

# Palynostratigraphic considerations on the Pennsylvanian interglacial microflora from Monte Mor (SP), Itararé Group, NE, Paraná Basin (Brazil) and its diachronic correlations with Indian Gondwana microflora

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## ABSTRACT

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In the present communication the palynological contents of the Monte Mor taphoflora has been restudied in surface samples from the upper and lower levels of the coal beds from this type-locality and its Interval palynozone position has been reinterpreted and revised.

Four palynological Interval zones were recognized from the Upper Palaeozoic Brazilian Paraná Basin by Souza (2000, 2006) and Souza & Marques-Toigo (2001, 2003, 2005), where Monte Mor microflora was placed in the lowermost *Ahrensisporites cristatus* Interval Zone (tentatively Late Bashkirian to Kazimovian). On the basis of presence of *Crucisaccites monoletus*, *Divarisaccus* spp., *Faunipollenites* (= *Protohaploxylinus*) *amplus*, *Faunipollenites* sp., *Scheuringipollenites maximus*, *Platysaccus* sp. and *Scheuringipollenites maximus* in the recovered microflora it is suggested that Monte Mor palynoflora belongs to *Crucisaccites monoletus* Interval Zone, which is contrary to the earlier studies which indicated that the Monte Mor palynoassemblage belongs to *Ahrensisporites cristatus* Interval Zone.

**Key-words**—Palynology, Itararé Group, Monte Mor, Paraná Basin, Late Carboniferous, Brazil.

मांटे मोर (एस.पी.) इतारैर समूह, पराना द्रोणी (ब्राज़ील) से प्राप्त पेन्सिलवेनियाई अंतः हिमनदीय सूक्ष्म वनस्पतिजात के परागाणुस्तरीक महत्व एवं भारतीय गोंडवाना सूक्ष्मवनस्पतिजात के साथ इसके द्विसमयसंबंधी सहसंबंध

नीरजा झा, सांद्रा ईको मुने, मैरी ई सी बर्नान्डीज-डी-ऑलीवीरा एवं नरेश सी. मेहरोत्रा

## सारांश

मौजूदा संप्रेषण में ऐसी उपवस्तियों से कोयला संस्तरों के ऊपरी व निचले स्तरों से प्राप्त पृष्ठीय नमूनों में मांटे मोर जैववनस्पति-जात की परागाणविक अंतर्वस्तुओं का पुनर्अध्ययन किया गया है तथा इसकी परागाणुमंडल स्थिति पुनर्व्याख्यायित व परिशोधित की गई है।

सूज़ा (2000, 2006) एवं सूज़ा व माकर्स-टेंडो (2001, 2003, 2005) ने ऊपरी पुराजीवी ब्राज़ील की पराना द्रोणी से चार परागणविक अंतराल मंडल पहचाने, जिसमें मांटे मोर सूक्ष्मवनस्पतिजात निचलीतम एरेन्सीस्योराइटिस क्रिस्टेटस अंतराल मंडल (प्रयोग के तौर पर अंतिम बशक्रीरियाई से काज़ीमोनियाई तक) में नियत की गई थी। प्राप्त सूक्ष्म पेड़-पौधों में क्रुसिसेक्काइटिस मोनोलेटस, डिवेरीसेक्कस जातियां, फॉनिपोल्लेनाइटिस (=प्रोटोहेल्पोक्सिपाइनस) एम्प्लस, फॉनिपोल्लेनाइटिस जाति, श्युरिंगीपोल्लेनाइटिस मैक्जीमस, प्लेटीसेक्कस जाति की विद्यमानता के आधार पर सुझावित किया जाता है कि मांटे मोर परागणु पेड़पौधे क्रुसिसेक्काइटिस मोनोलेटस अंतराल मंडल के हैं जो पहले के अध्ययनों के विपरीत है जिसने संकेत दिया कि मांटे मोर परागणु समुच्चय एरेन्सीस्योराइटिस क्रिस्टेटस अंतराल मंडल की है।

संकेत-शब्द—परागणुविज्ञान, इतारैर समूह, मांटे मोर, पराना द्रोणी, अंतिम कार्बोनिफेरस, ब्राज़ील

## Considerações palinoestratigráficas sobre a microflora interglacial Pensilvaniana de Monte Mor (SP), Grupo Itararé, nordeste da Bacia do Paraná (Brasil) e suas correlações diacrônicas com a microflora Gondvânica Indiana

### RESUMO

Neste trabalho, o conteúdo palinológico da taoflora de Monte Mor foi re-estudado com base em amostras de superfície procedentes de níveis superiores e inferiores das camadas de carvão, desta localidade-tipo, e sua posição no palinozonamento de intervalo foi reinterpretada e revista. Quatro zonas de intervalo palinológicos foram reconhecidas no Paleozóico superior da bacia do Paraná no Brasil, por Souza (2000, 2006) e Souza & Marques-Toigo (2001, 2003 e 2005), onde a microflora de Monte Mor foi colocada na zona de intervalo mais inferior chamada de *Ahrensisporites cristatus* (tentativamente Neo Bashkiriano a Kazimoviano). Com base na presença de *Crucisaccites monoletus*, *Divarisaccus* spp, *Faunipollenites* (= *Protohaploxypinus*) *amplus*, *Faunipollenites* sp., *Scheuringipollenites maximus*, *Platysaccus* sp. e *Scheuringipollenites maximus* na microflora coletada, sugere-se que a palinoflora de Monte Mor pertencem a zona de intervalo *Crucisaccites monoletus* contrariando estudos anteriores que indicam que a palinoassembléia de Monte Mor pertence a Zona de Intervalo *Ahrensisporites cristatus*.

Palavras-chave—Palinologia, Grupo Itararé, Monte Mor, Bacia do Paraná, Neocarbonífero, Brasil.

### INTRODUCTION

Milani and Zalán (1999) have recognized six supersequences in the 5000 meters thick sediments in Paraná Basin on the basis of the sedimentary / magmatic records which were repeated by Milani *et al.* (1998, 2007): *Rio Ivaí* (related to the Rio Ivaí Group of Ordovician / Silurian age); *Paraná* (Paraná Group, Devonian); *Gondwana I* (Itararé, Guatá, Passa Dois Groups, Pirambóia and Sanga do Cabral formations, Pennsylvanian to Early Triassic); *Gondwana II* (Santa Maria Formation, Middle to Early Late Triassic) and *Gondwana III* (Botucatu and Serra Geral formations, Late Jurassic to Early Cretaceous) and *Bauru* (Bauru / Caiuá groups, Late Cretaceous) (Fig. 1).

The Itararé Group, corresponding to the lowest part of Gondwana I Supersequence partially represent Late Palaeozoic Gondwana glacial event. Based on several lithostratigraphical and sedimentary evidences, Rocha-Campos *et al.* (2008) asserted that the origin of diamictites and associated rocks of this group and equivalent units were indisputably under the influence of continental glaciers.

