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Palynological investigations and biostratigraphic correlations of Permian sedimentary rocks from eastern Paraguay

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with 2 plates and 4 figures

Abstract. Geological and palynological studies have been carried out on a sequence of Permian rocks from a borehole in eastern Paraguay and a list of identifiable palynomorphs is presented.The sequence studied belongs to the Tacuary Formation of the Independencia Group. Most of the microspores are the same as those described from other Permian sequences of the Chaco-Paraná Basin (Argentine) and the Paraná Basin (Brazil). The palynomorph assemblage provides a late Early Permian to early Late Permian (Kungurian – Kazanian) age for the interval studied. The sedimentary sequence was deposited in a transitional, marine-nonmarine environment.

Zusammenfassung. Permische Sedimentgesteine eines Bohrloches im östlichen Paraguay wurden geologisch und palynologisch untersucht. Das Bohrloch durchörterte die Tacuary Formation, die zur Independencia Gruppe gehört. Die meisten der beobachteten Mikrosporen treten auch in den permischen Abfolgen im Chaco-Paraná-Becken (Argentinien) und im Paraná-Becken (Brasilien) auf. Die palynologische Vergesellschaftung liefert Hinweise auf ein spätes eopermisches bis frühes neopermisches Alter des untersuchten Bohrabschnittes. Die geologischen und palynologischen Untersuchungsergebnisse zeigen, daß die Sedimente im Bereich des Überganges vom marinen zum nichtmarinen Sedimentationsmilieu abgelagert wurden.

1 Introduction

The aim of this study is to present the palynomorphic analysis and to establish a biostratigraphic correlation of the middle to upper Permian sedimentary rocks in eastern Paraguay with neighbouring areas. To the authors' knowledge, no palynological studies on Permian rocks in eastern Paraguay have yet been published.

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In Late Paleozoic times, one large sedimentary basin existed in the South American part of Gondwana. The part of the basin situated in Brazil is referred to as the Paraná Basin, and the portion situated in Argentine is called the Chaco-Paraná Basin. The sedimentary rock sequence in eastern Paraguay constitute the link between the Upper Paleozoic sediments of the Paraná and Chaco-Paraná Basins. Sedimentary rocks of Permian age in the Paraná Basin are considered potential reservoirs for gaseous and liquid hydrocarbons, and, therefore, the results of the present study may be helpful in the search for oil and gas in the Paraguayan part of the Paraná Basin.

The sedimentary rocks of Permian age constitute the Independencia Group, which occupies a N–S zone in the central part of eastern Paraguay (Fig. 1). They are underlain by the Coronel Oviedo Group of Carboniferous age in the west, which contain evidence of glaciation, and are overlain in the east by sedimentary rocks of the Misiones Formation of Lower Mesozoic age. The present study is restricted to stratigraphic investigation of the Tacuary Formation, which occupies the middle to upper part of the Independencia Group. The stratigraphy of the investigated area is described in Section 3.

The Independencia Group sediments represent a transgressive-regressive cycle. They were laid down in a marine/nonmarine transitional environment and consist of shallow-marine, lagoonal, river-dominated deltaic, lacustrine and continental sediments. Towards the close of the Permian, the sedimentary basin was entirely filled up and continental sediments were laid down.

On account of the poor exposure and the complex and varied lithology, it is impossible to obtain a satisfactory composite section of the stratigraphic sequence from outcrops. Therefore, borehole records were used to complement the surface geology. The borehole data also helped greatly in understanding the depositional conditions and the paleoenvironment.

The Anschutz Corporation, in the search for sandstone-hosted uranium deposits, drilled a large number of shallow rotary boreholes in the mainly Permian sediments of eastern Paraguay. Cuttings and drilling records are preserved and filed in the Dirección de Recursos Minerales in Asunción. In order to correlate the Permian sedimentary rocks of the Independance Group with the sedimentary successions established in the Paraná Basin in Brazil and the Chaco-Paraná Basin in Argentine, one borehole (RD74) was selected for palynological and lithological study. The drilling records can be correlated with surface exposures, which thus provide lithostratigraphic control.

Borehole RD74 penetrated most of the Tacuary Formation in the middle to upper part of the Independancia Group and contains several fossil-rich layers which permit to identify and to determine the palynomorphs in the drill cuttings and their frequency distribution. A lithological log was constructed from the drilling records and drill cuttings (Fig. 2). The drilled sequence comprises predominantly calcareous siltstones, sandstones and shales. The shale layers vary in thickness from a few mm to approximately 10 cm. In the lower part of the sequence, the drilling record indicates the presence of oolitic chert layers and oolitic sandstone.

This study was carried out jointly by the Dirección de Recursos Minerales in Asunción, Paraguay and the Federal Institute for Geosciences and Natural Resources in Hannover, Germany within the scope of the Paraguayan-German Geological Cooperation Project.

