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ADDITIONAL SYSTEMATIC INFORMATION ON THE EARLY CARBONIFEROUS PALYNOFLORA FROM THE AMBO FORMATION, PONGO DE MAINIQUE, PERU

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ABSTRACT - Palynologic results presented in this contribution come from six productive samples located in the upper part of the Ambo Formation at Pongo de Mainique, Peru. A brief geologic information and an annotated species list (some illustrated) including taxonomic and morphologic remarks for some taxa (genera or species) and their stratigraphic and geographic occurrences outside Peru, are displayed herein. The lectotype of *Verrucosisporites nitidus* Playford is here designed. The composition of the palynoflora allows correlating to the *Cordylosporites magnidictyus* Palynozone (late Viséan of the Amazon Basin, Brazil). More information such as the complete and illustrated list of taxa, are part of a recent publication on the palynology of the same unit realised by the same authors.

Key words: Systematic, occurrences, Ambo Formation, Early Carboniferous, Peru.

RESUMO – Os dados palinológicos apresentados nesta contribuição foram obtidos a partir de seis amostras férteis procedentes da parte superior da Formação Ambo, na localidade de Pongo de Mainique, Peru. Uma síntese das informações geológicas e a lista de espécies registradas, algumas das quais ilustradas, são apresentadas, bem como comentários morfológicos e taxonômicos de alguns táxons e sua distribuição geográfica e estratigráfica fora do Peru. É designado o lectótipo de *Verrucosisporites nitidus* Playford. A composição da palinoflora permite correlação com a Palinozona *Cordylosporites magnidictyus* (Viseano final da bacia do Amazonas, Brasil). A lista completa de táxons, suas ilustrações e outras informações adicionais são parte de uma publicação recente sobre o tema realizada pelos autores.

Palabras-chave: Sistemática, ocorrências, Formação Ambo, Carbonífero inicial, Peru.

INTRODUCTION

Publications on palynology of Late Palaeozoic sequences of Peru are scarce (*e.g.*, Wood *et al.*, 2002; Azcuy *et al.*, 2002; Azcuy & di Pasquo, 2005). This work is part of a major research that attempts to increase the palaeontological knowledge of Late Palaeozoic sequences in southern South America in the framework of projects that allow work in collaboration with other palaeontologists. This is the second contribution on Early Carboniferous palynofloras from Peru and it is an addition to the first one recently published (Azcuy & di Pasquo, 2005). This paper aims to complete the systematic analysis of a late Viséan palynoflora in Peru, to discuss the correlation with other stratigraphic units dated by palaeontologic means and to confirm once again that international (Euramerican) and Western Gondwanan (mainly derived from Brazilian and Argentinian basins) miospore zonal schemes, can be successfully applied to the dating of Carboniferous rocks of this region.

MATERIAL AND METHODS

A significant number of palynological samples were collected throughout the Ambo Formation; six of them yielded palynomorphs from the upper most part, last 100 m (Azcuy & di Pasquo, 2005). The state of preservation of the miospores varies from highly carbonized to good or excellent. Standard methods of palynomorph recovery have been used. The slides have been housed with sample numbers from the Laboratory of Palynology of Petroperú S.A., in the Laboratory of Palynology, Department of Geology, University of Buenos Aires, Argentina. Palynomorph identifications were made using a Leitz Orthoplan binocular transmitted light microscope Nº 871080, with 1000x maximum magnification. The photomicrographs were taken with a Pixera digital camera. Coordinates of specimens are denoted by an England Finder (EF) reference.

BRIEF GEOLOGIC INFORMATION

The palynologic results presented in this contribution come from six productive samples located in the upper part of the Ambo Formation at Pongo de Mainique (12°20'S, 72° 50'W), Peru. This locality displays one of the most complete sedimentary sequences, ranging in age from Silurian to Tertiary, located in the Andean Range, about 450 km to the east of Lima and 160 km to the northwest of Cusco. The Upper Palaeozoic sedimentary rocks present in the Madre de Dios Basin are mainly siliciclastic in the Early Carboniferous and calcareous sediments appear in the Late Carboniferous and increase to the Permian. The Upper Palaeozoic sequence in this region is subdivided into four formational units that in ascending stratigraphic order are: Ambo, Tarma, Copacabana and Ene Formations (see Azcuy & di Pasquo, 2005).

The Ambo Formation at the Pongo de Mainique is 822 m thick, and it unconformably overlies Devonian rocks of the Cabanillas Formation. It consists mainly of light grey, fine-grained sandstones and subordinated medium to coarse-grained and slightly carbonaceous and hard micaceous units. These fine to coarse-grained layers have internal cross-stratification with lenticular geometry, and alternate with subordinate siltstones, light to dark grey lutites, sometimes with abundant pyrite, and thin laminated mudstone layers. A very thick bed of light grey, pebbly sandstone with rounded clasts and pyrite, showing internal cross-stratification, constitutes the base of the unit. Plant remains and calcareous deposits were not recorded at this locality.

The Tarma Formation (237 m thick), conformably overlies the Ambo Formation and is overlain by the Copacabana Formation. At the top of the Tarma Formation, the *Illinites unicus* Palynozone is recorded, which is considered to be Late Westphalian in age (Azcuy *et al.*, 2002). The Copacabana Formation consists mainly of 647 m, light to dark grey, micritic to bioclastic, compact limestones, containing fusulinids, brachiopods, pelecypods, bryozoans, and abundant fragments of fossils and chert nodules, in medium to thick beds. Interbedded, are dark grey calcareous claystones, and light grey to brown dolostones in thin to medium layers. Their basal and upper contacts are conformable. Recently, Wood *et al*. (2002) analyzed palynomorphs and microfossils from this unit and assigned an "Early-Middle" Pennsylvanian age. Above the Copacabana Formation, the Ene Formation is 168 m and consists mainly of subordinated limestones and dolostones interbedded within shales and sandstone layers. The upper contact with the Oriente Group (Cretaceous) is unconformable.