Actually, a large portion of the Gondwana had been covered by glaciers having evidences of their movements from the central-south Africa towards the southeastern region of the South America, from Antarctica towards the southeastern region of Australia and from Antarctica to the region of central-

eastern India. The glaciations were characterized, not only for the low temperatures in the polar or subpolar regions, but also by the dryness of the subtropical regions, having caused great extinctions in floras and accentuated provincialism.

The levels of coal and plant remains including those with palynological contents found in the Itararé Group are interpreted as related to Interglacial or interstadial and periglacial events (Souza, 2000, 2003 2006; Bernardes-de-Oliveira *et al.*, 2001, 2005). In the Gondwana sedimentary basins there are evidences of some interglacial or interstadial phases, when glaciers had withdrawn and other environments (fluvial, deltaic, lacustrine and marine) established themselves on the landscapes. By these times, different floristic associations succeeded one to the other, caused by vegetational or evolutionary factors. Evidences of these interglacial associations are, simultaneously or diachronically present in the Gondwana sediments of Brazil, Argentina, Africa, India, Antarctica and Australia.

In the beginnings of 1970's, Daemon and Quadros proposed the first palynostratigraphical zonation for Paraná Basin, where the level corresponding to the Monte Mor microflora was included in the "G" level (Stephanian-Sakmarian).

Rösler (1978) recognized, informally, a macrofloristic succession in the Paraná Basin, the first taphofloristic association named by him as Taphoflora "A" is characterized

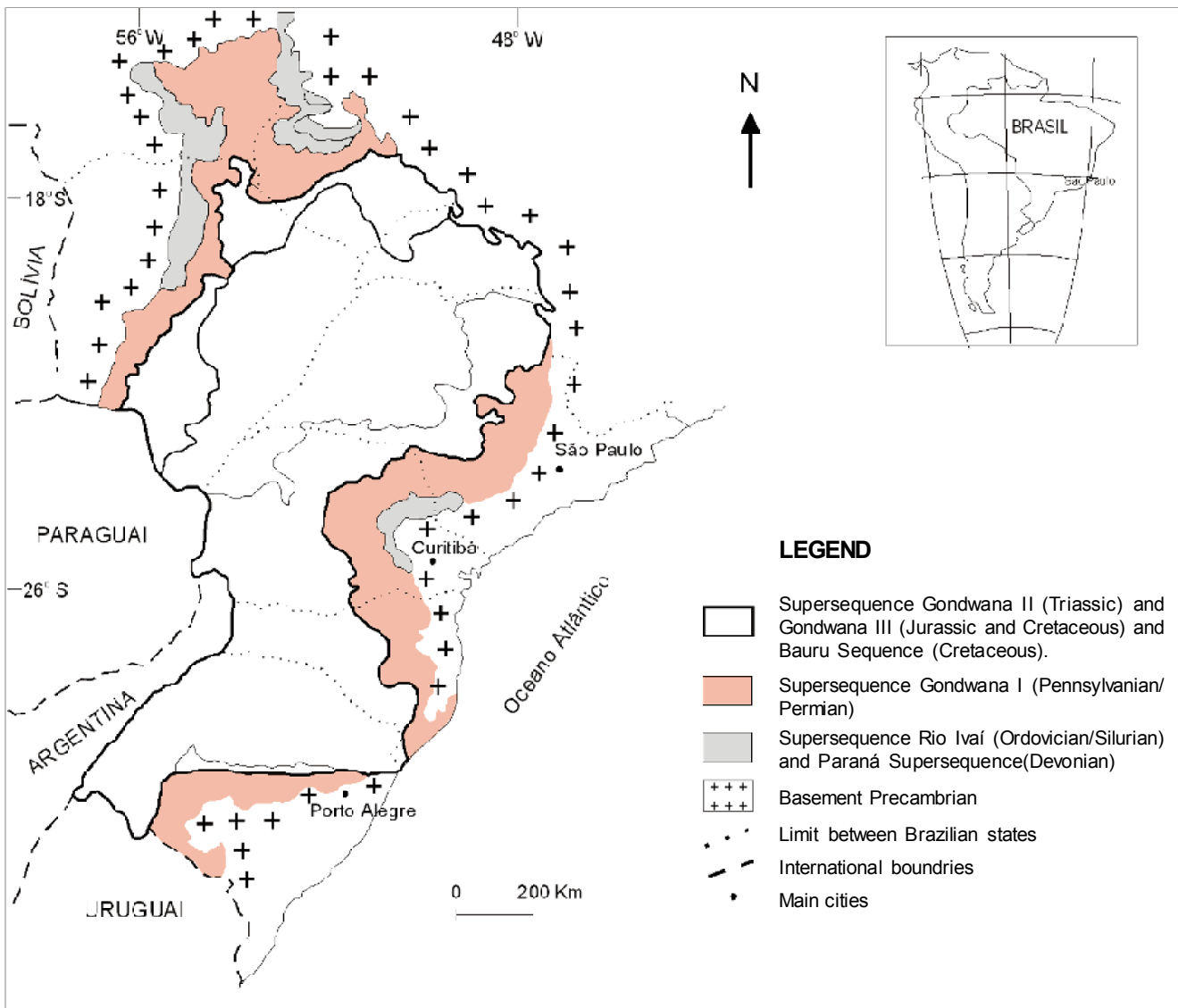


Fig. 1—Supersequences of Paraná Basin (simplified from Milani *et al.*, 1998).

by a Pre-Glossopteris Flora, from type-locality Monte Mor, situated in the Volpe Ranch (ex-Mine Ranch).

Daemon (1974) carried out the first palynological work on the Monte Mor coal. He reported laevigate spores like *Laevigatosporites* sp., apiculate spores, viz. *Verrucosisporites* sp., zonate / cingulate spores like *Vallatisporites* sp., *Hymenozonotriletes* sp., monosaccate pollen grains, viz. *Plicatipollenites* spp., *Virkipollenites* spp., *Potonieisporites* spp., *Sahnites* spp., *Striomonosaccites* spp. and *Crucisaccites* cf. *C. latisulcatus* and striate disaccate pollen grains like, *Faunipollenites* (= *Protohaploxylinus*) sp. On the basis of a preliminary taxonomy Daemon (1974) suggested a position in “H” Interval, subinterval H<sub>1</sub>/H<sub>2</sub>, for the Monte Mor coal. This level was considered corresponding to the Sakmarian.

Lima *et al.* 1983 studied the palynology of calciferous concretions of the Itararé Group in the Araçoiaba da Serra (SP) area recognized for this locality equivalent to Buri and Monte Mor. The palynological association was designated by them as “Pre-G” Association.