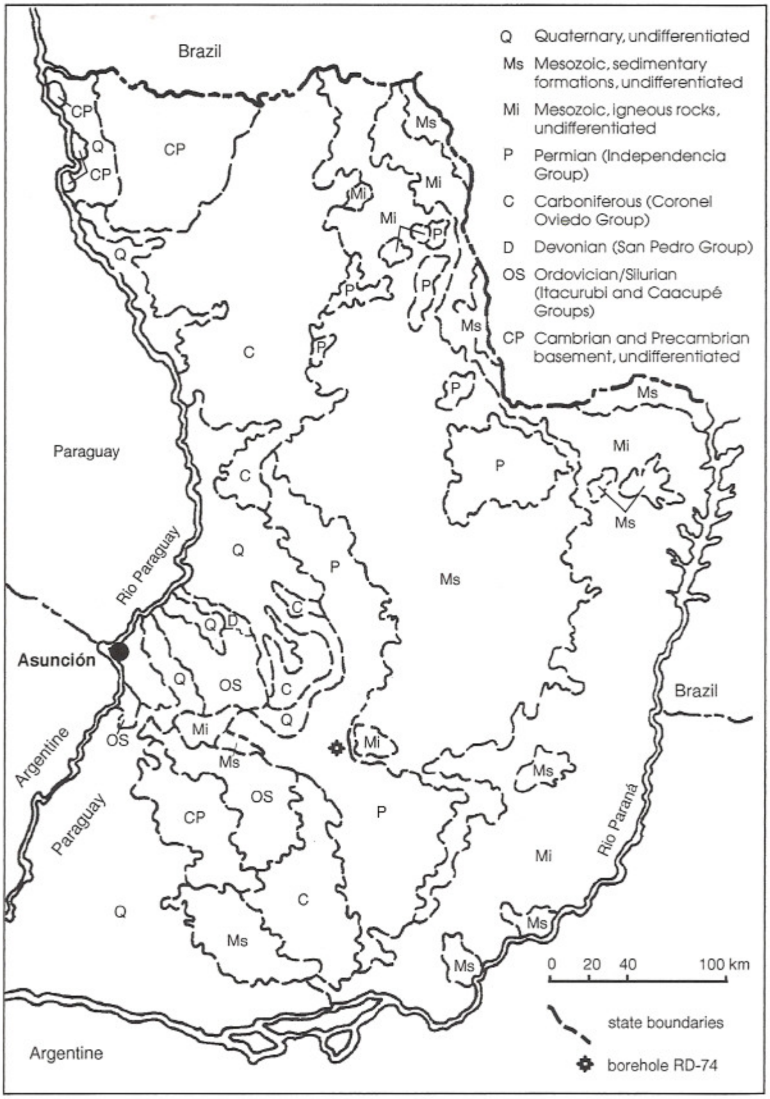

Fig. 1. Geological sketch map of eastern Paraguay and location of borehole RD 74.

2 Material and methods

The palynological work was done on drill cuttings obtained from the Anschutz Corporation's borehole RD74. The borehole is located at 25° 43′ S and 56° 23′ W (Fig. 1) in the Guairá Department, 23 km E of the township Mbocayaty on the road leading to the town of Independencia. The borehole reached a depth of 206 m.

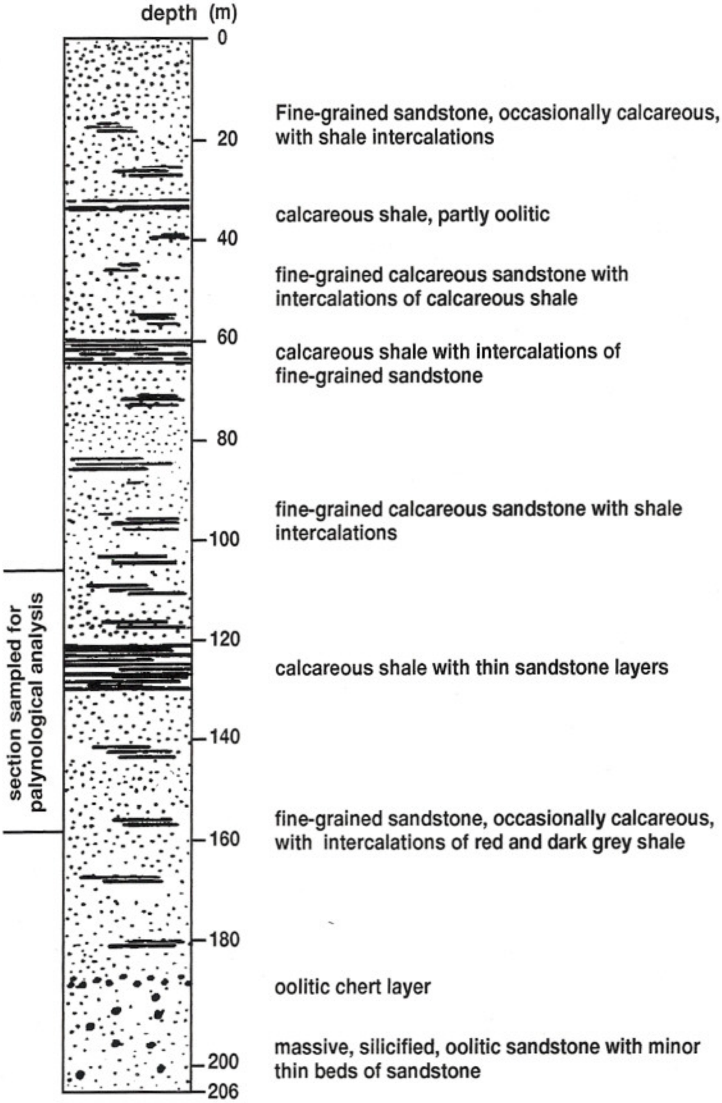

Fig. 2. Lithological log of borehole RD 74.