ANNOTATED LIST OF MIOSPORES

An annotated species list including taxonomic and morphologic remarks for some taxa (genera or species) and their stratigraphic and geographic occurrences outside Peru, is presented. The species are arranged in taxonomic order, although suprageneric categories are not cited. The references cited in occurrence sections include detailed systematic works and those with illustrated lists of species. Synonymies are only provided if not previously published. Rules given in the lastest edition of the ICBN in its Spanish version (Kiesling, 2002) are here adopted for the treatment of form taxa. Morphological terminology adopted herein is mainly in accordance with the last glossary provided by Punt *et al.* (1994). The reference list includes only the works cited in the remarks, synonymy lists and occurrences.

Waltzispora lanzonii Daemon 1974
(Figure 1A)

Occurrence. Early Carboniferous of Brazil (Daemon, 1974; Melo *et al*., 1999).

Waltzispora polita (Hoffmeister, Staplin & Malloy) Smith & Butterworth 1967

Leiotriletes politus Hoffmeister *et al*.; Menéndez & Azcuy, 1969 :80, pl. 1: figs. A, B.
Leiotriletes politus Hoffmeister *et al.*; González Amicón, 1973:11, pl. I, fig. 2.
Occurrence. Widely recorded in microfloras from Early to Late Carboniferous rocks of South America, North America, Australia, Africa and Europe (Playford, 1991; di Pasquo, 2002).

Punctatisporites lucidulus Playford & Helby 1968

Punctatisporites resolutus Playford; Souza *et al.*, 1997, pl. I, fig. 2.
Occurrence. Late Carboniferous of Argentina (Gutiérrez & Césari, 1988), Brazil (Souza *et al.*, 1997), Australia (Playford & Helby, 1968; Jones & Truswell, 1992).

Retusotriletes anfractus Menéndez & Azcuy 1969

Occurrence. It is a very common component of Late Carboniferous microfloras from Argentina, and recently, it was also recorded in the Itararé Subgroup of Brazil (di Pasquo *et al.*, 2003).

Retusotriletes crassus Clayton *in* Clayton, Johnston, Sevastopulo & Smith 1980
(Figure 1B)

Retusotriletes sp. A Higgs, 1975:395, pl. 1, figs. 9, 13.
Retusotriletes sp. A Higgs; Keegan, 1977:548, pl. 1 figs. 4, 5.
Retusotriletes sp. A Higgs; Clayton *et al.*, 1977:7, pl. 6 fig. 4.
Retusotriletes sp. A Higgs; Utting, 1987a:79, pl. 2, fig. 11.
Occurrence. Late Devonian-Early Carboniferous of Europe (Higgs, 1975; Keegan, 1977; Van der Zwan, 1980a; Keegan & Feehan, 1981). Tournaisian-Viséan of Europe (Clayton *et al.*, 1977; Higgs *et al.*, 1988; Graham & Clayton, 1994), Canada (Utting, 1987a; Utting *et al.*, 1989a), Saudi Arabia (Clayton, 1995).

Apiculiretusispora semisenta (Playford) Massa, Coquel, Loboziak & Taugourdeau-Lantz 1980
(Figure 1C)