Bernardes-de-Oliveira *et al.* (2005) based on macrofloristic studies have recognized, informally five interglacial macrofloristic associations in the Itararé Group of the northeastern margin of Paraná Basin, comprising from the lowermost to the top : aff. *Dwykea* – *Sublagenicula* – *Calamospora* association (**DSC association**); *Eusphenopteris* – *Nothorhacopteris* – *Botrychiopsis* association (**ENB association**); *Paranocladus* – *Ginkgophyllum* – *Brasilodendron* association (**PGB association**); recurrent

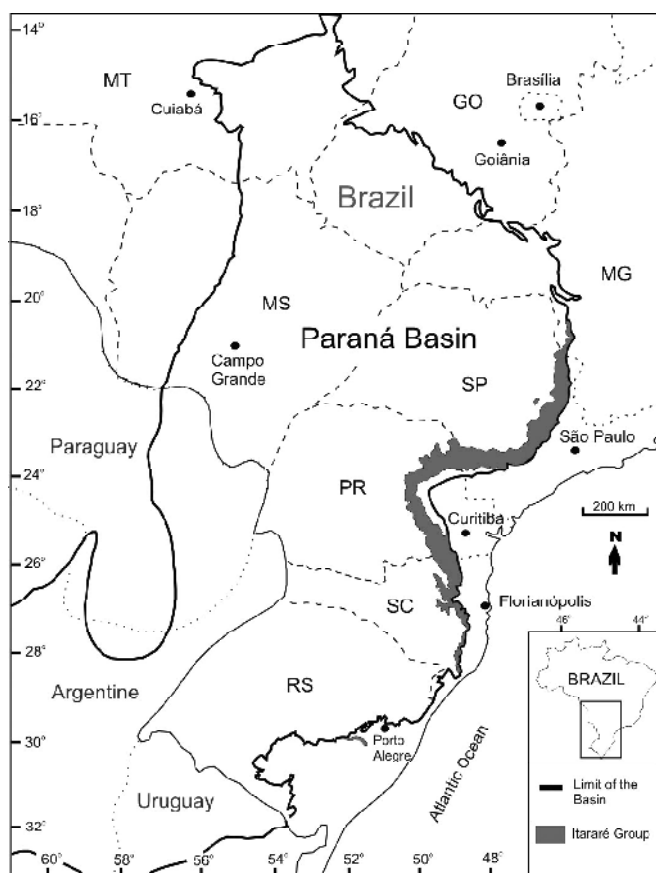


Fig. 2—Geological map of the studied area with outcrop location (modified from IPT, 1981) Itararé Group outcropping on the right border of Paraná Basin.

*Dwykea* association (**rD association**) and *Gangamopteris* – *Rubidgea* – *Arberia* association (**GRA association**). The first four ones are Pennsylvanian in age corresponding to the Pre-*Glossopteris* floras and the last one is Cisuralian (Asselian to Sakmarian) and is the oldest of the *Glossopteris* flora. In this case the Monte Mor taphoflora is type-locality for the PGB association.

Souza (2000, 2006) established a new palynostratigraphical zonation for the Itararé Group in the northeastern margin of Paraná Basin in which the lower two Interval zones were recognized as the Pennsylvanian and one subzone of the third Interval zone was recognized as the Cisuralian (Asselian-Sakmarian) the uppermost Itararé sediments.

Souza (2000, 2006) and Souza and Marques-Toigo (2001, 2003, 2005) have recognized four palynological Interval zones for the Upper Palaeozoic Brazilian Paraná Basin, where Monte Mor microflora has been placed in the lowermost *Ahrensia* *cristatus* Interval Zone (tentatively Late Bashkirian to Kazimovian).

Due to the absence of regional guide levels, the stratigraphy of the Paraná Basin was difficult to understand. Palynology is the more reliable parameter in the correlations and in the characterization of the continental and glacio-marine sediments of the Paraná Basin.

In the present communication the palynological contents of the Monte Mor sediments were studied based on surface samples from the upper and lower levels of the coal beds from this type-locality and its Interval palynozone position has been reinterpreted and revised.

#### GEOGRAPHIC AND STRATIGRAPHIC LOCATION OF THE PROVENANCE AREA

The Monte Mor sediments occur in the Volpe Ranch, situated in the north-northeast area of the homonymous municipality of São Paulo State, precisely at 22°50'548 latitude South and 47°16'759 longitude West (Fig. 2). The outcrop is located 20 m away from the entrance of the old mine at the left margin of a creek originated at this private property.

The samples were collected from a carbonaceous laminated mudstone bed, underlying a thin bed of coal (20 cm thick) and from another carbonaceous laminated mudstone covering this coal (5 cm thick).

After field observations, the fossiliferous levels are stratigraphically positioned at the basal portion of a sequence of carbonaceous shales / mudstones, coal, siltstones and sandstones underlying a diamictite (Fig. 3).

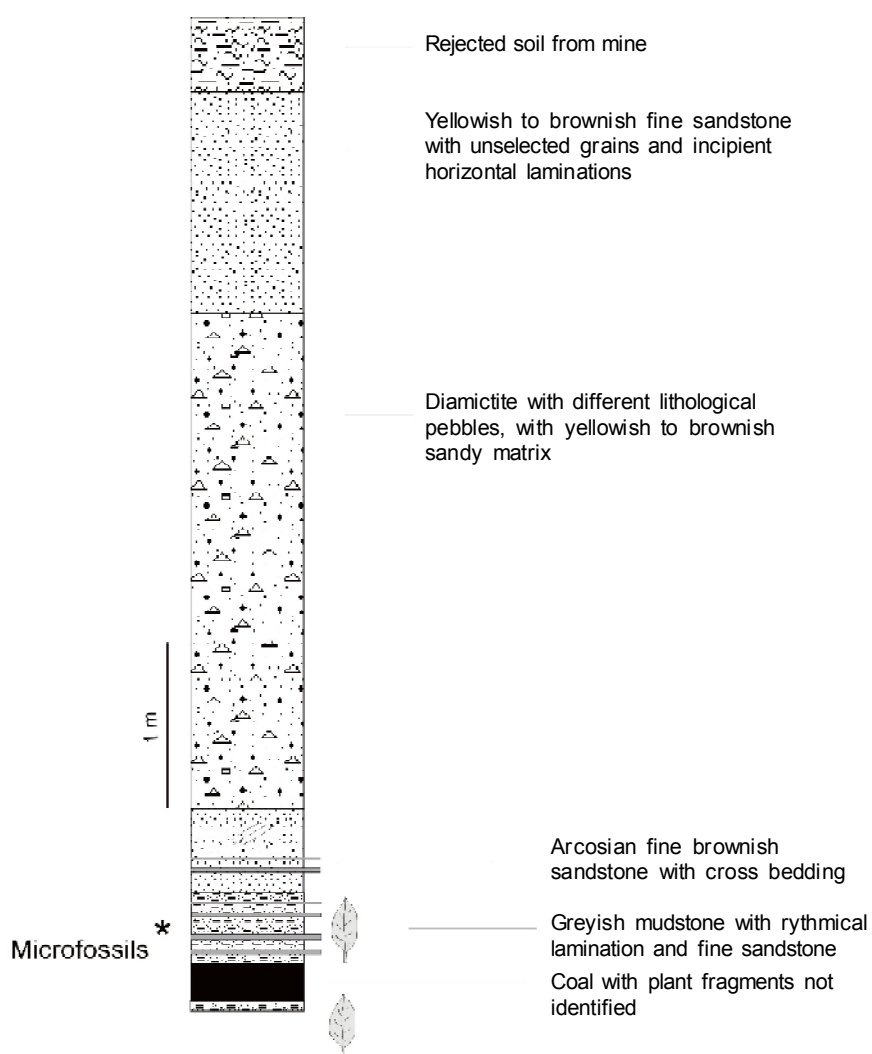
This overlying diamictite (named in the past Elias Fausto Formation by Barbosa & Gomes, 1958), presents big erratic boulders of granite scattered for all the Monte Mor Municipality area near the Volpe Ranch.