The drill cuttings from borehole RD74 are stored at the Dirección de Recursos Minerales in Asunción in paper envelopes. The footage sampled in each envelope is variable and ranges from 1 to 3 m. Altogether, 21 envelopes of cuttings were selected by eye for palynological analysis, out of which 13 contained identifiable palynomorphs. The palynomorph-bearing sample intervals are shown in the distribution diagram (Fig. 3).

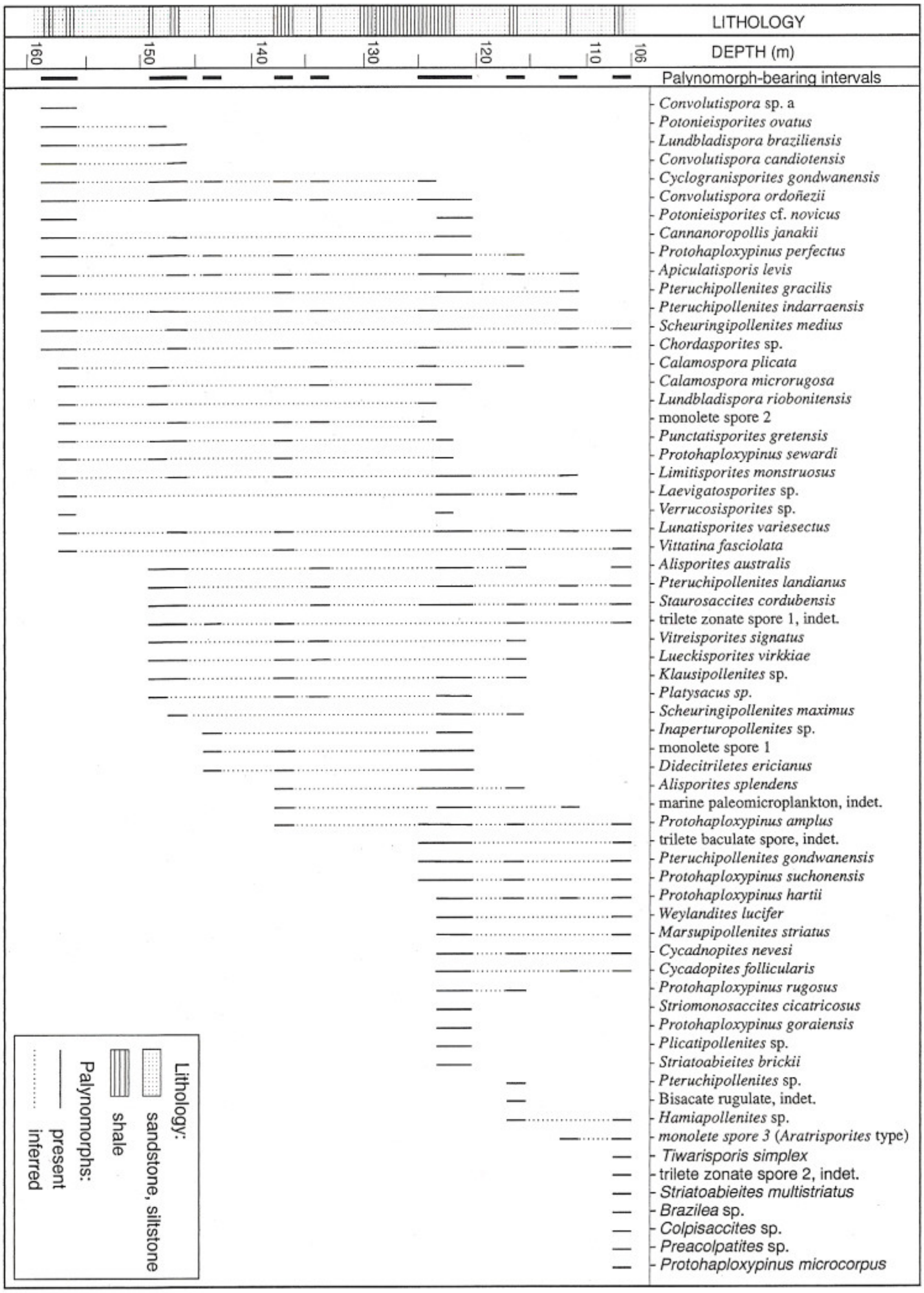

Fig. 3. Stratigraphic distribution of palynomorph taxa between 106 and 158.5 m in borehole RD 74.

In each sample, approximately 130 palynomorphs were counted and their relative proportion estimated. 64 forms were identified. Most of these are also present in other Upper Paleozoic sedimentary sequences in the South American part of Gondwana. Palynomorphs marked "sp." in this study have not yet been recorded from this region and are the subject of further detailed studies.

The cuttings were ground to approximately 2 mm and all samples were treated with standard palynological extraction techniques. HCl, HF and HNO_3 were used to remove mineral matter. The palynomorphic material was classified into 20 µm, 100 µm and 150 µm fractions and permanent slides were made of the residue using glycerine jelly. The slides are kept in the Palynological Collection of the Miguel Lillo Institute, San Miguel de Tucumán, Argentine.

Microphotographs of most of the palynomorphs encountered in this study are shown in Plates I and II.