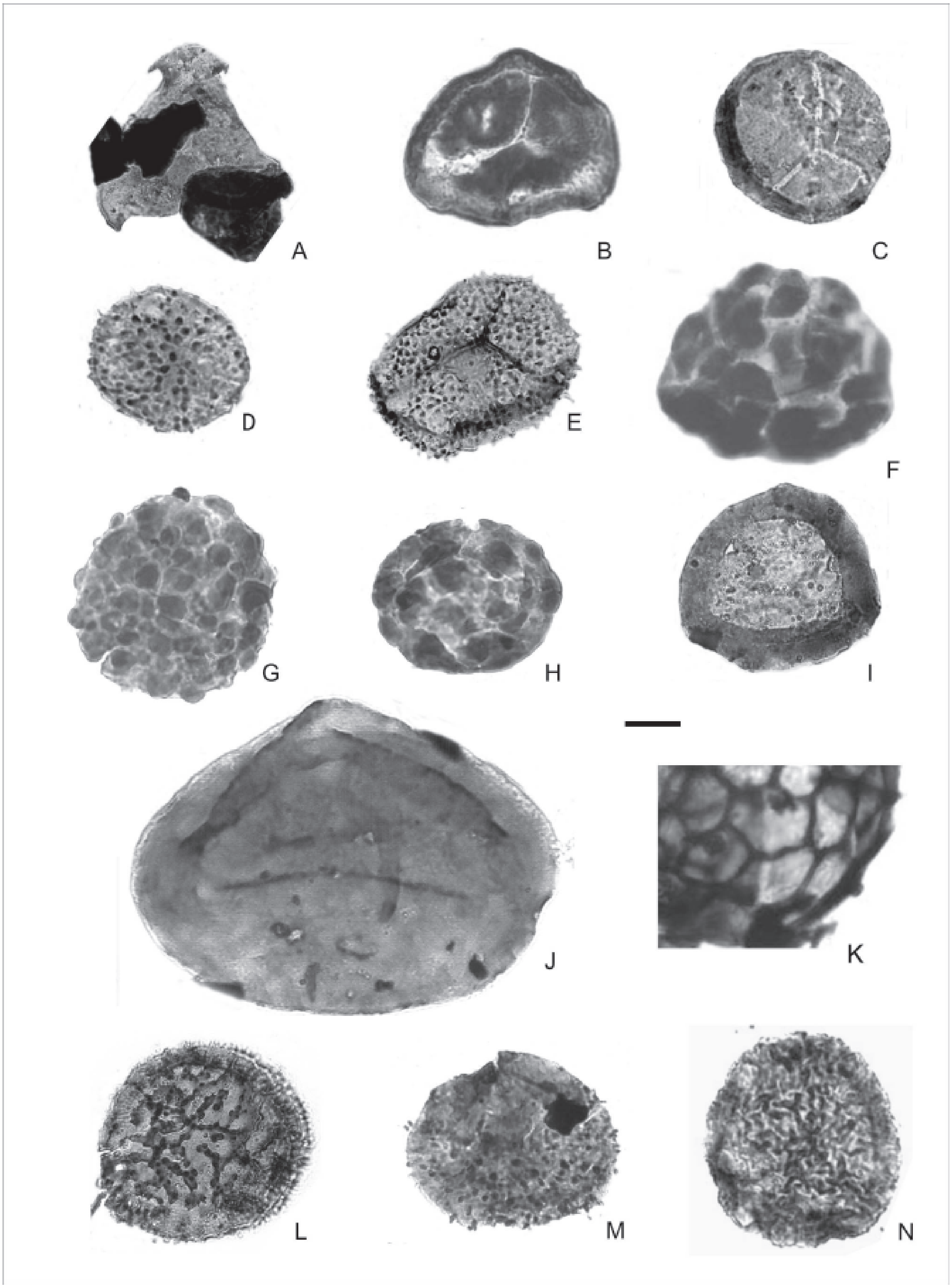

Figure 1. Selected miospores from the Ambo Formation (in parenthesis are the slide number and the England Finder coordinate). **A**, *Waltzispora lanzonii* (1039, S54/3); **B**, *Retusotriletes crasus* (1043, Q51); **C**, *Apiculiretusispora semisenta* (1039, P43/3); **D**, *Anapiculatisporites* cf. *A. austrinus* (1043, Q52/4); **E**, *Dibolisporites microspicatus* (1037, O33/2); **F**, *Verrucosisporites congestus* (1035, W62); **G**, *Verrucosisporites nitidus* (1037, E54/2-4); **H**, *Convolutispora insulosa* (1039, P46); **I**, *Densosporites anulatus* (1037, Q33/1-3); **J**, *Schopfipollenites ellipsoides* (1043, U36/3); **K**, *Cordylosporites magnidictyus* (1035; N41/1); **L**, *Cristatisporites peruvianus* (1039, D29/4); **M**, *Schofites claviger* (1043, M51/4); **N**, *Velamisporites minutus* (1043, P66/3). Scale bar = 10 mm in K; scale bar = 15 mm in A-J, L-N.

Occurrence. Early Carboniferous of Argentina (Césari & Limarino, 1995), Bolivia (Azcuy & Ottone, 1987), Brazil (Melo & Loboziak, 2000), Australia (Playford, 1971, 1978; 1985; Playford & Satterthwait, 1986), Algeria (Attar *et al.*, 1980), Libya (Massa *et al.*, 1980), Niger (Loboziak & Alpern, 1978; Coquel *et al.*, 1995), Egypt (Kora, 1993).

Granasporites medius (Dybová & Jachovicz) Ravn, Butterworth, Phillips & Peppers 1986

Cyclogranisporites sp. di Pasquo *et al.* 2003:284, pl. 3, fig. G.
Remarks. It is noted that some specimens of *Granasporites medius* (Dybová & Jachowicz) Ravn *et al.* (1986) from Peru show reduced ornamentation on the proximal face, and occasionally the presence of gemmae and clavae that are mainly seen at the margin of the spore. The scarce elements on the proximal face are clumped close to the laesurae in some specimens. Additionally, the revision of more specimens of this species previously recorded from the Tupambi Formation (Argentina; di Pasquo, 2002) allowed reassigning Brazilian material from the Itararé Subgroup (di Pasquo *et al.*, 2003) to this taxon.
Occurrence. Late Carboniferous of Argentina (di Pasquo, 2002), Brazil (di Pasquo *et al.*, 2003). For previous records in U.S.A. and Europe see Ravn *et al.* (1986).

Cyclogranisporites australis Azcuy 1975

Occurrence. Early Late Carboniferous of Argentina (Azcuy, 1975).

Anapiculatisporites cf. *A. austrinus* Playford & Satterthwait 1986
(Figure 1D)

Remarks. The species assignment is tentative because the Peruvian specimens have indistinct laesurae without lips and curvatures.
Occurrence. Viséan of Australia (Playford & Satterthwait, 1986), Argentina (Césari & Limarino, 1992).

Dibolisporites microspicatus Playford 1978
(Figure 1E)

Remarks. *Dibolisporites disfacies* Jones & Truswell 1992, differs from *D. microspicatus* Playford mainly because in the latter the ornamentation is never discrete and evenly spaced.
Occurrence. Visean of Australia (Playford, 1978; Playford & Satterthwait, 1986), Argentina (Césari & Limarino, 1992).

Verrucosisporites congestus Playford 1964
(Figure 1F)

Occurrence. Early Carboniferous of Argentina (Césari & Limarino, 1992, 1995), Brazil (Melo & Loboziak, 2000, 2003), Canada (Playford, 1964; Smith, 1971; Utting, 1987a; Utting *et al.*, 1989a), Ireland (Van der Zwan, 1980a; Van Veen, 1981; Higgs *et al.*, 1988; Turnau *et al.*, 1994).