In Campinas and Monte Mor areas a detailed geological mapping was done by Souza Filho (1986) recognizing for the Pennsylvanian sediments the following informal lithostratigraphic units in ascending order: *Unit I* – upward granodrecrescent sandstones; *Unit II* - mudstones; *Unit III* - mudstones and diamictites; *Unit IV* - sandstones; *Unit V* - diamictites and sandstones; *Unit VI* - sandstones with wave marks and *Unit VII* – red diamictites) (Fig. 4).

After Souza Filho (1986 : 32-35), the Monte Mor area, with its carbonaceous levels is included in the Unit IV, consisting of several sandstone bodies which occur in different levels distributed into the Unit III. The principal lithologies of the Unit IV are conglomeratic sandstones and median to fine sandstones, with conglomeratic mudstones and coal. The Monte Mor area corresponds to a facies of deltaic lobes with wave cross-bedded sandstones. In the facies of deltaic lobes, the mudstones with coal, muddy sandstones and greyish mudstones are rich in organic material, coal and plant remains, deposited in a continental environment of flood plain, almost in a final sequence of pro-delta ambient before the installation of a new glacial phase.



**A**



**B**

Fig. 3—A. Photograph of outcrop in Monte Mor showing the coal measures details. B. Columnar section of the exposed Monte Mor outcrop (Volpe Ranch), showing position of microfossil yielding sediments.

## MATERIAL AND METHODS

The samples were subject to a chemical processing (maceration) normal to the Palaeozoic Palynology. The material was identified and documented graphically as optical microscopy. The slides described here correspond to one sample, have been deposited in the Scientific Collection of the Institute of Geosciences, University of São Paulo, SP, Brazil, registered in the type slides USP collection under the numbers: GP/L-3T486 (=GP/3E 9202), GP/L-3T487 (=GP/3E 9203), GP/L-3T488 (=GP/3E 9204).

## PALYNOLOGY

A rich and diversified palynological assemblage was recovered with predominance of triletes genera, attributed to 21 different species, among which the most abundant were related to filicophytes and/ or progymnosperms, followed by lycophytes and sphenophytes. The pollen grains (monosaccates and bisaccates) referred to pteridospermales, cordaitales and coniferales show diversification (eleven species) which give evidences for a meso-xerophytic community, corresponding to the vegetation growing at more distance from the depositional environment.

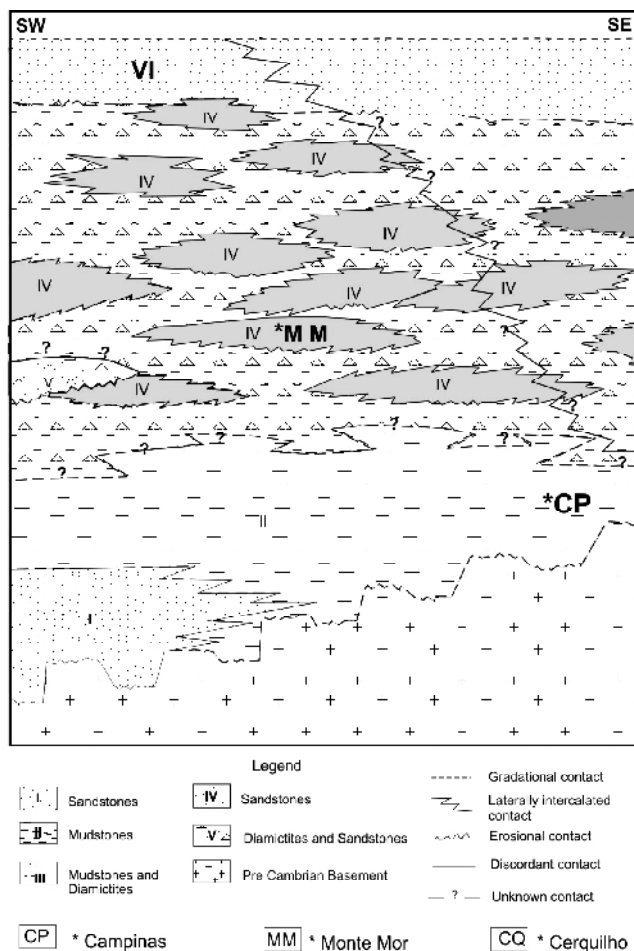


Fig. 4—The Itararé Group with lithostratigraphical informal units, in ascending order, recognized in the studied area by Souza Filho (1986), including the levels of the localities.