3 Geology

The sedimentary rocks of Permian age in eastern Paraguay belong to the Independencia Group. Harrington (1950) used the name Independencia Series, and in a later study (Harrington 1956) he termed them Independencia Formation. Eckel (1959) applied the name Independencia Series, while Putzer (1962) named them Passa Dois Series following the Brazilian stratigraphic nomenclature. Evaluating the extensive drilling program of the Anschutz Corporation, Wiens (1982) proposed a four-fold division for the Independencia Group which are, from bottom to top: the San Miguel, Tacuary, Tapytá and Cabacuá Formations. The 1:1,000,000 Geological Map of Paraguay (Undp 1986) places the Tapytá and Cabacuá Formations at the base of the overlying Mesozoic formations. Since there is as yet no consensus on the lithostratigraphy in the upper part of the Independencia Group, in this study the units above the Tacuary Formation are marked as

Plate 1

1. *Cyclogranisporites gondwanensis* Bharadwaj & Salujha 1964. 1000×; Prep. N° 393/1 (475–80 m): 105,2/22,9. **2.** *Apiculatisporis levis* Balme & Hennelly 1956. 1000×; Prep. N° 393/1 (475–80 m): 96,2/24,1. **3.** *Convolutispora ordoñezii* Archangelsky & Gamerro 1979. 1000×; Prep. N° 393/1 (475–80 m): 97,4/22,6. **4.** *Convolutispora candiotensis* Ybert 1975. 800×; Prep. N° 393/1 (475–80 m): 85,8/8,9. **5.** *Cannanoropollis janakii* Potonié & Sah 1960. 600×; Prep. N° 396/1 (510–15 m): 115,8/18,9. **6.** *Potonieisporites ovatus* (Kar) Gutiérrez 1993. 500×; Prep. N° 396/1 (510–15): 117,8/22,5. **7.** *Chordasporites* sp. 600×; Prep. N° 393/1 (475–80 m): 122,8/5,6. **8.** *Pteruchipollenites gondwanensis* (Jain) Ottone & García 1991. 800×; Prep. N° 387/1 (380–85 m): 117,8/17,1. **9.** *Protohaploxypinus microcorpus* (Schaarschmidt) Clarke 1965. 1000×; Prep. N° 385/1 (350–55 m): 98/15,4. **10.** *Marsupipollenites striatus* (Balme & Hennelly) Foster 1975. 1000×; Prep. N° 388/1 (395–405 m): 98,4/23,1. **11.** *Protohaploxypinus amplus* (Balme & Hennelly) Hart 1964. 500×; Prep. N° 388/1 (395–405 m): 99,9/15,4. **12.** *Scheuringipollenites maximus* (Hart) Tiwari 1973. 500×; Prep. N° 388/1 (395–405 m): 119,2/5,6. **13.** *Protohaploxypinus hartii* Foster 1979. 600×; Prep. 386/1 (365–70 m): 119/0,4. **14.** *Lunatisporites variesectus* Archangelsky & Gamerro 1979. 500×; Prep. N° 388/1 (395–405m): 116,4/23,1. **15.** *Protohaploxypinus rugosus* (Jansonius) Foster 1979. 500×; Prep. N° 388/1 (395–405 m): 110/5,8.

