Paganzo Basin, San Juan Province, Argentina), confirmed by radiometric dates. The *Potonieisporites neglectus* Zone of Tiwari & Tripathi (1992) was attributed to the earliest Permian and very few works to the latest Pennsylvanian. We suggest a constrainment to the late Pennsylvanian (Kasimovian–Gzhelian) considering the above biostratigraphic correlation together with the stratigraphic position of the studied lower interval of the Talchir Formation lying directly over Precambrian rocks. A Carboniferous–Permian age is also confirmed by correlation with the *Converrucosisporites confluens* assemblage from the Ganigobis lower shale Member (Dwyka Group) of Namibia, South Africa. The isotopic data obtained from the interbedded ash layers yielded ages of 299.2±3.2 Ma and 302.0±3.0 Ma, extending into the late Asselian–Sakmarian.

The integration of our palynostratigraphic information from the Talchir Formation with palynologic, radiometric and faunal dates is applied herein to propose a more accurate age for the two palynoassemblages documented and their correlation with late Kasimovian–Ghzelian to Asselian palynozones of southern South America, Africa, Australia and correlative palynofloras of this age interval elsewhere in Gondwana. Future work should focus on providing radiometric data to improve current palynostratigraphic knowledge and known biozonation schemes in a robust lithostratigraphic framework from the Indian Gondwana basins. In this context, the Talchir Formation should be our main target as it was overlooked in favor of the economically important coal-bearing Barakar and Raniganj formations.

ACKNOWLEDGMENTS

The authors are grateful to V. Prasad, Director of the Birbal Sahni Institute of Palaeosciences, for her kind permission to publish this work (BSIP/RDCC 43/2020–21). AR is thankful to the Director of BSIP and Head of the Department of Botany, Somaiya Vidhya Vihar College, for allowing him to carry out his master's degree dissertation at BSIP. PSK and AR are thankful to the authorities of CMPDI for allowing them to carry out fieldwork and to A. Saxena, Regional Director CMPDI in Nagpur, for providing samples and assistance in the field. MDP is grateful to CICYTTP-CONICET-ER-UADER (Entre Ríos, Argentina) for permitting to collaborate in this work supported by research grants PIP CONICET 0812 (Argentina). Technical staff S.

Srivastava is thanked for preparing the slides. We thank E. G. Ottone and P. A. Souza for their constructive comments and editorial suggestions to improve the manuscript.

REFERENCES

Acharyya, S. K. (2000). *Coal and lignite resources of India: an overview*. Publications of the Geological Society of India.

Agarwal, A., Tewari, R., & Rajanikanth, A. (2007). A gymnospermous (Araucariaceae) wood from the Kamthi Formation, Wardha Valley Coalfield. *Gondwana Geological Magazine*, *22*, 103–107.

Agashe, S. N. (1979). Megaspores from the Permian coal seams (Lower Gondwana) from Umrer Colliery, Nagpur District, Maharashtra, India. *Proceedings of the IV International Palynological Conference* (pp. 627–634). Lucknow.

Agashe, S. N. (2001). Studies in fossil gymnospermous woods—Part X; Three new species of *Araucarioxylon* from Lower Gondwana strata of Chandrapur district of Maharashtra, India. *The Palaeobotanist*, *50*, 381–393.

Agashe, S. N., & Chitnis, S. R. (1970). Palynological investigation of coalseams of Lower Gondwana strata from Maharashtra, India-A preliminary report. *Palynological Bulletin*, *6*(1), 6–8.

Agashe, S. N., & Chitnis, S. R. (1972a). Palaeopalynology of a Permian coal seam from the Hindustan Lalpeth Colliery, Chandrapur District., Maharashtra, India. *Seminar on Palaeopalynology and Indian Stratigraphy* (pp. 21–29). Nagpur.

Agashe, S. N., & Chitnis, S. R. (1972b). A preliminary sporological analysis of some carbonaceous shale samples from Kamptee Coalfield, Nagpur District, M.S., India. *The Palaeobotanist*, *21*(1), 107–112.

Agashe, S. N., Gowda, R. N., Suresh, F. C., & Geetha, K. R. (1981). Recent advances in the palaeobotanical studies on Lower Gondwana strata of Chandrapur district, Maharashtra. *Proceedings of the Symposium on evolutionary Botany and Biostratigraphy, A.K. Ghosh Commemoration Volume* (pp. 369–382). Calcutta.

Agashe, S. N., & Kumar, M. S. (1996). Studies in fossil gymnospermous wood, part VIII. A new species of *Araucarioxylon i.e. A. wejgaoense* from Lower Gondwana strata of Chandrapur district of Maharashtra, India. *The Palaeobotanist*, *45*(1), 15–19.

Agashe, S. N., & Kumar, M. S. (2001). Studies in fossil gymnospermous woods, Part X; Three new species of *Araucarioxylon* from Lower Gondwana Strata of Chandrapur District of Maharashtra, India. *The Palaeobotanist*, *50*(2 & 3), 381–393.

Agashe, S. N., & Prasad, K. R. (1989). Studies on fossil gymnospermous woods, part VII: 6 new species of Lower Gondwana (Permian) gymnospermous woods from Chandrapur district of Maharashtra state, India. *Palaeöntographica B*, *212*(4–6), 71–102.

Aggarwal, N., & Jha, N. (2013). Permian palynostratigraphy and palaeoclimate of Lingala-Koyagudem coalbelt, Godavari Graben, Andhra Pradesh, India. *Journal of Asian Earth Sciences*, *64*, 38–57.

Anand-Prakash, & Khare, R. C. (1974). Petrology and Palynostratigraphy of some Wardha Valley coals, Maharashtra, India. *The Palaeobotanist*, *23*(2), 124–138.

Anderson, J. M. (1977). The biostratigraphy of the Permian and Triassic. Part 3. A review of Gondwana palynology with particular reference to the northern Karoo Basin, South Africa. *Memoirs of the Botanical Survey of South Africa*, *41*, 1–133.

Archangelsky, S., & Gamerro, J. C. (1979). Palinología del Paleozoico Superior en el subsuelo de la Cuenca Chacoparanense, República Argentina. I. Estudio sistemático de los palinomorfos de tres perforaciones de la Provincia de Córdoba. *Revista Española de Micropaleontología*, *11*(3), 417–478.