## PLATE 1

1. *Leiotriletes virkkii* Tiwari 1965, Lam. IG-P 383 C, R43/2 (40x).
2. *Leiotriletes gracilis* Menéndez 1965, Lam. IG-P 383 C, O48 (63x).
3. *Calamospora hartungiana* Schopf in Schopf, Wilson & Bentall 1944, Lam. IG-P 383 B, K49/3-4 (63x).
4. *Calamospora liquida* Kosanke 1950, Lam. IG-P 384 A, T42/1 (63x).
5. *Callumispora* (= *Punctatisporites*) *gretensis* Balme & Hennelly 1956, Lam. IG-P 384 A, S28/2-4 (63x).
6. *Granulatisporites austroamericanus* Archangelsky & Gamero 1979, Lam. IG-P 385 A, Q35 (63x).
7. *Cyclogranisporites microgranulatus* Menéndez & Azcuy emend. Archangelsky & Gamero 1979, Lam. IG-P 384 A, G42 / 3-4 (63x).
8. *Cyclogranisporites minutus* Bharadwaj 1957, Lam. IG-P 383 – B, T41 / 2 (63x).
9. *Apiculatisporis aculeatus* (Ibrahim) Potonié & Kremp 1955, Lam. IG-P 384 A, C42 / 3-4 (63x).
10. *Horriditriletes uruguaiensis* (Marques-Toigo) Archangelsky & Gamero 1979, Lam. IG-P383 A, X 32 / 3 (63x).
11. *Apiculatisporites parviapiculatus* Azcuy 1975, Lam. IG-P 383 A – G 52/ 3-4 (40x).
12. *Apiculatisporites caperatus* Menéndez & Azcuy 1969, Lam. IG-P 383-B, S53 / 3 (40x).
13. *Reticulatisporites pseudopalliatius* Staplin 1960, Lam. IG-P 384 A, R 55 / 2. (63x).
14. *Lundbladispora riobonitensis* Marques-Toigo & Picarelli 1984, Lam. IG-P 383 B, M 53 / 1 (63x).
15. *Lundbladispora braziliensis* (Pant & Srivastava) Marques-Toigo & Pons emend. Marques-Toigo & Picarelli 1984, Lam. IG-P 383 A, Q 31 / 4 (63x).
16. *Vallatisporites arcuatus* (Marques-Toigo) Archangelsky & Gamero 1979, Lam. IG-P 384 A, F 40 / 1 (63x).
17. *Vallatisporites ciliaris* (Lüder) Sullivan 1964, Lam. IG-P 383 A, Q 52 1 / 2 (63x).
18. *Vallatisporites spinosus* Cauduro 1970, Lam. IG-P 384 A, N 39/ 4 (63x).
19. *Cristatisporites indignabundus* (Loose) Potonié & Kremp, emend. Staplin & Jansonius 1964, Lam. IG-P 384 A, U 35 1-2 (63x).
20. *Cristatisporites crassilabrus* (Archangelsky & Gamero 1979), Lam. IG-P 384 A, T 42 / 2 (63x).
21. *Spelaeotriletes ybertii* (Marques-Toigo) Playford & Powis emend. Playford, Dino & Marques, Toigo 2001 – Lam. IG-P 383 A, M48 (63x).
- 22, 23. Tétrades de esporos: Lam 383 B , S 51/ 3-4 (40x); Lam. IG-P 384 B, S41/2 (63x).
24. *Botryococcus braunii* Kützing 1849, Lam. IG-P 385 F, P 43 / 2-4 (40x).

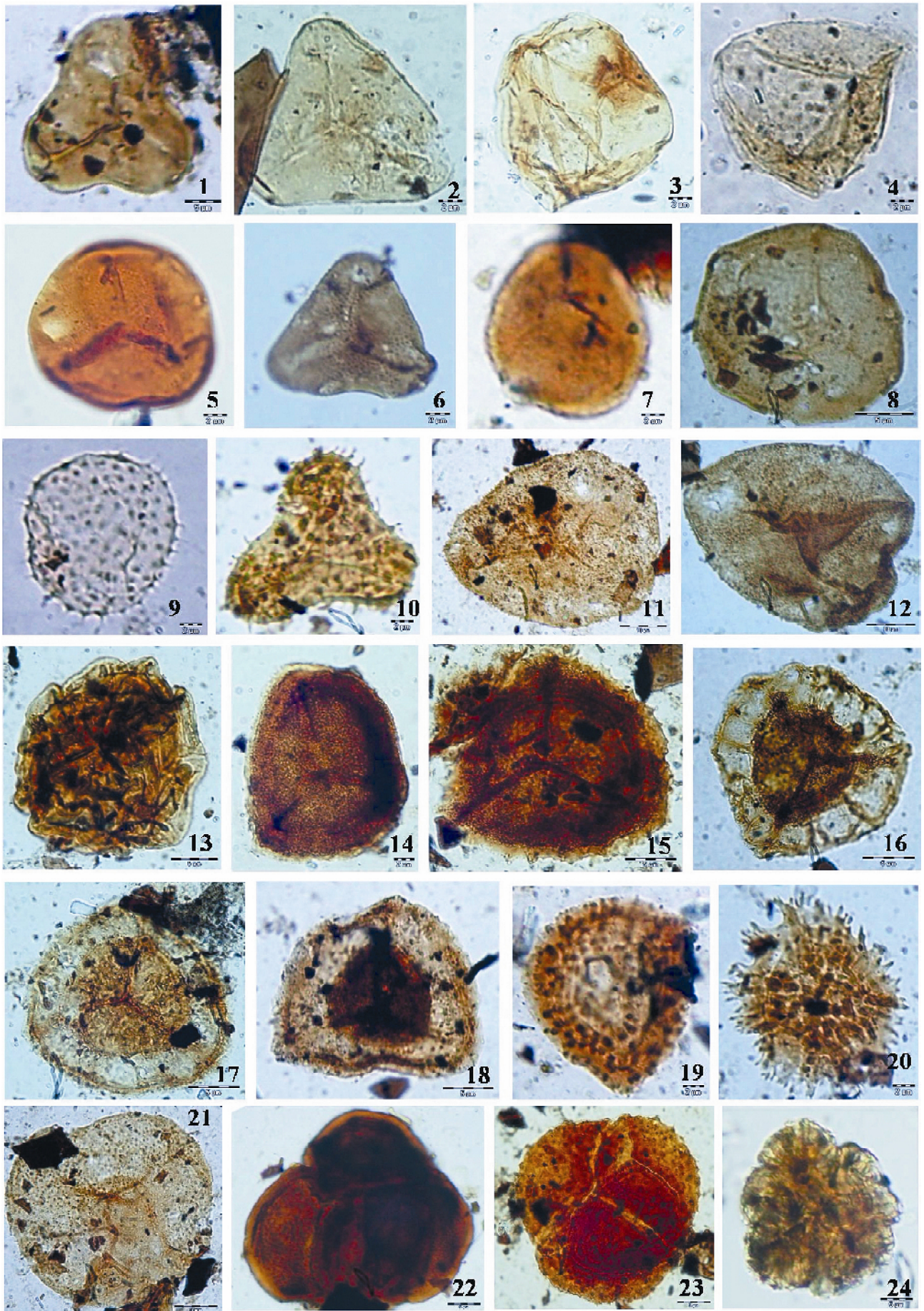


PLATE 1

The palynological composition in the slides of the sample studied is as follows:

**GP/L-3T 487 (=GP/3E/9203)**—The palynoassemblage recorded in this slide shows dominance of cingulate zonate spores, viz. *Cristatisporites* (24%) and *Vallatisporites* (8%) along with radial and bilateral monosaccates, viz. *Parasaccites* (19%), *Plicatipollenites* (2%), *Potonieisporites* (1%) and *Caheniasaccites* (24%). Trilete spores, viz. *Callumispora* (2%), *Verrucosisporites* (1%), *Horriditriletes* (2%) are also present in low amounts. Non striate disaccate *Scheuringipollenites maximus* (9%), *Vestigisporites* (3%) is recorded in the present sample. Striate disaccates, viz. *Striatopodocarpites*, *Schizopollis* and *Crescentipollenites* are very low (1% each). Tetrads of *Verrucosisporites* present.