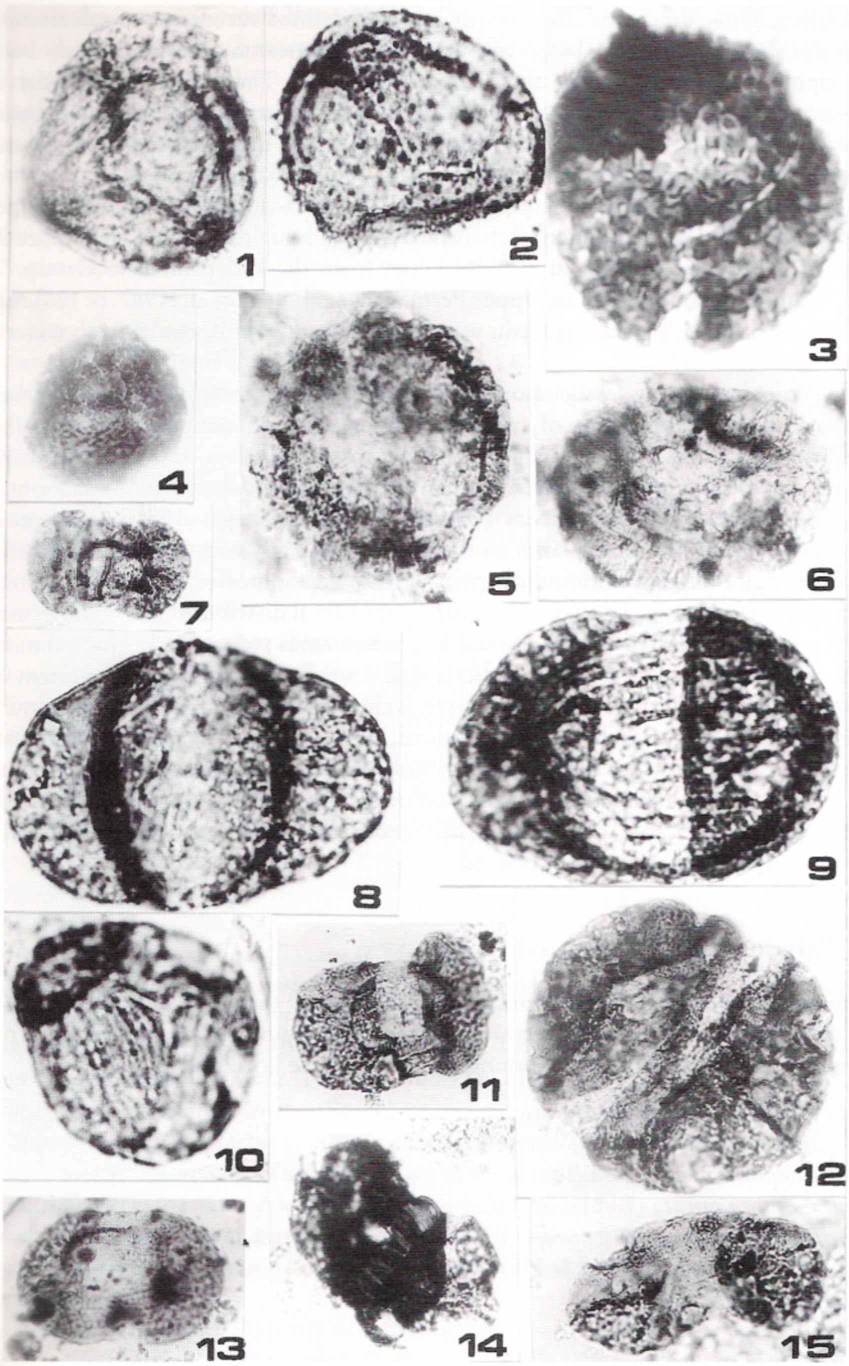

Plate I

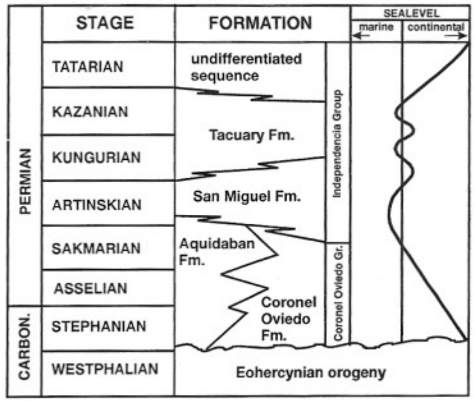

Fig. 4. Lithostratigraphic subdivision of the Independencia Group and schematic sea-level curve.

"undifferentiated sequence" (Fig. 4). Whether these units are part of the Permian sedimentary succession or whether they are part of the overlying Misiones Formation of (?)Jurassic age is a matter for further investigations.

The San Miguel Formation, which forms the base of the group, is made up of conglomeratic sandstones succeeded by cross-bedded sandstone with silt layers. In the west, the San Miguel Formation exhibits scour channels indicating deposition in a braided river system, while massive sandstones prevail in the east.

The Tacuary Formation rests transitionally on the San Miguel Formation and consists of a succession of shales, siltstones, sandstones and minor limestone lenses. The siliciclastic sediments are often calcareous. The sandstones are massive, of varied colors, fine-grained and well-sorted. The siltstones are well bedded and in parts marly. The local limestone lenses are finely banded, sometimes oolitic and often show cross-bedding. The individual lenses may attain a thickness of up to 1 m and a lateral extent of several hun-

Plate 2

1. *Tiwarisporis simplex* (TIWARI) MAHESHWARI & KAR 1967. 500×; Prep. N° 385/1 (350–55 m): 107,2/22,3. **2.** *Striomonosaccites cicatricosus* ARCHANGELSKY & GAMERRO 1979. 500×; Prep. N° 388/1 (395–405 m): 88,1/14,1. **3.** *Staurosaccites cordubensis* ARCHANGELSKY & GAMERRO 1979. 500×; Prep. N° 385/1 (350–55 m): 111,6/23,6. **4.** *Cycadopites nevesi* (HART) HART 1965. 500×; Prep. N° 385/1 (350–55 m): 116,6/4. **5.** *Vitreisporites signatus* LESCHIK 1955. 800×; Prep. N° 391/1 (445–50 m): 101,3/7,3. **6.** monolete spore 2. 1000×; Prep. N° 386/2 (365–70 m): 97,3/17,9. **7.** *Platysacus* sp. 500×; Prep. N° 388/1 (395–405 m): 92,6/23,5. **8.** monolete spore 1. 500×; Prep. N° 393/1 (475–80 m): 83,6/11,4. **9.** *Laevigatosporites* sp. 500×; Prep. N° 395/1 (505–10 m): 106/21,6. **10.** *Vittatina fasciolata* (BALME & HENNELLY) BHARADWAJ 1962. 1000×; Prep. N° 385/1 (350–55 m): 90,6/19,6. **11.** *Preacolpatites* sp. 800×; Prep. N° 385/1 (350–55 m): 117,8/14,7. **12.** marine paleomicroplankton. 600×; Prep. N° 388/1 (395–405 m): 116,2/23,6. **13.** *Brazilea* sp. 800×; Prep. N° 385/1 (350–55 m): 119/3. **14.** *Weylandites lucifer* (BHARADWAJ & SALUJHA) FOSTER 1975. 1000×; Prep. N° 385/1 (350–55 m): 118,4/18,9.