Verrucosisporites depressus Winslow 1962

Occurrence. Early Carboniferous of U.S.A. (Winslow, 1962), Poland (Turnau, 1978; Turnau *et al.*, 1994), Ireland (Van der Zwan, 1980a; Van Veen, 1981), Brazil (Melo & Loboziak, 2000).

Verrucosisporites morulatus (Knox) Potonié & Kremp 1955 *emend.* Smith & Butterworth 1967

Verrucosisporites nodosus Sullivan & Marshall, 1966:269, pl. 1, figs. 20, 21.
Remarks. The ornamentation is regular in size and distribution, with elements possessing more or less parallel sides. Elements display variable separation although occasionally may appear fused. The differences in the total diameter, mentioned by Sullivan & Marshall (1966) to establish *V. nodosus* as a new species, must be discarded because Smith (1971) found that *V. morulatus* displays a size range of 30-80 mm, which accomodates *V. nodosus*.
Occurrence. Early Carboniferous of Europe (Butterworth & Williams, 1958; Neves, 1961; Sullivan & Marshall, 1966; Smith & Butterworth, 1967; Smith, 1971), Canada (Utting, 1987b), Egypt (Kora, 1993).

Verrucosisporites nitidus Playford 1964
(Figure 1G)

Lectotype. *Verrucosisporites nitidus* Playford, 1964:13, pl. 3, fig. 6 (designated herein).
Remarks. Turnau *et al.* (1994:290) examined the type material of *Lophotriletes grumosus* Naumova (1953) and found that the proximal face is laevigate. Therefore, it was separated from *Verrucosisporites nitidus* and it was stated in the text that one specimen amongst the four illustrated by Playford (1964) would be selected as the lectotype but finally, none was proposed. This task is here resolved by proposing as lectotype the specimen figured in Playford (1964, pl. 3, fig. 6).
Occurrence. Latest Devonian-Early Carboniferous of Brazil (Melo *et al.*, 1999; Melo & Loboziak, 2003), Australia (Playford, 1976, 1985; Playford *et al.*, 1976), Europe (Sullivan, 1964; Utting & Neves, 1971; Keegan, 1977; Van der Zwan, 1980a; Van Veen, 1981; Higgs *et al.*, 1988; Loboziak *et al.,* 1994), Russia (Avchimovitch *et al.*, 1988). Early Carboniferous of Bolivia (Azcuy & Ottone, 1987; Vavrdová *et al.*, 1993), Brazil (Loboziak *et al.*, 1991; Melo & Loboziak, 2000), Europe (Neves & Ioannides, 1974; Higgs, 1975, 1996; Streel, 1977; Owens *et al.*, 1977; Clayton *et al.,* 1978; Turnau, 1978; Phillips & Clayton, 1980; Higgs & Clayton, 1984; Higgs *et al.*, 1992; Graham & Clayton, 1994), USA (Clayton *et al.*, 1998), Alaska (Ravn, 1991), Australia (Playford, 1971, 1978, 1985; 1988, 1991; Playford & Satterthwait, 1986), Canada (Playford, 1964; Utting, 1980, 1987a, 1987b; Utting *et al.*, 1989a), Libya (Massa *et al.*, 1980), Niger (Coquel *et al.*, 1995), Saudi Arabia (Clayton, 1995), Egypt (Kora, 1993). For other previous records see Playford (1991).

Verrucosisporites perverrucosus (Loose) Potonié & Kremp 1955 *emend.* Smith 1971

Occurrence. This species has been reported from the Early to Late Carboniferous of Europe (Smith, 1971).

Verrucosisporites verrucosus (Ibrahim) Ibrahim 1933

Tuberculatisporites gigantonodatus Dybová & Jachowicz, 1957:116, pl. 27, figs. 1-4.
Occurrence. Early Carboniferous of Canada (Utting, 1987b). Late Carboniferous of Argentina (di Pasquo *et al.*, 2001), Europe (Smith & Butterworth, 1967), U.S.A. (Peppers, 1970). For Early Permian records of Uruguay and Brazil see di Pasquo *et al*. (2001).

Genus *Schopfites* Kosanke 1950

Remarks. The generic diagnosis states that the contact areas lack ornamentation, distinguishing it from *Raistrickia* Schopf *et al.* 1944. Indeed, the original description of *Raistrickia*, later amended by Potonié & Kremp (1954), suggests that the sculpture is distributed on both faces like in all or almost all the known species of this genus.

Schopfites claviger Sullivan 1968
(Figure 1M)

Schopfites delicatus Higgs, 1975:396-397, pl. 2, figs. 6, 7.
Schopfites cf. *S. delicatus* Higgs *et al.*, 1988:60, pl.5, fig.9, 14.
Discussion. In this work the criterion of Playford & Satterthwait (1986) to assign this species to the genus *Raistrickia* is not followed because of the absence of sculpture over almost all the proximal face. Besides, in accordance with Playford (1991), the amendments proposed by Higgs *et al.* (1988) for *Schopfites claviger* Sullivan (1968) and *S. delicatus* Higgs (1975) are not accepted herein. The mentioned species, including also *S.* cf. *delicatus* Higgs *et al.* (1988), display a gradational ornamentation, as shown in Higgs *et al.* (1988, fig. 30). Therefore, in order to avoid an artificial separation of these forms, they are considered herein as one same taxon. *Ceratosporites delicatus* (Higgs) Van der Zwan 1980 is rejected herein because it lacks a description and the illustration does not show ornamentation on the equator of the spore, a feature mentioned in the diagnosis of the species.
Occurrence. Early Carboniferous of Brazil (Loboziak *et al.*, 1991, 1998; Melo & Loboziak, 2003), Europe (Sullivan, 1968; Neves & Belt, 1971; Neves *et al.*, 1972, 1973; Neves & Ioannides, 1974; Higgs, 1975; Owens *et al.*, 1977; Clayton *et al.*, 1977, 1978; Turnau, 1978; Higgs & Clayton, 1984; Higgs *et al.*, 1988; Clayton & Turnau, 1990; Avchimovitch & Turnau, 1994), Canada (Utting, 1987b; Utting *et al*., 1989a), Australia (Playford, 1971, 1991; Playford & Satterthwait, 1986), Morocco (Loboziak *et al.*, 1990). For other previous records see Playford (1991).