Archbold, N. W. (1999). Permian Gondwanan correlations: the significance of the western Australian marine Permian. *Journal of African Earth Sciences*, *29*(1), 63–75.

Azcuy, C. L. (1975). Miosporas del Namuriano y Westfaliano de la comarca Malanzán-Loma Larga, Provincia de la Rioja, Argentina. II. Descripciones sistemáticas y significado estratigráfico de las microfloras. *Ameghiniana*, *12*(2), 113–163.

Azcuy, C. L., & di Pasquo, M. M. (2000). Palynology of the Late Carboniferous from the Tarija Basin, Argentina: a systematic review of monosaccate pollen genera. *Palaeöntographica B*, *253*(4–6), 103–137.

Azcuy, C. L., di Pasquo, M. M., & Ampuero, H. V. (2002). Late Carboniferous miospores from the Tarma Formation. *Review of Palaeobotany and Palynology*, *118*(1–4), 1–28.

Backhouse, J. (1988). Trilete spores from the Collie Basin, Western Australia. *Australasian Association of Palaeontologists*, *Memoir 5*, 53–72.

Backhouse, J. (1991). Permian palynostratigraphy of the Collie Basin, Western Australia. *Review of Palaeobotany and Palynology*, *67*(3–4), 237–314.

Backhouse, J., & Mory, A. J. (2020). Mid-Carboniferous–Lower Permian palynology and stratigraphy, Canning Basin, Western Australia. *Geological Survey of Western Australia*, *Report 207*, 1–133.

Balme, B. E. (1970). Palynology of Permian and Triassic Strata in the Salt Range and Surghar Range, West Pakistan. In B. Kummel & C. Teichert (Eds.), *Stratigraphic boundary problems: Permian and Triassic of West Pakistan. Vol. 4* (pp. 305–453). Kansas University Press.

Balme, B. E., & Hennelly, J. P. F. (1956). Monolete, monocolpate and alete sporomorphs from Australian Permian sediments. *Australian Journal of Botany*, *4*(3), 54–67.

Balme, B. E., & Playford, G. (1967). Late Permian plant microfossils from the Prince Charles Mountains, Antarctica. *Revue de Micropaléontologie*, *10*, 179–192.

Bangert, B. (2000). *Tephrostratigraphy, petrography, geochemsisrty, age and fossil record of the Ganigobis Shale Member and associated glaciomarine deposits of the Dwyka Group, Late Carboniferous, southern Africa* (Unpublished PhD thesis, Bayerischen Julius-Maximilians-Universität Würzburg, Germany).

Bangert, B., Stollhofen, H., Lorenz, V., & Armstrong, R. (1999). The geochronology and significance of ash-fall tuffs in the glaciogenic Carboniferous-Permian Dwyka Group of Namibia and South Africa. *Journal of African Earth Sciences*, *29*(1), 33–49.

Barbolini, N., Bamford, M. K., & Rubidge, B. (2016). Radiometric dating demonstrates that Permian spore-pollen zones of Australia and South Africa are diachronous. *Gondwana Research*, *37*, 241–251.

Barbolini, N., Rubidge, B., & Bamford, M. K. (2018). A new approach to biostratigraphy in the Karoo retroarc foreland system: Utilising restricted-range palynomorphs and their first appearance datums for correlation. *Journal of African Earth Sciences*, *140*, 114–133.

Beri, Á., Gutiérrez, P., & Balarino, L. (2011). Palynostratigraphy of the late Palaeozoic of Uruguay, Paraná Basin. *Review of Palaeobotany and Palynology*, *167*(1–2), 16–29.

Bernardes-de-Oliveira, M. E. C., Kavali, P. S., Mune, S. E., Shivanna, M., Souza, P. A., Iannuzzi, R., Jasper, A., Hoelzel, A., Boardman, D. R., & Rohn, R. (2016). Pennsylvanian–early Cisuralian interglacial macrofloristic succession in Paraná Basin of the State of São Paulo. *Journal of South American Earth Sciences*, *72*, 351–374.

Bharadwaj, D. C. (1954). Einige neue Sporengattungen des Saarkarbons. *Neues Jahrbuch für Geologie und Paläontologie*, 11, 512–525.

Bharadwaj, D. C., & Anand-Prakash (1974). Palynostratigraphy of lower Gondwana sediments from Umrer Quarry, Nagpur, Maharashtra, India. *Geophytology*, *4*(2), 130–140.

Bharadwaj, D. C., & Salujha, S. K. (1964). Sporological study of Seam

VIII in Raniganj Coalfield, Bihar (India)–Part -1. Description of *sporae dispersae*. *The Palaeobotanist*, *12*(2), 181–215.

Bhattacharrya, A. P. (1997). Palynological recognition of the Karharbari-Barakar Formations in the sub-surface sediments of Wardha Coalfield, Maharashtra, India. *The Palaeobotanist*, *46*(1–2), 217–219.

Bose, M. N., & Kar, R. K. (1966). Palaeozoic *Sporae dispersae* from Congo. I. Kindú Kalima and Walikale regions. *Annales du Musée Royal de L'Africa Centrale, Serie 8, Sciences Géologiques*, *53*, 1–238.

Bose, M. N., & Maheshwari, H. K. (1966). Palaeozoic sporae dispersae from Congo. II. The Epulu River (Ituri). *Annales du Musée Royal de L'Africa Centrale, Série 8, Sciences Géologiques*, *53*, 241–251.

Bose, M. N., & Maheshwari, H. K. (1968). Palaezoic *sporae dispersae* from Congo. VII - Coal measures near lake Tanganyika, South of Albertiville. *Annales du Musée Royal de L'Africa Centrale*, *Série 8*, *Sciences Geologiques*, *60*, 1–116.

Bunbury, C. J. F. (1861). Notes on a collection of fossil plants from Nagpur, central India. *Quaternary Journal Geological Society of London*, *17*, 325–346.