**GP/L-3T 486 (=GP/3E/9202)**—The palynoassemblage is dominated by monosaccates (both radial and bilateral), viz. *Parasaccites* (19%), *Caheniasaccites* (15%) and *Potonieisporites* (7%) while zonate triletes, viz. *Cristatisporites* (3%), *Vallatisporites* (1%) are very rare. *Crucisaccites* (1%) is recorded in this but due to dissolution of central part of exine we cannot identify the species but it is evidently *Crucisaccites* due to the cruciform type of saccus attachment. Non striate disaccate *Scheuringipollenites maximus* (1%), *Vestigisporites* (3%), laevigate monolete spore *Latosporites* (2%) has also been recorded in this assemblage. But the striate disaccates, viz. *Faunipollenites* (1%) are much low in percentage. Tetrads of *Verrucosisporites* and alete spore *Singraulipollenites* are also recorded.

**GP/L-3T 488 (=GP/3E/9204)**—The palynoassemblage is dominated by radial and bilateral monosaccates, viz. *Parasaccites* (24%), *Plicatipollenites* (1%), *Caheniasaccites* (14%), *Potonieisporites* (7%) and *Divarisaccus* (2%). In this assemblage cingulate zonate spores, viz. *Vallatisporites* (1%) and *Cristatisporites* (1%) are very poor in occurrence.

Laevigate monolete spore *Latosporites* is 2%. Tetrads of *Verrucosisporites* also recorded. Non-striate disaccate, viz. *Scheuringipollenites* (3%) and striate disaccate *Striatopodocarpites* (2%) are also present in very low amounts.

Tetrads of trilete spore *Verrucosisporites* and good percentage of *Caheniasaccites* is present in all the slides. A critical analysis of the palynoflora recovered from the Monte Mor locality show that palynoflora is dominated by lycophytes spores and coniferous pollen. *Ahrensipollenites cristatus* is not recorded in these slides. *Crucisaccites* cf. *C. monoletus* is recorded. *Scheuringipollenites maximus* is also present in the assemblage.

Among 11 species stratigraphically restricted to *Ahrensipollenites* zone, *Cristatisporites spinosus* and *C. indignabundus* have been recorded. This indicated that these species continue to occur in *C. monoletus* zone.

Felix (2007) recorded *Divarisaccus lelei* Venkatachala & Kar, 1966 from Jundiá (SP) which is considered to belong to the *Crucisaccites monoletus* Interval zone, is also present in the assemblage of Monte Mor. Spore pollen taxa recorded in Monte Mor palynoflora have been shown in Pls. 1, 2.

**List of spore pollen species identified in Monte Mor, SP, Brazil, by Souza et al. 1993; Mune, 2005; Mune & Bernardes-de-Oliveira, 2007 and present investigation**

**Triletes:**

*Leiotriletes* sp.

*Leiotriletes virkki* Tiwari, 1965

*Leiotriletes gracilis* Menéndez, 1965

*Calamospora hartungiana* Schopf in Schopf et al., 1944

*Calamospora liquida* Kosanke, 1950

**PLATE 2**

- |   |   |
|---|---|
| <ol style="list-style-type: none"> <li>1. <i>Lundbladispora</i> sp., GP-3E/ 9203/ Res.E, Lam.1, V-42.</li> <li>2. <i>Vallatisporites arcuatus</i> (Marques-Toigo) Archangelsky &amp; Gamero 1979, GP-3E/ 9203/ Res. E, Lam. 2, M34/2.</li> <li>3. <i>Krauselisporites</i> sp., GP-3E/ 9203/ Res. E, Lam. 2, K-37/1.</li> <li>4. <i>Potonieisporites neglectus</i> Potonié &amp; Lele, 1961, GP-3E/ 9202 Res. D, Lam. 2, U-37/4.</li> <li>5. <i>Vallatisporites ciliaris</i> (Lüber) Sullivan 1964, GP-3E/ 9203/ Res. E, Lam1, R-38.</li> <li>6. <i>Crucisaccites</i> ? <i>monoletus</i>, GP-3E/ 9202/ Res. D, Lam. 2, U-44/3.</li> <li>7. <i>Parasaccites diffuses</i> Tiwari 1965, GP-3E/ 9203/ Res. E, Lam. 2, H34/4.</li> <li>8. <i>Parasaccites difusus</i> Tiwari 1965, GP-3E/ 9203/ Res. E, Lam. 2 S-33/2.</li> <li>9. <i>Plicatipollenites malabarensis</i> (Potonié &amp; Sah) Foster 1975, Lam. IG-P385 A, M43 / 3 (40x).</li> <li>10. <i>Plicatipollenites densus</i> Srivastava 1970, Lam. IG-P385 F, P40/ 4 (40x).</li> <li>11. <i>Potonieisporites novicus</i> Bharadwaj emend. Poort &amp; Veld 1997, GP/3E 9203, Res. E, Lam. 1 (R 46/1).</li> </ol> | <ol style="list-style-type: none"> <li>12. <i>Potonieisporites magnus</i> Lele &amp; Karim 1971, GP/3E 9203, Res. E, Lam. 1, K48 (63x).</li> <li>13. <i>Caheniasaccites</i> sp. GP3E/9202 Res D, Lam. 2.</li> <li>14. <i>Caheniasaccites flavatus</i> (Bose &amp; Kar) emend. Azcuy &amp; Di Pasquo 2000, GP/3E / 9204, Res. F, Lam. 1, W 33/1 (63x).</li> <li>15. <i>Scheuringipollenites maximus</i> (Hart) Tiwari 1973, Lam. IG-P 384 A, N 43 (63x).</li> <li>16. <i>Scheuringipollenites ovatus</i> (Balme &amp; Hennelly) Foster 1975, GP/3E / 9204, Res. F Lam. 1, U40/1 (63x).</li> <li>17. <i>Vestigisporites</i> sp. GP3E/9202 Res D, Lam. 2.</li> <li>18. <i>Limitisporites luandensis</i> Bose &amp; Maheshwari 1968, GP/3E 9199, Lam. Res. B, S 52 (63x).</li> <li>19. <i>Limitisporites rectus</i> Leschik 1956, GP/3E / 9204, Res. F, Lam. 1, S 46/3 (63x).</li> <li>20. <i>Scheuringipollenites maximus</i> (Hart) Tiwari 1973, GP/3E 9203, Res. E Lam. 1, F 35/1(63x).</li> <li>21. <i>Striatopodocarpites</i> sp. GP/3E/9203/Res.E, Lam 1, J38/3.</li> <li>22. <i>Meristocarpus explicatus</i> Playford &amp; Dino 2000, GP/3E 9203, Res. E, Lam. 2, O48/3 (63x).</li> <li>23, 24. <i>Strotersporites</i> sp.</li> </ol> |
|---|---|