Convolutispora insulosa Playford 1978
(Figure 1H)

Verrucosisporites sp. cf. *V. gobbettii* Playford; Ravn, 1991:100, pl. 4, fig. 10.
Remarks. The absence or scarcity of sculptural elements on the contact areas and the lack of anastomosing ornamentation characterize this species.
Occurrence. Viséan of Australia (Playford, 1978; Playford & Satterthwait, 1985), Alaska (Ravn, 1991).

Convolutispora oppressa Higgs 1975

Remarks. This species is characterized by a verrucose ornamentation, which to a large extent is fused to form rugulae that meet and anastomose without defining a true reticulum. The presence of rugulae prevents its assignment to the genus *Verrucosisporites*, in accordance with Higgs *et al.* (1988).
Occurrence. Strunian of Libya (Massa & Moreau-Benoit, 1985). Late Devonian – Early Carboniferous of Europe (Higgs, 1975; Higgs *et al.*, 1988; Loboziak *et al.*, 1994), Bolivia (Vavrdová *et al.*, 1993).

Convolutispora cf. *C. elimata* Playford 1978

Occurrence. Viséan of Australia (Playford, 1978; Playford & Satterthwait, 1985).

Convolutispora cf. *C. varicosa* Butterworth & Williams 1958

Remarks. The Peruvian specimens differ from the original material and others recorded by Smith & Butterworth (1967) and Playford & Satterthwait (1988) only by their smaller size.
Occurrence. Visean-Namurian A of Europe (Butterworth & Williams, 1958; Smith & Butterworth, 1967), Australia (Playford & Satterthwait, 1988).

Cordylosporites magnidictyus (Playford & Helby) Melo & Loboziak 2000
(Figure 1K)

Remarks. In spite of the scarce and incomplete specimens recorded in the Peruvian samples, it was possible to recognize the diagnostic characters to justify its specific allocation.
Occurrence. Viséan of Brazil (Loboziak *et al.*, 1998; Melo *et al.*, 1999; Melo & Loboziak, 2000, 2003), Australia (Playford & Helby, 1968). Viséan – Namurian of Saudi Arabia (Clayton, 1995), Niger (Coquel *et al.*, 1995), Algeria (Lanzoni & Magloire, 1969; Attar *et al.*, 1980; Clayton & Loboziak, 1985; Abdesselam-Rouighi & Coquel, 1997), Libya (Massa *et al.*, 1980), Syria (Ravn *et al.*, 1994).

Crassispora kosankei (Potonié & Kremp) Bharadwaj 1957 *emend.* Smith & Butterworth 1967

Remarks. The sculpture distribution in the studied specimens is slightly denser than in the European ones; this character seems insufficient to establish a new taxon, in agreement with di Pasquo (2002).
Occurrence. Recently recognized in late Namurian rocks of Argentina and widely registered in the Namurian-Westphalian of Europe, U.S.A., and Russia (di Pasquo, 2002).

Bascaudaspora submarginata (Playford) Higgs, Clayton & Keegan 1988

Occurrence. Late Devonian - Early Carboniferous of Europe (Van Veen, 1981; Avchimovitch *et al.*, 1988; Loboziak *et al.,* 1994). Early Carboniferous of Canada (Playford, 1964; Utting, 1987a, 1987b), Alaska (Ravn, 1991), Europe (Turnau, 1978; Van der Zwan, 1980a; Higgs *et al.*, 1988; Higgs, 1996), Brazil (Melo & Loboziak, 2000).

Densosporites anulatus (Loose) Schopf, Wilson & Bentall 1944 (Figure 1I)

Occurrence. Strunian of France (Coquel & Deunff, 1977). Late Devonian - Early Carboniferous of Libya (Coquel & Moreau-Benoit, 1986). Early Carboniferous of U.S.A. (Schopf *et al.*, 1944; Kosanke, 1950), Alaska (Ravn, 1991), Canada (Utting *et al.*, 1989b; Utting, 1991), Spitsbergen (Bharadwaj & Venkatachala, 1962; Playford, 1963), Brazil (Melo & Loboziak, 2000). Early - Late Carboniferous of Europe (Smith & Butterworth, 1967; Turner & Spinner, 1993), Canada (Braman & Hills, 1977), Egypt (Kora, 1993).

Kraeuselisporites mitratus Higgs 1975

Occurrence. Early Carboniferous of Europe (Higgs, 1975; Owens *et al.*, 1976; Keegan & Feehan, 1981; Higgs & Clayton, 1984; Higgs *et al.*, 1988), Niger (Loboziak & Alpern, 1978), Brazil (Loboziak *et al.*, 1998; Melo *et al.*, 1999; Melo & Loboziak, 2003).

Cristatisporites echinatus Playford 1963

Occurrence. Late Devonian - Early Carboniferous of Europe (Utting & Neves, 1971), Brazil (Melo & Loboziak, 2003). Early Carboniferous of Brazil (Melo & Loboziak, 2000), Spitsbergen (Playford, 1963), Canada (Playford, 1964), Europe (Combaz & Streel, 1970; Streel, 1977), Niger (Loboziak & Alpern, 1978).