Butterworth, M. A., Jansonius, J., Smith, A. H. V., & Staplin, F. L. (1964). *Densosporites* (Berry) Potonié and Kremp and related genera. *Comptes Rendus 5 International Congres Stratigraphie et Géologie du Carbonifère 1* (pp. 1049–1057). Paris.

Casshyap, S. M., & Qidwai, H. A. (1974). Glacial sedimentation of Late Palaeozoic Talchir diamictite, Pench valley coalfield, Central India. *Geological Society of America Bulletin*, *85*(5), 749–760.

Césari, S. N. (1986). Zonación palinológica del Carbonífero tardío de Argentina. *Actas de IV Congreso Argentino de Paleontología y Bioestratigrafía, 1* (pp. 227–230). Mendoza.

Césari, S. N., & Chiesa, J. O. (2017). Palynology of the Bajo de Veliz Formation, central-western Argentina: Implications for Carboniferous–Permian transition biostratigraphy. *Journal of South American Earth Sciences*, *78*, 238–249.

Césari, S. N., & Gutiérrez, P. R. (2001). Palynostratigraphic study of the Upper Paleozoic central-western Argentinian sequences. *Palynology*, *24*(1), 113–146.

Césari, S. N., Gutiérrez, P. R., Sabattini, N., Archangelsky, A., Azcuy, C. L., Carrizo, H. A., Cisterna, G., Crisafulli, A., Cúneo, R. N., Díaz Saravia, P., di Pasquo, M. M., González, C. R., Lech, R., Pagani, M. A., Sterren, A., Taboada, A. C., & Vergel, M. M. (2007). Paleozoico Superior de Argentina: un registro fosilífero integral en el Gondwana Occidental. *Publicación Especial de la Asociación Paleontológica Argentina*, *11*(1), 35–54.

Césari, S. N., Limarino, C. O., Spalletti, L. A., Colombo Piñol, F., Pérez Loinaze, V. S., Ciccioli, P. L., & Friedman, R. (2019). New U/Pb zircon age for the Pennsylvanian in Argentina: Implications in palynostratigraphy and regional stratigraphy. *Journal of South American Earth Sciences*, *92*, 400–416.

Césari, S. N., Limarino, S. O., & Gulbranson, E. L. (2011). An Upper Paleozoic biochronostratigraphic scheme for the western margin of Gondwana. *Earth-Science Reviews*, *106*(1–2), 149–160.

Césari, S. N., Pérez Loinaze, V. S., & Limarino, C. O. (2013). La Biozona *Pakhapites fusus-Vittatina subsaccata* en la Formacion Patquía (Pérmico), Precordillera de La Rioja, Argentina. *Revista Museo Argentino de Ciencias Naturales*, *n.s.*, *15*(1), 71–88.

Chakraborthy, R. K. (1999). Studies on the relationship of the distribution pattern of Gondwana Basins of Peninsular India with the nature of Precambrian crustal framework. *Gondwana Research (Gondwana Newsletter Section)*, *2*(4), 662.

Chandra, S., & Prasad, M. N. V. (1981). Fossil plants from the Kamthi Formation of Maharashtra and their biostratigraphic significance. *The Palaeobotanist*, *28/29*(1), 99–121.

Chitnis, S. R., & Vagyani, B. A. (1979). Additions to the *Glossopteris* flora from the Kamthi beds near Satnavri, district Nagpur, (M.S.). *Geophytology*, *9*, 62–64.

De, A. K. (1979). Sedimentation in North Karanpura basin- A model in Damodar valley graben, peninsular India. *Proceedings of the 4th International Gondwana Symposium* (pp. 649–657). Calcutta.

di Pasquo, M. M. (2003). Avances sobre palinología, bioestratigrafía y correlación de los grupos Macharetí y Mandiyutí, Neopaleozoico de la Cuenca Tarija, provincia de Salta, Argentina. *Ameghiniana*, *40*(1), 3–32.

di Pasquo, M. M. (2009). The Pennsylvanian palynoflora of the Pando X-1 Borehole, northern Bolivia. *Review Paleobotany and Palynology*, *157*(3–4), 266–284.

di Pasquo, M. M., Anderson Folnagy, H. J., Isaacson, P. E., & Grader, G. W. (2019). Late Palaeozoic carbonates and glacial deposits in Bolivia and northern Argentina: significant paleoclimatic changes. *SEPM Special Publication*, *108*, 185–203.

di Pasquo, M. M., & Grader, G. W. (2012). The palynology of the Lower Permian (Asselian–?Artinskian) Copacabana Formation of Apillapampa, Cochabamba, Bolivia. *Palynology*, *36*(2), 264–276.

di Pasquo, M. M., Grader, G. W., Isaacson, P., Souza, P. A., Iannuzzi, R., & Díaz-Martínez, E. (2015). Global biostratigraphic comparison and correlation of an early Cisuralian palynoflora from Bolivia. *Historical Biology*, *27*(7), 868–897.

di Pasquo, M. M., Isaacson, P., & Anderson, H. (2017). Record of a Pennsylvanian-Cisuralian marine transgression, southern Bolivia: A short-lived event in western Gondwana? *Palaeogeography, Palaeoclimatology, Palaeoecology*, *485*, 30–45.

di Pasquo, M., Isaacson, P., Grader, G. W., Hamilton, M. A., & Soreghan, G. S. (2016). Palynostratigraphy of the Yaurichambi and Copacabana formations in the Manuripi X-1 core, Madre de Dios Basin, northern Bolivia: first constraints from U-Pb dating of volcanic ash. *Boletín de la Asociación Latinoamericana de Paleobotánica y Palinología*, *16*, 110.

di Pasquo, M. M., Kavali, P. S., Dino, R., Shivanna, M., Bernardes-de-Oliveira, M. E. C., & Roy, A. (2021). *Faunipollenites* Bharadwaj 1962 and *Protohaploxypinus* Samoilovich 1953 emend. Morbey 1975: morphologic comparison of oxidized and non- oxidized specimens from India and Brazil, and its taxonomic importance. *Annals of the Brazilian Academy of Sciences*, *93*(1). http://dx.doi.org/10.1590/0001-3765202120190094

di Pasquo, M., Vergel, M. M., & Azcuy, C. L. (2010). Pennsylvanian and Cisuralian palynofloras from the Los Sauces area, La Rioja Province, Argentina: chronological and paleoecological significance. *International Journal of Coal Geology*, *83*(2–3), 276–291.