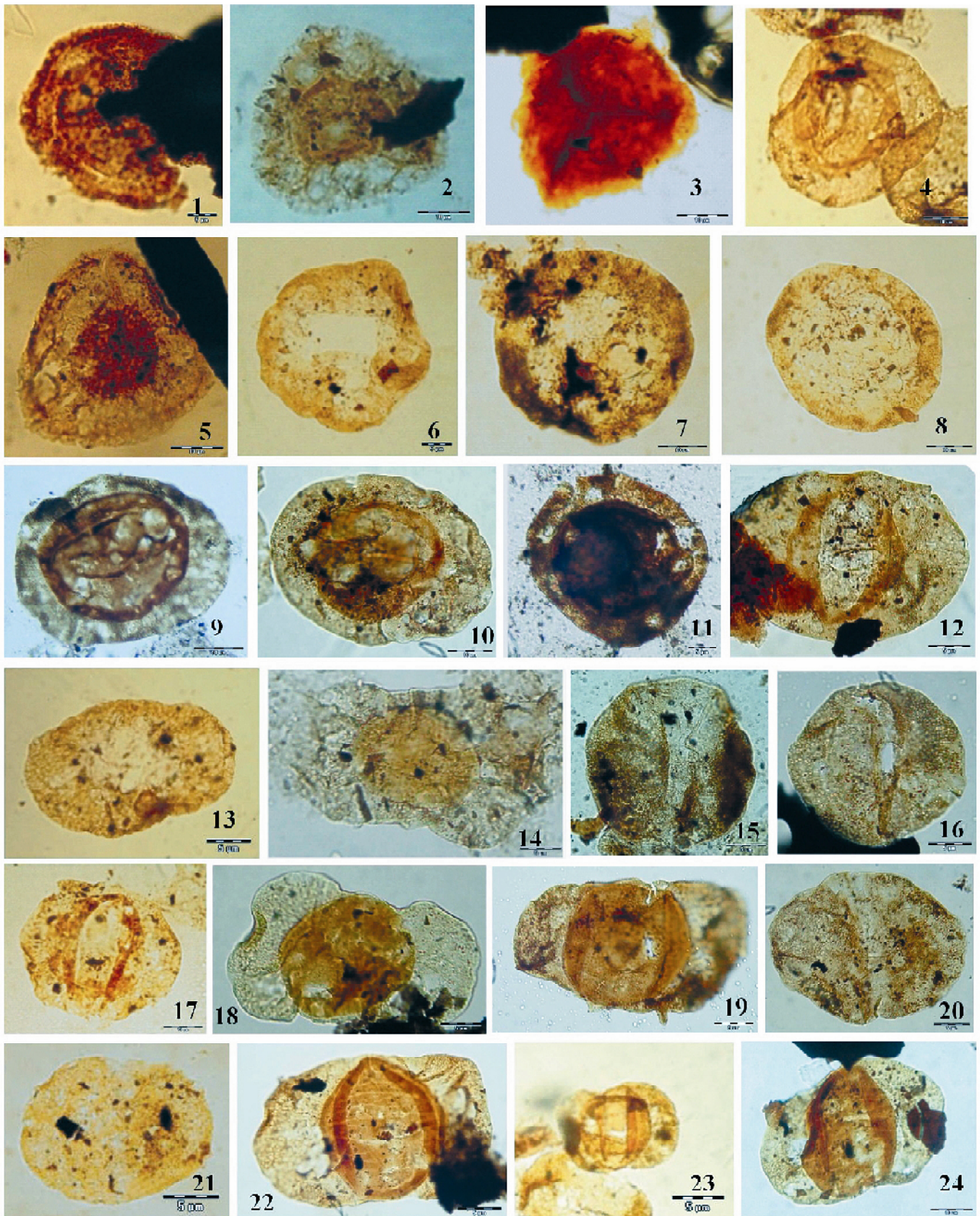


PLATE 2

- Callumispora gretensis* (Balme & Hennelly) Bharadwaj & Srivastava, 1969 emend Tiwari *et al.*, 1989  
*Callumispora barakarensis* (Bharadwaj & Srivastava) Tiwari *et al.* 1989  
*Callumispora (Punctatisporites) resolutus* Playford, 1971  
*Retusotriletes nigritellus* (Lüber) Foster, 1979  
*R. golatensis* Staplin, 1960  
*Apiculiretusispora* cf. *A. coalescens* Menéndez & Azcuy, 1973  
*Granulatisporites austroamericanus* Archangelsky & Gamarro, 1979  
*Granulatisporites parvus* (Ibrahim) Schopf *et al.*, 1944  
*Cyclogranisporites microgranulatus* Menéndez & Azcuy emend. Archangelsky & Gamarro, 1979  
*Cyclogranisporites minutus* Bharadwaj, 1957  
*Verrucosisporites microtuberosus* (Loose) Smith & Butterworth, 1967  
*Verrucosisporites* sp. in Souza *et al.*, 1995  
*Apiculatisporis aculeatus* (Ibrahim) Potonié & Kremp, 1955  
*Horriditriteles uruguaiensis* (Marques-Toigo) Archangelsky & Gamarro, 1979  
*H. ramosus* (Balme & Hennelly) Bharadwaj & Salujha, 1964  
*Apiculatasporites parviapiculatus* Azcuy, 1975  
*Apiculatasporites caperatus* Menéndez & Azcuy, 1969  
*Granulatisporites varigranifer* Azcuy, 1975  
*Reticulatisporites pseudopalliatus* Staplin, 1960  
*Raistrickia rotunda* Azcuy, 1975  
*Foveosporites hortonensis* Azcuy, 1975  
*Densosporites simplex* Staplin & Jansonius, 1964  
*Lundbladispota riobonitensis* Marques-Toigo & Picarelli, 1984  
*Lundbladispota braziliensis* (Pant & Srivastava) Marques-Toigo & Pons emend. Marques-Toigo & Picarelli 1984  
*Vallatisporites arcuatus* (Marques-Toigo) Archangelsky & Gamarro, 1979  
*Vallatisporites ciliaris* (Lüber) Sullivan, 1964  
*Vallatisporites spinosus* Cauduro, 1970  
*Vallatisporites* cf. *V. ciliaris* (Lüber) Sullivan, 1964  
*Krauselisporites* sp.  
*Cristatisporites indignabundus* (Loose) Potonié & Kremp, emend. Staplin & Jansonius, 1964  
*Cristatisporites crassilabratus* Archangelsky & Gamarro, 1979  
*Cristatisporites spinosus* (Menéndez & Azcuy) Playford emend. Césari, 1985.  
*Cristatisporites irradiatus* (Dias Fabricio) Picarelli & Dias Fabricio, 1990  
*Cristatisporites menendezii* (Menéndez & Azcuy) Playford emend. Césari, 1986  
*Spelaeotriletes ybertii* (Marques-Toigo) Playford & Powis emend. Playford *et al.*, 2001