Cristatisporites indignabundus (Loose) Potonié & Kremp 1954 *emend.* Staplin & Jansonius 1964

Occurrence. Early Carboniferous of Alaska (Ravn, 1991). Westphalian B of England (Staplin & Jansonius, 1964; Smith & Butterworth, 1967).

Cristatisporites peruvianus Azcuy & di Pasquo 2005 (Figure 1L)

Remarks. This cavate species bears a cingulum ornamented with biform elements fused in the equatorial region; equator and distal face with galeae and coni are fused forming rugulae which give it a beady appearance. These rugulae may be branched or anastomosed into an irregular reticulum. The proximal exoexine is microgranular or smooth. Comparisons may be consulted in Azcuy &di Pasquo (2005).
Occurrence. Early Carboniferous of Ireland (Van der Zwan, 1980a; Higgs *et al.*, 1988).

Vallatisporites vallatus Hacquebard 1957

Remarks. This species is distinguished from others of the genus by having small, discrete coni and grana and less common spines on distal surface. The zona width is narrower than that of *Vallatisporites ciliaris* (Luber) Sullivan 1964 with a thinner outer portion without a "limbus".
Occurrence. Latest Devonian-Early Carboniferous of Europe (Van der Zwan, 1980a; Van Veen, 1981; Avchimovitch *et al.,* 1988), Brazil (Melo *et al.*, 1999; Melo & Loboziak, 2003), Libya (Coquel & Moreau-Benoit, 1986). Early Carboniferous of Brazil (Loboziak *et al.*, 1991; Melo & Loboziak, 2000), Europe (Sullivan, 1968; Hibbert & Lacey, 1969; Combaz & Streel, 1970; Streel, 1977; Keegan, 1977; Clayton *et al.*, 1978; Garrote & Broutin, 1979; Keegan & Feehan, 1981; Higgs & Clayton, 1984; Higgs *et al.,* 1988; Clayton & Turnau, 1990), USA (Clayton *et al.*, 1998), Canada (Hacquebard, 1957; Playford, 1964; Utting, 1987a; Utting *et al.*, 1989a), Libya (Massa *et al.*, 1980), Morocco (Loboziak *et al.*, 1990). For other previous records of Latest Devonian - Early Carboniferous palynofloras from Euramerica, Brazil and Africa see Playford & McGregor (1993), and of Late Carboniferous palynofloras from Argentina and Brazil see di Pasquo (2002).

Grandispora debilis Playford 1971

Occurrence. Early Carboniferous of Australia (Playford, 1971, 1985, 1991; Playford & Satterthwait, 1988).

Spelaeotriletes balteatus (Playford) Higgs 1996

Remarks. From the discussions on *Spelaeotriletes* presented by Higgs *et al.* (1988) and Playford *et al.* (2001) it is concluded that the main distinguishing feature of this genus with relation to *Grandispora* is the presence of discrete and fused, variably apiculate and verrucose elements that form short rugulae. The variability of other features in both genera is considered to be almost the same.
Occurrence. Early Carboniferous of Spitsbergen (Playford, 1963), Europe (Higgs, 1975, 1996; Keegan, 1977; Clayton *et al.,* 1978; Van der Zwan, 1980a; Keegan & Feehan, 1981; Higgs & Clayton, 1984; Higgs *et al.*, 1988, 1992), USA (Clayton *et al.,* 1998), Canada (Utting *et al.*, 1989b; Utting, 1991), Alaska (Ravn, 1991), Algeria (Attar *et al.*, 1980), Libya (Massa *et al.*, 1980), Morocco (Loboziak *et al.*, 1990), Brazil (Loboziak *et al.*, 1991; Melo *et al.*, 1999; Melo & Loboziak, 2003). For other records of Tournaisian-Viséan microfloras from Euramerica, China and Gondwana see Playford *et al.* (2001).

Spelaeotriletes cf. *S. pretiosus* (Playford) Utting 1987

Comparisons. This specimen bears a close similarity to *S. pretiosus* var. *bellii* (Playford) Utting (1987b, pl. 4, figs. 2-4) in respect of the type and size of the sculpture, but it is more closely spaced. Another comparable species is *Spelaeotriletes* sp. A Neves & Belt (1971, plate 2, fig. 14), which is almost identical to the Peruvian specimen except for the diameter of the spore. An imprecise assignment is therefore maintained till more specimens are obtained.
Occurrence. Early Carboniferous of Canada (Playford, 1964; Utting, 1987a, 1987b; Utting *et al.*, 1989a), U.S.A. (Clayton *et*

al., 1998), Europe (Neves & Belt, 1971; Higgs, 1975, 1996; Owens *et al.*, 1977; Keegan, 1977; Clayton *et al.*, 1978; Turnau, 1978; Phillips & Clayton, 1980; Van der Zwan, 1980a; Keegan & Feehan, 1981; Welsh & Owens, 1983; Higgs & Clayton, 1984; Higgs *et al.*, 1988, 1992; Avchimovitch & Turnau, 1994), Algeria (Attar *et al.*, 1980), Libya (Massa *et al.*, 1980), Brazil (Melo *et al.*, 1999; Melo & Loboziak, 2003). For other records of Tournaisian-Viséan microfloras from Euramerica, China and Gondwana see Playford *et al.* (2001).

Genus *Velamisporites* Bharadwaj & Venkatachala 1962

Remarks. Recently and in agreement with Ravn (1991), di Pasquo *et al.* (2003) have discussed the status of the genera *Rugospora* and *Velamisporites* and concluded that *Rugospora* is a junior synonym of *Velamisporites*. This conclusion is followed herein.