Feistmantel, O. (1881). The fossil flora of the Gondwana System. The flora of the Damuda–Panchet division. *Memoirs of the Geological Survey of India, Palaeontologia Indica*, *12*(3), 78–149.

Felix, C. J., & Burbridge, P. P. (1967). Palynology of the Springer Formation of southern Oklahoma, U.S.A. *Palaeontology*, *10*, 349–425.

Fielding, C. R., Frank, T. D., Birgenheier, L. P., Rygel, M. C., Jones, A. T., & Roberts, J. (2008). Stratigraphic record and facies associations of the late Paleozoic ice age in Australia, New South Wales and Queensland. *Geological Society of America Special Paper*, *441*, 47–57.

Foster, C. B. (1975). Permian plant microfossils from the Blair Athol Coal Measures, Central Queensland, Australia. *Palaeöntographica B*, *154*(5–6), 121–171.

Foster, C. B. (1979). Permian plant microfossils of the Blair Athol Coal Measures, Baralaba Coal Measures, and basal Rewan Formation of Queensland. *Geological Survey of Queensland*, *372*, 1–154.

Foster, C. B., & Waterhouse, J. (1988). The *Granulatisporites confluens* Oppel-zone and Early Permian marine faunas from the Grant Formation on the Barbwire Terrace, Canning Basin, Western Australia. *Australian Journal of Earth Sciences*, *35*(2), 135–157.

Gradstein, F. M., Ogg, J. G., Schmitz, M. D., & Ogg, G. M. (2012). *The Geologic Time Scale 2012*. Elsevier.

Griffis, N. P., Montañez, I. P., Mundil, R., Richey, J., Isbell, J., Fedorchuk, N., Linol, B., Iannuzzi, R., Vesely, F., Mottin, T., da Rosa, E., Keller, B., & Yin, Q. (2019). Coupled stratigraphic and U-Pb zircon age constraints on the late Paleozoic icehouse-to-greenhouse turnover in south-central Gondwana. *Geology*, *47*(12), 1146–1150.

Griffis, N., Mundil, R., Montañez, I., Isbell, J., Fedorchuk, N., Vesely, F. F., Iannuzzi, R., & Yin, Q. Z. (2018). New stratigraphic framework built on U-Pb single zircon TIMS ages with implications for the timing of the penultimate icehouse (Paraná Basin, Brazil). *GSA Bulletin*, *130*(5–6), 848–858.

Guerra-Sommer, M., Cazzulo-Klepzig, M., Menegat, R., Formoso, M. L. L., Basei, M. A. S., Barboza, E. G., & Simas, M. W. (2008). Geochronological data from the Faxinal coal succession, southern Paraná Basin, Brazil: a preliminary approach combining radiometric U-Pb dating and palynostratigraphy. *Journal of South American Earth Sciences*, *25*, 246–256.

Gulbranson, E. L., Montañez, I. P., Schmitz, M. D., Limarino, C. O., Isbell, J. L., Marenssi, S. A., & Crowley, J. L. (2010). High-precision U-Pb calibration of Carboniferous glaciation and climate history, Paganzo Group, NW Argentina. *GSA Bulletin*, *122*(9–10), 1480–1498.

Gutiérrez, P. R., & Limarino, C. O. (2001). Palinología de la Formación Malanzán (Carbonífero Superior), La Rioja, Argentina: nuevos datos y consideraciones paleoambientales. *Ameghiniana*, *38*(1), 99–118.

Gutiérrez, P. R., & Limarino, C. O. (2006). El perfil del sinclinal del Rincón Blanco (noroeste de La Rioja): El límite Carbonífero–Pérmico en el noroeste Argentina. *Ameghiniana*, *43*(4), 687–703.

Hamilton, M. A., Soreghan, G. S., Carvajal, C. P., Isaacson, P. E., Grader, G. W., & di Pasquo, M. M. (2016). A precise U-Pb zircon age from volcanic ash in the Pennsylvanian Copacabana Formation, Bolivia. *Abstracts with Programs of GSA 68th Annual Meeting*, *Rocky Mountain Section* (Abstract 276278). Moscow.

Hart, G. F. (1960). Microfloral investigation of the lower coal measures (K2); Ketewaka-Mchuchuma Coalfield. *Bulletins of the Geological Survey of Tanganyika*, *30*, 1–18.

Henderson, C. M. (2018). Permian conodont biostratigraphy. *Geological Society of London*, *Special Publications*, *450*, 119–142.

Holz, M., França, A. B., Souza, P. A., Iannuzzi, R., & Rohn, R. (2010). A stratigraphic chart of the Late Carboniferous/Permian succession of the eastern border of the Paraná Basin, Brazil, South America. *Journal of South American Earth Sciences*, *29*, 381–399.

Ibrahim, A. C. (1932). Beschreibung von sporen formenaus Flöz Ägir. In R. Potonié Sporenformenaus den Flözen Ägir und Bismarck des Ruhrgebietes. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, 67*, 447–449.

Ibrahim, A. (1933). *Sporenformen des Aegir horizonts des Ruhr-Reviers.* (Dissertation Thesis, University of Berlin, Würzburg).

Jha, N., Aggarwal, N., & Mishra, S. (2018). A review of the palynostratigraphy of Gondwana sediments from Godavari graben, India: global comparison and correlation of the Permian-Triassic palynoflora. *Journal of Asian Earth Sciences*, *163*, 1–21.

Jha, N., Kavali, P. S., Tewari, R., & Mehrotra, N. C. (2011). Palynological dating and correlation of surface and subsurface sediments from Wardha Valley Coalfield, Maharashtra. *Journal of the Geological Society of India*, *77*, 137–148.

Jha, N., Tewari, R., & Rajnikanth, A. (2007). Palynology of Permian Gondwana Sequence of Umrer Coalfield, Maharashtra. *Journal of the Geological Society of India*, *69*, 851–857.

Jin, Y., Wardlaw, B. R., Glenister, B. F., & Kotlyar, G. V. (1997). Permian chronostratigraphic subdivisions. *Episodes*, *20*(1), 10–15.