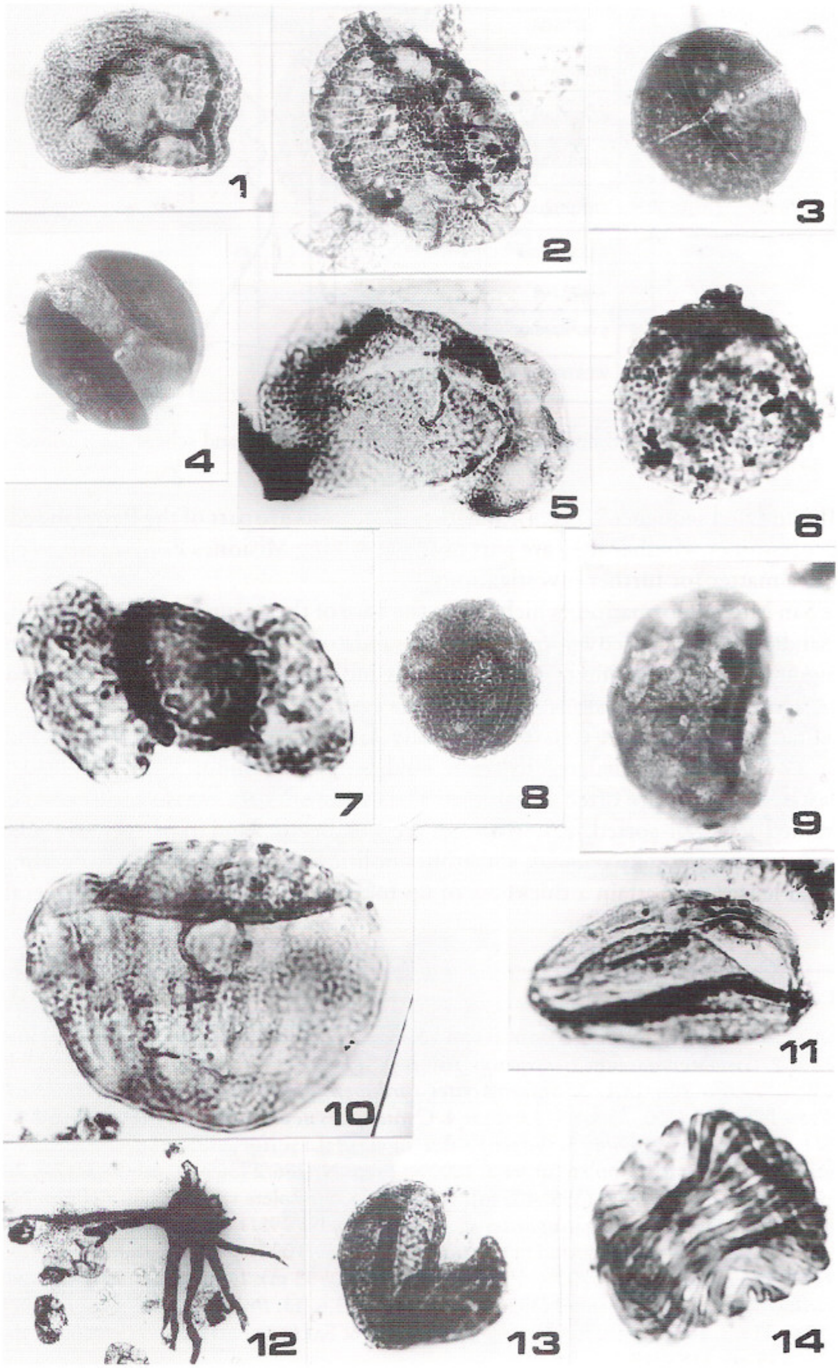

Plate II

dred meters. These limestone lenses occur in a well defined succession of calcareous siltstones and shales, which may be up to 6 m thick. The limestone lenses are finely banded, show ripple marks and display abundant bioturbation. They contain lenticular chert concretions up to 20 cm thick; they lie mostly parallel to the bedding and cross-bedding, or follow fractures cross-cutting the bedding planes. The origin of the silica appears to be intraformational and the chert lenses are syn- to postdiagenetic.

In a paleontological study, Herbst et al. (1987) found 6 different forms of pelicipodes, 13 forms of ostracods, 1 specimen of charophyta, plant remains, and the megaspore *Triletes* sp. cf. *T. nitens* Dijkstra in samples taken from the Independencia Group. They assigned this fossil assemblage an Upper Permian age. Herbst et al. (1987, p. 120) suggest that, in the Kazanian, the Paraná Basin was characterized by episodes of fresh water conditions.

The geological setting (association with freshwater sediments, presence of carbonate sediments, limited dimensions of carbonate lenses), the sedimentary structures (ripple marks, cross-bedding, laminated shale), and the fossils (bivalves, bioturbation) indicate deposition in locally restricted, partially open or closed lagoonal estuaries or lagoons. Jalfin (1986) suggested that the Tacuary Formation in the investigated area represents sediments laid down in near-shore lakes which were periodically connected to the open sea.

The geological observations indicate that the borehole is located on the western margin of the then Paraná Basin. The close association and lateral distribution of shallow-marine, lagoonal, river-dominated deltaic, fluvial and continental sediments in the sedimentary record of the Independencia Group indicate that it was formed at the sea-continent interface and represents a transgressive-regressive cycle. The transgressional phase culminated in the Artinskian stage. Under these conditions, minor sea level changes or modifications of the basin geometry led to the deposition of different sedimentary facies, and, therefore, continental, lacustrine and shallow-marine sediments are spatially closely associated in the investigated area. Towards the end of the Permian, a final regression took place and fluvial and continental sediments were deposited.

4 Palynology

The distribution of the palynomorphs encountered in the interval between 106 and 158.5 m is shown in Figure 3. Species of continental origin predominate; marine paleomicroplankton is present in minor amounts only in three horizons.