Velamisporites minutus (Neves & Ioannides) Ravn 1991
(Figure 1N)

Basionym. *Rugospora minuta* Neves & Ioannides, 1974, pl. 8, figs. 7, 8.
Occurrence. Early Carboniferous of Europe (Neves & Ioannides, 1974; Turnau, 1978; Phillips & Clayton, 1980; Van der Zwan, 1980a; Higgs *et al.*, 1988), Libya (Massa *et al.*, 1980), Algeria (Abdesselam-Rouighi & Coquel, 1997), Niger (Coquel *et al.*, 1995), Canada (Utting, 1980, 1987b, 1991; Utting *et al.*, 1989a), Alaska (Ravn, 1991), Brazil (Loboziak *et al.*, 1991; Melo & Loboziak, 2003).

Genus *Auroraspora* Hoffmeister, Staplin & Malloy 1955

Remarks. Pseudosaccate spores assigned to *Auroraspora* are characterized by the following diagnostic characteristics: thick, dark coloured central body; delicate and spongy outer layer; distinction between pseudosaccus and body sometimes poorly defined; trilete mark generally with lips that do not extend beyond the edge of the spore body; exoexine sometimes carrying minute granulose sculpture.

Auroraspora macra Sullivan 1968

Occurrence. Late Devonian of Belgium (Becker *et al.*, 1974), Brazil (Loboziak *et al.*, 1988). Late Devonian – Early Carboniferous of Europe (Sullivan, 1968; Turnau, 1975, 1978; Keegan, 1977; Van der Zwan, 1980a, 1980b; Higgs *et al.,* 1988; Loboziak *et al.,* 1994), Brazil (Melo & Loboziak, 2003), Algeria (Coquel & Latreche, 1989). Early Carboniferous of Bolivia (Azcuy & Ottone, 1987), Peru (Aliaga López, 1985), Brazil (Loboziak *et al.*, 1991, 1998), Europe (Neves *et al.*, 1972, 1973; Neves & Ioannides, 1974; Higgs, 1975; Owens *et al.,* 1977; Phillips & Clayton, 1980; Graham & Clayton, 1994), Canada (Utting, 1980, 1987a, 1987b; Utting *et al.*, 1989a, 1989b), Australia (Playford, 1971, 1978, 1985, 1991; Playford & Satterthwait, 1988), Libya (Massa *et al.*, 1980), Egypt (Kora, 1993), Morocco (Loboziak *et al.*, 1990), Niger (Coquel *et al.*, 1995). For other records see Playford (1991).

Endoculeospora gradzinskii Turnau 1975

Remarks. The Peruvian specimens show a diffuse and irregular central body, and the laesurae are not visible. *Endoculeospora rarigranulata* var. *densigranulata* Staplin 1960 is closely comparable to this species, but differs in having a more distinct and less dense central body and ornamentation apparently restricted to grana. The features observed in *A. macra* (without visible ornamentation) and *E. gradzinskii* (with minute ornamentation) appear to confirm the *Auroraspora* morphon proposed by Van der Zwan (1980b).
Occurrence. Strunian of Germany (Hartkopf-Fröder & Streel, 1994). Latest Devonian - Early Carboniferous of Poland (Turnau, 1975, 1978), Ireland (Van der Zwan, 1980a 1980b; Van Veen, 1981; Higgs *et al.*, 1988), Russia (Avchimovitch *et al.*, 1988).

Colatisporites decorus (Bharadwaj & Venkatachala) Williams *in* Neves, Gueinn, Clayton, Ioannides, Neville & Kruszewska 1973

Remarks and comparisons. The Peruvian specimens show close affinity with the original specimens illustrated by Bharadwaj & Venkatachala (1962) and *Colatisporites decorus* variant A of Van der Zwan (1980b). *Velamisporites autraliensis* (Playford & Helby) di Pasquo, Azcuy & Souza 2003 differs in having a densely microfolded-microrugulate exoexine as described by Jones & Truswell (1992).
Occurrence. Early Carboniferous of Spitsbergen (Bharadwaj & Venkatachala, 1962), Europe (Neves *et al.*, 1973; Neves & Ioannides, 1974; Van der Zwan, 1980a, 1980b; Higgs *et al.*, 1988), Alaska (Ravn, 1991), Niger (Loboziak & Alpern, 1978), Canada (Utting, 1987b, 1991; Utting *et al.*, 1989a, 1989b), Morocco (Loboziak *et al.*, 1990), Brazil (Melo *et al.*, 1999; Melo & Loboziak, 2000, 2003).

Schopfipollenites ellipsoides (Ibrahim) Potonié & Kremp 1954
(Figure 1J)

Schopfipollenites acadiensis Utting, 1987b:38, pl. 5, figs. 7-11.
Schopfipollenites sp., Melo & Loboziak, 2003:192, pl. 7, fig. 6.
Comparison. Utting (1987b) erected *Schopfipollenites acadiensis* to include specimens clearly with the same characters as *S. ellipsoides* but somewhat smaller. On the other hand, Taylor (1978) and Taylor & Rothwell (1982), amongst others, stated that lamellar differentiation, development of distal grooves (which are generally obscured by folding) and grain size are function of maturity and cannot be reliably used for systematic purposes. There are in the literature some other examples of smaller specimens assigned to *S. ellipsoides* like the Peruvian ones, as cited by Coquel *et al.* (1988) from Libya, Loboziak *et al.* (1998) from Brazil and di Pasquo (2002) from Argentina. Therefore, the former species is here considered a junior synonym that extends the size range for *S. ellipsoides*.
Occurrence. Widely recorded in microfloras spanning Late Viséan to Stephanian in Euramerica, Middle East (Libya, Saudi Arabia) and Argentina (di Pasquo, 2002). There are also Late

Viséan records in Brazil (Loboziak *et al.*, 1998; Melo *et al.*, 1999; Melo & Loboziak, 2003), Libya (Coquel *et al.*, 1988), Saudi Arabia (Clayton, 1995), Russia (Reitlinger *et al.*, 1996) and Canada (Utting, 1987b).