Jones, M. J., & Truswell, E. M. (1992). Late Carboniferous and Early Permian palynostratigraphy of the Joe Joe Group, southern Galilee Basin, Queensland, and implications for Gondwanan stratigraphy. *BMR Journal of Australian Geology and Geophysics*, *13*(2), 143–185.

Kalkar, S. A., Bhute, S. D., & Sarate, O. S. (2010). Palynoflora recorded from Makardhokada area, Nagpur district, Maharashtra. *The Palaeobotanist*, *59*(1), 63–70.

Kar, R. K., & Bose, M. N. (1976). Palaeozoic s*porae dispersae* from Zaïre (Congo). XII. Assise a couches de houille from Greinerville region. *Annales de Musée Royal de l'Afrique Centrale*, *Serie 8*, *Sciences Géologiques*, *77*, 21–133.

Kavali, P. S., Bilwa, L. M., & Shivanna, M. (2010). Palaeoenvironmental implications of the Umrer Coalfield, Wardha basin, Central India, through palynological studies. *Gondwana Geological Magazine*, *25*(1), 175–180.

Kavali, P. S., Shivanna, M., Bilwa, L. M., & Bernardes-de-Oliveira, M. E. C. (2016). A palynostratigraphic study of the Umrer Coalfield of Wardha Basin, Maharashtra State, Central India and its putative correlation with Indian and other Gondwanan areas. *Geologia Série cientifica*, *USP*, *São Paulo*, *16*(4), 99–117.

Kemp, E. M., Balme, B. E., Helby, R. J., Kyle, R. A., Playford, G., & Price, P. L. (1977). Carboniferous and Permian palynostratigraphy in Australia and Antarctica: a review. *Journal of Australian Geology and Geophysics*, *2*, 177–208.

Kosanke, R. M. (1950). Pennsylvanian spores of Illinois and their use in correlation. *State Geological Survey of Illinois*, *Bulletin*, *74*, 1–128.

Kumar, P., & Jha, N. (2000). Subsurface palynological succession from Katol area, Nagpur, Maharashtra. *Geophytology*, *2*, 65–68.

Kützing, F. T. (1849). *Species algarum*. Brockhaus.

Lech, R. (2002). Consideraciones sobre la edad de la Formación Agua del Jagúel (Carbonífero Superior), Provincia de Mendoza, Argentina. *Actas de 15° Congreso Geológico Argentino* (pp. 142–146). El Calafate.

Lele, K. M. (1964). Studies in the Talchir flora of India: 2. Resolution of the sporegenus *Nuskoisporites* Potonié & Klaus. *The Palaeobotanist*, *12*(1), 147–168.

Lele, K. M. (1979). Studies in the Talchir flora of India-12. Basal Talchir palynofossils from the Penganga Valley and their biostratigraphic value. *Proceedings of the Symposium on evolutionary Botany and Biostratigraphy*, *A.K. Ghosh Commemoration Volume* (pp. 267–283). New Delhi.

Lele, K. M., & Karim, R. (1971). Studies in the Talchir Flora of India. 6. Palynology of the Talchir Boulder Beds in Jayanti Coalfield, Bihar. *The Palaeobotanist*, *19*(1), 52–69.

Lele, K. M., & Makada, R. (1972). Studies in the Talchir Flora of India-7. Palynology of the Talchir Formation from Jayanti Coalfield, Bihar. *Geophytology*, *2*(1), 267–283.

Leschik, G. (1956). Spores aus den Salzten des Zechsteins von Neuhof (Bei Fulda). *Palaeöntographica B*, *100*, 125–141.

Limarino, C. O., & Césari, S. N. (1984). Primer registro paleoflorístico de la Formación La Colina (Paleozoico Superior) Cuenca Paganzo, República Argentina. *Boletim Instituto Geociências*, *Universidade Sâo Paulo*, *15*, 32–37.

Lindström, S. (1995a). Early Late Permian palynostratigraphy and palaeobiogeography of Vestfjella, Dronning Maud Land, Antarctica. *Review of Palaeobotany and Palynology*, *86*(1–2), 157–173.

Lindström, S. (1995b). Early Permian palynostratigraphy of the northern Heimefrontfjella mountain range, Dronning Maud Land, Antarctica. *Review of Palaeobotany and Palynology*, *89*(3–4), 359–415.

Luber, A. A., & Waltz, I. E. (1941). [Atlas of microspores and pollen of the Palaeozoic of the USSR]. *Trudy Vsesoi͡uznogo nauchno-issledovatel'skogo geologicheskogo instituta*, 139, 1–107. [In Russian, with English summary].

Maheshwari, H. K. (1967). Studies in the *Glossopteris* Flora of India - 29. Miospore assemblage from the Lower Gondwana exposures along Bansloi River in Rajmahal Hills, Bihar. *The Palaeobotanist*, *15*, 258–280.

Marques-Toigo, M. (1974). Some new species of spores and pollens of Lower Permian age from the San Gregorio Formation in Uruguay. *Anais da Academia Brasileira de Ciências*, *46*(3–4), 601–616.

Mehta, K. R. (1944). Microfossils from a carbonaceous shale from the pali beds of the South Rewa Gondwana Basin. *Proceedings of National Academy of Sciences of Allahabad*, *14*, 125–141.

Menéndez, C. A. (1971). Estudio palinológico del Pérmico de Bajo de Veliz, Provincia de San Luis. *Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"*, *Paleontología*, *1*, 263–306.

Menéndez, C. A., & Azcuy, C. L. (1972). *Ancistrospora*, un nuevo género de miospora del Carbónico de la Argentina. *Revista Española de Micropaleontología*, *4*(2), 157–168.

Metcalfe, I., Henderson, C. M., & Wakita, K. (2017). Lower Permian conodonts from Palaeo-Tethys Ocean Plate Stratigraphy in the Chiang Mai-Chiang Rai Suture Zone, northern Thailand. *Gondwana Research*, *44*, 54–66.

Metcalfe, I., & Sone, M. (2008). Biostratigraphy and palaeobiogeography of Lower Permian (lower Kungurian) conodonts from the Tak Fa Formation (Saraburi Limestone), Thailand. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, *257*(1–2), 139–151.