#### **Monolete**

- Laevigatosporites colliensis* (Ibrahim, 1933)

#### **Monosaccates**

- Divarisaccus lelei* Venkatachala & Kar, 1966  
*Divarisaccus* sp.  
*Crucisaccites indicus* Srivastava, 1970  
*Crucisaccites* cf. *C. monoletus* Maithy, 1965  
*C. latisulcatus* Lele & Maithy in Souza & Marques-Toigo, 2005.  
*Crucisaccites* cf. *C. latisulcatus* in Souza *et al.*, 1995  
*Caheniasaccites distinctus* Lele & Makada, 1972  
*C. flavatus* Bose & Kar, 1966 emend. Azcuy & di Pasquo, 2000  
*Potonieisporites novicus* Bharadwaj emend. Poort & Veld 1997,  
*Potonieisporites magnus* Lele & Karim 1971  
*Potonieisporites neglectus* Potonié & Lele, 1961  
*Parasaccites (=Cannanopolis) korbaensis* Bharadwaj & Tiwari, 1964  
*P. (=Cannanopolis) diffusus* Tiwari, 1965  
*Virkipollenites orientalis* Tiwari, 1965  
*Plicatipollenites malabarensis* (Potonié & Sah) Foster, 1975  
*Plicatipollenites densus* Srivastava, 1970  
*Plicatipollenites* sp.

#### **Striate disaccates**

- Faunipollenites (=Protohaploxylinus) amplus* (Balme & Hennelly), Hart, 1964  
*Faunipollenites* sp.  
*Striatopodocarpites* sp.  
*Crescentipollenites* sp.

#### **Non-striate disaccates**

- Scheuringipollenites maximus* (Hart) Tiwari, 1973  
*Scheuringipollenites ovatus* (Balme & Hennelly) Foster, 1975  
*Limitisporites luandensis* Bose & Maheshwari, 1968  
*Limitisporites rectus* Leschik, 1956  
*Platysaccus* sp.  
*Vestigisporites* sp.

#### **Others**

- Botryococcus braunii* Kützing, 1849

### **DISCUSSION**

The Volpe Ranch, in Monte Mor Municipality corresponds to the type-locality of the third megafloral succession level, named “*Paranocladus-Ginkgophyllum-Brasilodendron* Association” (Bernardes-de-Oliveira *et al.*, 2005). The megaflora records the arrival of conifers into the Paraná Basin (abundant *Paranocladus dusenii*, *Paranospermum* and less frequent representatives of the *Buriadia*-type), lycophytes (*Brasilodendron*, *Bumbudendron*) and *Ginkgophyllum*-like leaves, *Noeggerathiopsis*, many species of the seeds like *Samaropsis* and *Cordaicarpus* and few specimens of *Nothorhacopteris*,

*Botrychiopsis*, *Koretrophyllites* and *Sphenophyllum* (Mune & Bernardes-de-Oliveira, 2007).

The Pennsylvanian Monte Mor Taphoflora was studied by Millan (1972, 1974, 1976, 1977a, b, 1978, 1979a, b, 1980, 1981a, b, 1985) for the first time and revised by Mune & Bernardes-de-Oliveira (2007). The megaflores corresponds to the "Taphoflora A" described by Rösler (1978) from the Paraná Basin, and it may be correlated to the *Kräuselcladus-Asterotheca* Phytozone of Argentina (Carrizo & Azcuy, 2006), considered as Upper Pennsylvanian (Kasimovian)-Cisuralian (Asselian). In spite of to be included in *Ahrensiporites cristatus* Interval Zone (Souza, 2006), the Monte Mor palynological contents was suggested to be correlated to *Crucisaccites monoletus* Interval Zone of Souza 2006 by Mune & Bernardes-de-Oliveira (2009) based on the presence of *Scheuringipollenites maximus*. In this case, Monte Mor taphoflora is considered as Stephanian (Kasimovian-Gzhelian) in age, which is younger than Campinas taphoflora.

Its macrofloristic contents are defined by a hydro-hygrophilic community with six species of lycophytes and three to five of sphenophytes; one hygro-mesophilic with three species of putative progymnosperms, one species of cordaitales and other meso-xerophytic with three species of ginkgophytes and two species of conifers. This taphoflora shows that the conifers (*Paranocladus* and *Buriadia*) which appeared in the Pennsylvanian, were already diversified in this region. However, this group is absent in the basal macrofloras of Itararé Group (Campinas, Buri and Itapeva) (Amaral *et al.*, 2004; Zampirolli *et al.*, 2000; Zampirolli, 2001).

### CONCLUDING REMARKS

Presence of *Crucisaccites monoletus*, *Divarisaccus* spp., *Faunipollenites* (= *Protohaploxylinus*) *amplus* (Balme & Hennelly), Hart, 1964, *Faunipollenites* sp., *Platysaccus* sp. and *Scheuringipollenites maximus* indicates that Monte Mor palynoassemblage belongs to *Crucisaccites monoletus* Interval Zone, which is contrary to the earlier studies which indicated that the Monte Mor Palynoassemblage belongs to *Ahrensiporites cristatus* Interval Zone (Souza, 2006). In the present assemblage no *Vittatina* has been recorded which marks the beginning of *Vittatina costabilis* Interval Zone. *Crucisaccites monoletus* is stratigraphically restricted to this zone can be recognized and has been recorded in the present investigation.

The typical Carboniferous taxa, viz. *Vallatisporites arcuatus* (Marques-Toigo) Archangelsky & Gamero, 1979, *Vallatisporites ciliaris* (Lüder) Sullivan, 1964, *Vallatisporites spinosus* Cauduro, 1970, *Vallatisporites* cf. *V. ciliaris* (Lüder) Sullivan, 1964, *Cristatisporites indignabundus* (Loose) Potonié & Kremp, emend. Staplin & Jansonius, 1964, *Cristatisporites crassilabratius* (Archangelsky & Gamero, 1979), *Cristatisporites spinosus* (Menéndez & Azcuy)

Playford emend Césari, 1986, *Cristatisporites irradiatus* (Dias Fabricio) Picarelli & Dias Fabricio, 1990, *Cristatisporites menendezii* (Menéndez & Azcuy) Playford emend. Césari, 1986, *Spelaeotriletes ybertii* (Marques-Toigo) Playford & Powis emend. Playford, Dino & Marques-Toigo, 2001 identified in the present assemblage have never been recorded in Talchir palynoassemblages of India. Talchir Formation directly overlies the Archaeans or metamorphic that forms the basement. The intervening succession is missing in the Indian Gondwana basins. Talchir Formation is Early Permian in age.

*Scheuringipollenites maximus* and appearance of *Crucisaccites monoletus* in Monte-Mor palynoflora indicates that these Indian Permian taxa appeared earlier in Brazil than India and probably migrated from Brazil to India through Africa. These results suggest a diachronic correlation of this palynoflora with Indian Gondwana microflora.

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