CONCLUDING REMARKS

This is the second paper ever published on the Early Carboniferous palynology of Peru. The palynoflora of Pongo de Mainique is composed of 55 species, mostly defined at specific level, of which only one resulted a new one (*Cristatisporites peruvianus*, Figure 1L). The assemblages are generally abundant, diverse and variably preserved and the percentages for the parent plants sources of the groups of palynomorphs are showed in Figure 2. Pteridophyta and Lycophyta dominate the assemblage; Sphenophyta, spores with unknown botanical affinity and reworked spores/ microplankton are subordinated. Scarce acritarchs and other algal cysts (*e.g.*, *Veryhachium trispinosum* (Eisenack) Deunff, *Gorgonisphaeridium* sp., *Umbellasphaeridium deflandrei* (Moreau-Benoit) Jardine *et al*., *Palacanthus* sp., *Maranhites insulatus* Burjack & Oliveira, *Quadrisporites granulatus* (Cramer) Ströther) and some typically Devonian spore species like *Grandispora* sp. cf. *G. mammillata* Owens and *Retispora lepidophyta* (Kedo) Playford were considered as reworked. The geographical and stratigraphical distribution, and age range of selected species found in the Ambo Formation, were displayed and discussed in detail in Azcuy & di Pasquo (2005).

The comparison of the Peruvian palynoflora with others of the Early Carboniferous of the world presented by Azcuy & di Pasquo (2005) support its correlation to the *Cordylosporites magnidictyus* Palynozone of the late Viséan of the Amazon Basin, Brazil. Moreover, a greater affinity with Western Europe (66% of common species), Canada (57%) and South America (54%) and a lesser affinity with Africa (45%) and Australia (30%) was established based on the number of common species. The Poti Formation in the Parnaíba basin (Brazil, Melo & Loboziak, 2000) is the most similar association to the Peruvian microflora sharing more than 40% of its species and another comparable but slightly younger one is recovered from the Kaka Formation (Bolivia, Fasolo *et al.*, 2006). The location of all these assemblages analised in palaeogeographical reconstructions, supports the idea of a ecotonal palaeofloristic province (Paracas Kingdom, Iannuzzi & Pfefferkorn, 2002), between Gondwana and Euramerica during the late Early Carboniferous, with a palaeolatitudinal position around to 50° S. The affinity of 57% with the Viséan associations of Canada is interpreted by its equivalent palaeolatitudinal position ~50% N. Noteworthy, some species resulted endemic or exclusive of each Hemispheres, such as *Cordylosporites magnidictyus*, exclusive species with provincial value in the Late Viséan of Gondwana, which is not present in the Canadian associations, and *Schopfipollenites ellipsoides* is registered in Canada but it is not present in Europe and Australia during that time. Moreover, the associations of North Africa share with Peru

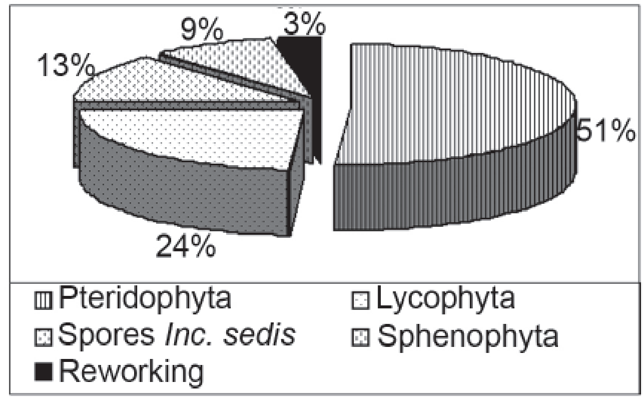

Figure 2. Percentages of major palaeobotanical groups of the Ambo Formation assemblage.

numerous Viséan species but the absence of certain taxa (*e.g.*, *Aratrisporites saharensis* Loboziak, Clayton & Owens) from this region also present in Brazil in palaeolatitudes something more losses prevents a closer correlation with Peru. The lesser affinity with palynofloras of Australia would have due to a different palaeolatitudinal position probably more loss added to a relative isolation favouring therefore the endemic character of its palynofloras. Finally, and considering quantitative affinities for the late Viséan only, it is evident that the proportion of species common to the upper part of the Ambo Formation and Europe is restricted (four species) probably as a result of Europe's lower palaeolatitudinal position. On the other hand, in higher palaeolatitudes, preliminary palynological studies carried out in Argentina also show differences with relation to the present palynoflora (Rodríguez Amenábar *et al*., 2003).

Concerning to the Ambo "Group" in Bolivia, Azcuy & di Pasquo (2005) suggest that if the Lower Carboniferous sequences presented sufficient lithostratigraphic differences to recognize three formational units, such as Cumaná, Kasa and Siripaca Formations (Díaz Martínez, 1991), it would be desirable to consider the convenience of not using the same established name to designate nondivisible sequences described in other region. On the other hand, some authors (Díaz Martínez, 1999; Suárez Soruco & Díaz Martínez, 1996; Díaz Martínez *et al*., 1999) have extended the correlation between the Ambo "Group" to units of the southern Subandean Belt of Bolivia and northern Argentina, *i.e*., to the Macharetí and Mandiyutí Groups. This attempt at correlation has been rejected on the evidence of palynological data from those groups as also discussed by di Pasquo *et al.* (2001) and di Pasquo (2002, 2003).

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