Modie, B. N., & Le Hérissé, A. (2009). Late Paleozoic palynomorph assemblages from the Karoo Supergroup and their potential for biostratigraphic correlation, Kalahari Karoo Basin, Botswana. *Bulletin of Geosciences*, *84*(2), 337–358.

Mori, A. L. O., Souza, P. A., Marques, J. C., & Lopes, R. C. (2012). A new U-Pb zircon age dating and palynological data from a Lower Permian section of the southernmost Paraná Basin, Brazil: biochronostratigraphical and geochronological implications for Gondwana correlations. *Gondwana Research*, *21*(2–3), 654–669.

Mukhopadhyay, G., Mukhopadhyay, S. K., Roychowdhury, M., & Parui, P. K. (2010). Stratigraphic correlation between different Gondwana basins of India. *Journal of the Geological Society of India*, *76*, 251–266.

Murthy, S., Kavali, P. S., di Pasquo, M., & Chakraborti, B. (2020). Late Pennsylvanian and Early Cisuralian palynofloras from the Rajmahal Basin, eastern India, and their chronological significance. *Historical Biology*, *32*(2), 143–159.

Murthy, S., & Sarate, O. S. (2016). Late Permian palynoassemblage from Chalburdi area, Chandrapur District, Maharashtra. *The Palaeobotanist*, *6*, 85–95.

Murthy, S., Sarate, O. S., & Aggarwal, N. (2019). Palynofloral and palynofacies evidences and its implication on the depositional environment from Wardha Valley Coalfield, Maharashtra. *Journal of the Geological Society of India*, *93*, 85–94.

Murthy, S., Sarate, O. S., Pillai, S. S. K., & Tewari, R. (2017). Early Permian micro and megaspores from the Nand–Besur Block, Bandar Coalfield, Wardha Basin, Maharashtra, India. *The Palaeobotanist*, *66*(2), 177–189.

Naumova, S. N. (1939). Spores and pollen of the coals of the U.S.S.R. *Reports of 17th International Geological Congress 1* (pp. 353–364). Moscow.

Ogg, J. G., Ogg, G. M., & Gradstein, F. M. (2016). *A Concise Geologic Time Scale*. Elsevier.

Pérez Loinaze, V. S., Limarino, C. O., & Césari, S. N. (2010). Glacial events in Carboniferous sequences from Paganzo and Río Blanco basins (northwest Argentina): palynology and depositional setting. *Geológica Acta*, *8*, 399–418.

Picarelli, A. T., Quadros, L. P., Marques-Toigo, M., & Klepzig, M. C. (1991). *Biostratigrafia do Permiano e Carbonífero das bacias do Solimões, Amazonas, Acre e Parnaíba, com base em fusulinídeos, palinología e conodontes*. (Petrobrás Internal Report (Cenpes/Supep/Divex/Sebipe), Rio de Janeiro).

Playford, G. (1978). Lower Carboniferous spores from the Ducabrook Formation, Drummond Basin, Queensland. *Palaeontographica Abteilung B*, *167*, 105–160.

Playford, G., & Dino, R. (2000a). Palynostratigraphy of Upper Palaeozoic strata (Tapajós Group), Amazonas Basin, Brazil: Part One. *Palaeöntographica B*, *255*, 1–46.

Playford, G., & Dino, R. (2000b). Palynostratigraphy of Upper Palaeozoic strata (Tapajós Group), Amazonas Basin, Brazil: Part Two. *Palaeöntographica B*, *255*, 87–145.

Playford, G., & Dino, R. (2002). Permian palynofloral assemblages of the Chaco-Paraná Basin, Argentina: systematics and stratigraphic significance. *Revista Española de Micropaleontología*, *34*(3), 235–288.

Playford, G., Dino, R., & Marques-Toigo, M. (2001). The Upper Paleozoic miospore genus *Spelaeotriletes* Neves and Owens, 1966, and constituent Gondwanan species. *Journal of South American Earth Sciences*, *14*, 593–608.

Poort, R. J., & Veld, H. (1997). Aspects of Permian palaeobotany and palynology. XVIII. On the morphology and ultrastructure of *Potonieisporites novicus* (prepollen of Late Carboniferous/Early Permian Walchiaceae). *Acta Botanica Neerlandica*, *468*(2), 161–173.

Potonié, R., & Kremp, G. (1954). Die Gattungen der Paläozoischen *Sporae dispersae* und ihre Stratigraphie. *Beihefte Geologischen Jahrbuch*, *69*, 111–194.

Potonié, R., & Lele, K. M. (1961). Studies in the Talchir Flora of India. I. *Sporae dispersae* from the Talchir Beds of South Rewa Gondwana Basin. *The Palaeobotanist*, *8*, 22–37.

Potonié, R., & Sah, S. C. D. (1960). *Sporae dispersae* of the lignites from Cannanore Beach on the Malabar Coast of India. *The Palaeobotanist*, *7*, 121–135.

Powis, G. D. (1984). Palynostratigraphy of the Late Carboniferous Sequence, Canning Basin, W.A. In P. G. Purcell (Ed.), *The Canning Basin, Western Australia* (pp. 429–438). *Geological Society of Australia Inc. and Petroleum Exploration Society of Australia Limited.*

Raja Rao, C. S. (1982). Coalfields of India. Vol. II, Coal resources of Tamil Nadu, Andhra Pradesh, Orissa and Maharashtra. *Bulletin of the Geological Survey of India*, *Series 45*, 62–100.

Raja Rao, C. S. (1983). Coalfields of India: Coal resources of Madhya Pradesh, Jammu and Kashmir. *Bulletin of the Geological Survey of India*, *3*, 1–103.

Raja Rao, C. S. (1987). Coal resources of Bihar (excluding Dhanbad District). *Bulletin of the Geological Survey of India Series*, *45*(IV), 300–322.

Ramezani, J., Schmitz, M. D., Davydov, V. I., Bowring, S. A., Snyder, W. S., & Northrup, C. J. (2007). High-precision U-Pb zircon age constraints on the Carboniferous-Permian boundary in the southern Urals stratotype. *Earth and Planetary Science Letters*, *256*(1–2), 244–257.