The following species were found:

- *Punctatisporites gretensis* Balme & Hennelly 1956
- *Calamospora microrugosa* (Ibrahim) Schopf, Wilson & Bentall 1944
- *Calamospora plicata* (Luber & Waltz) Hart 1965
- *Cyclogranisporites gondwanensis* Bharadwaj & Salujha 1964
- *Apiculatisporis levis* Balme & Hennelly 1956
- *Verrucosisporites* sp.
- *Convolutispora* sp. a
- *Convolutispora ordoñezii* Archangelsky & Gamerro 1979

- *Convolutispora candiotensis* YBERT 1975
- *Didecitriletes ericianus* (BALME & HENNELLY) VENKATACHALA & KAR 1965
- trilete spore baculala indet.
- *Lundbladispora riobonitensis* MARQUES TOIGO & PICARELLI 1985
- *Lundbladispora braziliensis* (PANT & SRIVASTAVA) MARQUES TOIGO & PONS 1976
- trilete zonate spore indet.
- trilete zonate spore indet.
- *Laevigatosporites* sp.
- monolete spore 1
- monolete spore 2
- monolete spore 3 (*Aratrisporites* type)
- *Potonieisporites ovatus* (KAR) GUTIÉRREZ 1993
- *Potonieisporites* cf. *novicus* BHARADWAJ 1954
- *Cannanoropollis janakii* POTONIÉ & SAH 1960
- *Plicatipollenites* sp.
- *Pteruchipollenites gracilis* (SEGROVES) FOSTER 1979
- *Pteruchipollenites indarraensis* (SEGROVES) FOSTER 1979
- *Pteruchipollenites landianus* (BALME) MACRAE 1988
- *Pteruchipollenites gondwanensis* (JAIN) OTTONE & GARCÍA 1991
- *Pteruchipollenites* sp.
- *Scheuringipollenites medius* (BURJACK) DIAS FABRICIO 1981
- *Scheuringipollenites maximus* (HART) TIWARI 1973
- *Chordasporites* sp.
- *Klausipollenites* sp.
- *Limitisporites monstruosus* (LUBER & VALTZ) HART 1965
- *Alisporites australis* DE JERSEY 1962
- *Alisporites splendens* (LESCHIK) FOSTER 1979
- *Vitreisporites signatus* LESCHIK 1955
- *Platysacus* sp.
- bisacate rugulate, indet.
- *Protohaploxypinus amplus* (BALME & HENNELLY) HART 1964
- *Protohaploxypinus suchonensis* (SEDOVA) HART 1964
- *Protohaploxypinus hartii* FOSTER 1979
- *Protohaploxypinus rugosus* (JANSONIUS) FOSTER 1979
- *Protohaploxypinus goraiensis* (POTONIÉ & LELE) HART 1964
- *Protohaploxypinus microcorpus* (SCHAARSCHMIDT) CLARKE 1965
- *Protohaploxypinus perfectus* (NAUMOVA) SAMOILOVICH 1953
- *Protohaploxypinus sewardi* (VIRKKI) HART 1964
- *Lunatisporites variesectus* ARCHANGELSKY & GAMERRO 1979
- *Striatoabieites brickii* SEDOVA 1966
- *Striatoabieites multistriatus* (BALME & HENNELLY) HART 1964
- *Hamiapollenites* sp.
- *Lueckisporites virkkiae* POTONIÉ & KLAUS 1954
- *Vittatina fasciolata* (BALME & HENNELLY) BHARADWAJ 1962

- *Weylandites lucifer* (Bharadwaj & Salujha) Foster 1975
- *Tiwarisporis simplex* (Tiwari) Maheshwari & Kar 1967
- *Staurosaccites cordubensis* Archangelsky & Gamerro 1979
- *Marsupipollenites striatus* (Balme & Hennelly) Foster 1975
- *Striomonosaccites cicatricosus* Archangelsky & Gamerro 1979
- *Cycadopites nevesi* (Hart) Hart 1965
- *Cycadopites follicularis* Wilson & Webster 1946
- *Colpisaccites* sp.
- *Preacolpatites* sp.
- marine paleomicroplankton, indet.
- *Brazilea* sp.
- *Inaperturopollenites* sp.

The frequency diagram in Figure 3 shows a high species diversity. Grains of bisaccate and striate pollen grains dominate. Between borehole depths of 121.6–158.5 m, they constitute approximately 55% of the total content of palynomorphs, and their abundance increases to about 80% towards the top of the studied sequence. In the lower part of the investigated sequence, the remaining portion comprises trilete spores (approximately 20%), monolete spores (approximately 10%) and grains of monosaccate and monocolpate pollen grains (approximately 13%) and decreases to about 7% of trilete spores, 7% monolete spores, and approximately 3% of grains of monosaccate and monocolpade pollen in the upper part (106–121.6m).

Between 137 m and 110 m, three individual sedimentary layers contain paleomicroplankton constituting approximately 2% of the total microflora and possessing spherical forms and long, thin processes. This type of paleomicroplankton has been shown to indicate a quiet, shallow-marine environment (Staplin 1961, Wall 1965, Sarjeant 1974). Paleomicroplankton considered to indicate fresh water has been observed (approximately 1%) in the upper part of the sequence with only one form (*Brazilea* sp.).