Roberts, J., Claoué-Long, J., Jones, P. J., & Foster, C. B. (1995).

SHRIMP zircon age control of Gondwanan sequences in Late Carboniferous and Early Permian Australia. *Geological Society of London Special Publication*, *89*, 145–174.

Rosa, E. L. M., Vesely, F. F., Isbell, J. L., Kipper, F., Fedorchuck, N., & Souza, P. A. (2019). Constraining the timing, kinematics and cyclicity of Mississippian-Early Pennsylvanian glaciations in the Paraná Basin, Brazil. *Sedimentary Geology*, *384*, 29–49.

Sabattini, N., Ottone, E. G., & Azcuy, C. L. (1991). La Zona de *Lissochonetes jachalensis-Streptorhynchus inaequiornatus* (Carbonífero Tardío) en la localidad de La Delfina, provincia de San Juan. *Ameghiniana*, *27*(1–2), 78–79.

Sabina, P. K., Bilwa, L. M., & Shivanna, M. (2007). A palynostratigraphic study of Lower Gondwana sediments from Bandar coalfield, Nagpur district, Maharashtra. *Journal of the Geological Society of India*, *69*, 834–840.

Samoilovich, S. R. (1953). [Pollen and spores from the Permian deposits of the Cherdyn' and Aktyubinsk areas, Cis-Urals]. *Trudy Vsesoiuznyi Nauchno-issledovatel'skii Geologo-razvedochnyi Institut, new series*, *75*, 5–57. [in Russian]

Santos, R. V., Souza, P. A., Alvarenga, C. J. S., Dantas, E. L., Pimentel, M. M., Oliveira, C. G., & Araújo, L. M. (2006). SHRIMP U-Pb zircon dating and palynology of bentonitic layers from the Permian Irati Formation, Paraná Basin, Brazil. *Gondwana Research*, *9*(4), 456–463.

Sarate, O. S. (1985). A Karharbari mioflora from the Kamptee Coalfield, Maharashtra State, India. *Geophytology*, *15*(2), 227–230.

Sarate, O. S., Kalkar, A., & Bhute, D. (2017). Palynofloral Evidences from Sub-surface Sediments of Bhadrawati Area, Wardha Valley Coalfield, Central India. *Journal of Geosciences Research*, *2*(1), 37–44.

Sarate, O. S., Murthy, S., & Kalkar, S. A. (2016). Late Permian palynoassemblage from Borehole No. WG–22 near Sekapur, Wardha District, Maharashtra, India. *The Palaeobotanist*, *65*, 177–187.

Schopf, J. M., Wilson, L. R., & Bentall, R. (1944). An annotated synopsis of Paleozoic fossil spores and the definition of generic groups. Illinois State. *Geological Survey*, *Report Investigation*, *91*, 1–73.

Segroves, K. L. (1970). Permian spores and pollen grains from the Perth Basin, Western Australia. *Grana Palynologica*, *10*(1), 43–73.

Shivanna, M., Kavali, P. S., & Bilwa, L. M. (2008). Permian sediments from the subsurface sediments of Lower Gondwana of Wardha Valley Coalfield, Maharashtra, India. *Gondwana Geological Magazine*, *23*(1), 63–67.

Shivanna, M., Kavali, P. S., & Bilwa, L. M. (2011). Palynodating and correlation of subsurface sediments from borehole CMWY-95 of Wardha Valley Coalfield, Maharashtra, Central India. *The Palaeobotanist*, *60*, 299–307.

Shivanna, M., Kavali, P. S., & Bilwa, L. M. (2014). Palynology and depositional facet of lower Permian (Artinskian) sediments from New Majri Opencast Mine, Wardha Basin, India. *Journal of the Geological Society of India*, *83*, 697–708.

Singh, K. J., Sarate, O. S., Bhattacharya, A. P., & Goswami, S. (2005). Record of megafloral assemblage from the Nand Coalfield, Wardha Basin, Nagpur district, Maharashtra. *Journal of the Geological Society of India*, *66*, 293–302.

Smith, A. J. (1963). Evidence for a Talchir (Lower Gondwana) glaciation: striated pavement and boulder bed at Irai, Central India. *Journal of Sedimentary Petrology*, *33*(3), 739–750.

Smith, A. H. V., & Butterworth, M. A. (1967). Miospores in the coal sequence of the Carboniferous of Great Britain. *Special Paper in Palaeontology*, *1*, 1–324.

Souza, P. A. (2006). Late Carboniferous palynostratigraphy of the Itararé Subgroup, northeastern Paraná Basin, Brazil. *Review of Palaeobotany and Palynology*, *138*(1), 9–29.

Souza, P. A., Boardman, D. R., Premaor, E., Félix, C. F., Oliveira, E. J., & Bender, R. R. (2021). The *Vittatina costabilis* Zone revisited: new characterization and implications on the Pennsylvanian-Permian icehouse-to-greenhouse turnover in the Paraná Basin, Western Gondwana. *Journal of South American Earth Sciences*, *106*, 102968. https://doi.org/10.1016/j.jsames.2020.102968

Stephenson, M. H. (2008). A review of palynostratigraphy of Gondwana Late Carboniferous to Early Permian glacigene succession. *Geological Society of America Special Paper*, *441*, 317–330.

Stephenson, M. H. (2009). The age of the Carboniferous-Permian *Converrucosisporites confluens* Oppel biozone: New data from the Ganigobis shale member (Dwyka Group) of Namibia. *Palynology*, *33*(1), 167–177.

Stephenson, M. H., Osterloff, P. L., & Filatoff, J. (2003). Palynological biozonation of the Permian of Oman and Saudi Arabia: progress and challenges. *GeoArabia*, *8*(3), 467–496.

Sundaram, D., & Nandi, A. (1984). Palaeobotanical study of Umrer Coalfield, Nagpur, Maharashtra, with special reference to biostratigraphy. *Proceedings of the Symposium of Evolutionary Botany & Biostratigraphy* (pp. 315–321). Calcutta.

Tewari, R. (2007). *Glossopteris* Flora from Kamptee Coalfield, Wardha Basin, Maharashtra, India. *Palaeöntographica B*, *227*, 43–64.

Tewari, R. (2008). The genus *Glossopteris* Brongniart from the Kamthi Formation of Camp IV area, Wardha Valley Coalfield, Wardha Basin, Maharashtra, India. *Journal of Palaeontological Society of India*, *53*, 19–30.

Tewari, R. C., & Mahejima, W. (2010). Origin of Gondwana Basins of Peninsular India. *Journal of Geosciences*, *53*(3), 43–49.

Tewari, R., Pandita, S. K., Agnihotri, D., Pillai, S. S. K., & Bernardes-de-Oliveira, M. E. C. (2012). An Early Permian *Glossopteris* flora from the Umrer Coalfield, Wardha Basin, Maharashtra, India. *Alcheringa*, *36*(3), 355–371.

Tewari, R., & Rajanikanth, A. (2001). Occurrence of *Glossopteris* Flora, Pisdura Nand Dongargaon Sub-Basin. *The Palaeobotanist*, *50*(3), 411–414.

Tewari, R., Rajanikanth, A., & Jha, N. (2004). Permian Gondwana megaspores of Wardha Basin, India. *The Palaeobotanist*, *53*(1), 35–50.

Thompson, R., & Mitchell, J. (1972). Palaeomagnetic and radiometric evidence for the age of the lower boundary of the Kiaman Magnetic Interval in South America. *Geophysics Journal of the Royal Astronomical Society*, *27*(2), 207–214.

Tiwari, R. S. (1965). Miospores assemblage in some coals of Barakar stage (Lower Gondwana) of India. *The Palaeobotanists*, *13*(1), 168–214.

Tiwari, R. S. (1968). Palynological investigations of some coalfields in the Ib-River Coalfield, Orissa, India. *The Palaeobotanist*, *16*(3), 222–242.

Tiwari, R. S. (1973). *Scheuringipollenites*, a new name for the Gondwana palynomorphs so far assigned to "*Sulcatisporites* Leschik 1955". *Senckenbergiana Lethaea*, *54*(1), 105–117.

Tiwari, R. S. (1996). Palynoevent stratigraphy in Gondwana sequence of India. *Proceedings of the 9° International Gondwana Symposium* (pp. 3–19). Calcutta.

Tiwari, R. S. (1999). The palynological succession and spatial relationship of the Indian Gondwana sequence. *PINSA*, *65*, 329–375.

Tiwari, R. S., & Moiz, A. A. (1971). Palynological study of Lower Gondwana (Permian) coals from Godavari Basin, India. I–On some new miospore genera. *The Palaeobotanist*, *19*(1), 95–104.

Tiwari, R. S., & Navale, G. K. B. (1968). Pollen and spore assemblages in some coals of Brazil. *Pollen et Spores*, *9*, 583–605.

Tiwari, R. S., & Tripathi, A. (1988). Palynological zones and their climatic inference in the coal bearing Gondwana of Peninsular India. *The Palaeobotanist*, *36*(1), 87–101.

Tiwari, R. S., & Tripathi, A. (1992). Marker Assemblage Zones of spores and pollen species through Gondwana Palaeozoic and Mesozoic sequence in India. *The Palaeobotanist*, *40*(1), 194–236.

Truswell, E. M. (1980). Permo-Carboniferous palynology of Gondwanaland: progress and problems in the decade to 1980. *Journal of Australian Geology and Geophysics*, *5*(2), 95–111.

Urban, J. B. (1971). Palynology and the Independence Shale of Iowa. *Bulletin of American Paleontology*, *60*, 103–189.

Valdez, V. B., Aquino, C. D., Paim, P. S. G., Souza, P. A., Mori, A. L., Fallgatter, C., Milana, J. P., & Kneller, B. (2019). Late Paleozoic glacial cycles and subcycles in western Gondwana: Correlation of surface and subsurface data of the Paraná Basin, Brazil. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, *531*(Part B), 108435. https://doi.org/10.1016/j.palaeo.2017.09.004

Valdez, V. B., Milana, J. P., di Pasquo, M., Paim, P. S. G., Philipp, R. P., Aquino, C. D., Cagliari, J., Junior, F. C., & Kellner, B. (2020). Timing of the Late Paleozoic glaciation in western Gondwana: New ages and correlations from Paganzo and Paraná Basins. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, *544*, 109624. https://doi.org/10.1016/j.palaeo.2020.109624

Varadpande, D. G. (1977a). *Dadoxylon satnauriense*, a new species of petrified gymnosperm wood from the Lower Gondwanas of India. *Journal of the University of Poona*, *Science and Technology*, *50*, 157–162.

Varadpande, D. G. (1977b). Fossil plants from Kamthi Beds of Lower Gondwana of India. *Journal of the University of Poona*, *Science and Technology*, *50*, 227–234.

Venkatachala, B. S., & Kar, R. K. (1966). *Divarisaccus* gen. nov., a new saccate pollen genus from the Permian sediments of India. *The Palaeobotanist*, *15*(1), 102–106.

Venkatachala, B. S., & Tiwari, R. S. (1988). Lower Gondwana marine incursions-periods and pathways. *The Palaeobotanist*, *3*(1), 24–29.

Vergel, M. M. (2008). Palynology of Upper Palaeozoic sediments (Tupe Formation) at La Herradura creek, San Juan province, Argentina. *Alcheringa*, *32*(4), 339–352.

Vergel, M. M., Cisterna, G. A., & Sterren, A. F. (2015). New palynological records from the glaciomarine deposits of the El Paso formation (late Serpukhovian–Bashkirian) in the Argentine Precordillera: biostratigraphical implications. *Ameghiniana*, *52*(6), 613–624.

Vijaya (1996). Advent of Gondwana deposition on Indian peninsula: a palynological reflection and relationship. *Proceedings of the 9° International Gondwana Symposium* (pp. 283–298). Calcutta.

Waterhouse, J. B. (1997). The Permian Time-scale. *Permophiles*, *30*, 6–8.

doi: 10.5710/AMGH.29.03.2021.3423

Submitted: January 5th, 2021
Accepted: March 29th, 2021
Published: August 31st, 2021