Figure 3 shows a distinct pattern of distribution of palynomorphs and permits important paleoenvironmental changes to be inferred:

1. The presence of the forms *Cyclogranisporites gondwanensis*, *Convolutispora ordoñezii*, *Potonieisporites* cf. *novicus*, *Calamospora microrugosa*, *Lundbladispora riobonitensis*, monolete spore 2, *Punctatisporites gretensis*, *Protohaploxypinus sewardi*, *Platysacus* sp., *Inaperturopollenites* sp., *Didecitriletes ericianus* and monolete spore 1 range from the lowermost samples to approximately 120 m.
2. The forms *Pteruchipollenites gondwanensis*, *Protohaploxypinus suchonensis*, *P. hartii*, *Weylandites lucifer*, *Marsupipollenites striatus*, *Cycadopites nevesi*, *C. follicularis*, *Protohaploxypinus rugosus* appear for the first time at the depth of above approximately 124 m.
3. Another group is only present in the intermediate depth range of the sampled sequence. These are: *Vitreisporites signatus*, *Klausipollenites* sp., *Scheuringipollenites maximus*, *Inaperturopollenites* sp., monolete spore 1, *Didecitriletes ericianus.*

The presence of the three groups outlined above could indicate either variations of paleoecological conditions along the analyzed drill section or it could indicate the presence of different biozones or lithostratigraphic units. The notable decrease of spores and monosaccate pollen grains and the increasing frequency of bisaccate and striate pollen towards the top of the sequence coincide with the observed frequency variations in neighbouring Neopaleozoic sequences in the Chaco-Paraná Basin of Argentine (Russo et al. 1980, Vergel 1993) and the Paraná Basin in Brazil (Marques Toigo 1991) and other Gondwanian areas (Wood et al. 1992). Correlation with established palynological sections of Argentine and Brazil is discussed below.

Lithostratigraphic and biostratigraphic correlation studies of Permian sedimentary rocks in the Chaco-Paraná basins have been carried out by Russo et al. (1980), Vergel (1993), Archangelsky & Marques Toigo (1978). They established three palynozones, the *Potonieisporites – Lundbladispora* Zone in the Stephanian C stage (and possibly including Asselian), the *Cristatisporites* Zone of the Artinskian and Sakmarian stages, and the *Striatites* Zone of Kungurian and Kazanian age. Certain palynological similarities exist between the RD 74 section and the Chaco-Paraná Basin in the Argentine, i. e. between the upper part of RD 74 and the *Striatites* Zone and between the lower part of RD 74 and the upper part of the *Cristatisporites* Zone. Some of the spores typical of the *Cristatisporites* Zone were not found in RD 74, but this may be due to environmental variations caused by the considerable distance between the two areas.

Aceñolaza & Vergel (1987) describe microflora from the La Cuesta Formation of the Famatima System in the Catamarca Province, eastern Argentine, comprising pollen elements (abundant bisaccate and striate pollen grains) similar to those found in the upper part of RD74. The microflora of the La Cuesta Formation is considered to be of late Permian age and is only slightly younger than the *Striatites* Zone (Russo et al. 1980).

Daemon & Quadros (1970) and Marques Toigo (1991) provide palynological data for the Paraná Basin which can be compared with the palynomorphs recorded from RD-74. They established palynozones for the Itararé Group, Guatá Group (Rio Bonito and Palermo Formation) and Passa Dois Group (Iratí Formation) of Permian age. Marques Toigo (1991) defined a *Lueckisporites virkkiae* Zone of Kazanian age and a *Cannanoropollis korbaensis* Zone spanning the Artinskian and Kungurian. The *Cannanoropollis korbaensis* Zone is divided into the three subzones, from bottom to top, the *Protohaploxypinus goraiensis*, *Caheniasaccites ovatus*, and *Hammiapollenites karooensis Subzones*. In the *Lueckisporites virkkiae* Zone, disaccate striatiti dominate over nonstriate disaccate and monosaccate pollen grains, while trilete and alete spores are less common. The palynomorphs of the *Cannanoropollis korbaensis* Zone, *Hamiapollenites karroensis* Subzone, and *Lueckisporites virkkiae Zone* are similar to those of the drilled section of the Taquary Formation, which is therefore assigned to a Kungurian and Kazanian age.

It should be mentioned that taxons such as the monolete spore of the *Aratrisporites* type, and various species of the genera *Protohaploxypinus* and *Chordasporites* sp. are present in the samples investigated and are considered to indicate an Early Triassic age. However, little evidence is present to support a younger age for the interval investigated because the microfossils indicative of Lower Triassic age could well possess a biochron spanning a wide age range.

Paleoecologically, the sequence investigated is characterized by dominance of species of continental origin, and short, sporadic marine episodes are indicated by the presence of paleomicroplankton. The increasing frequency of bisaccate and striate pollen and decreasing abundance of spores and monosaccate pollen grains towards the top of the sequence could indicate important climatic changes. The continuity of palynomorphs along the drill section precludes the presence of a major hiatus and points to a continuous sedimentation under relatively stable conditions.

5 Summary

The palynological studies on material from borehole RD74 permit us to assign a late Early Permian to early Late Permian age (Kungurian – Kazanian) to the investigated sequence. The sedimentary environment was mainly continental with sporadic marine incursions documented by the presence of isolated horizons containing paleomicroplankton.

Lithological studies are compatible with the palynological findings and show that sedimentation took place in a transitional continental-marine environment during a generally regressive regime and that in the final phase when the Tacuary Formation was laid down, continental sedimentation prevailed.

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