GEOLOGICA BELGICA (2000) 3/1-2 : 87-96

PALYNOLOGY AND SEDIMENTOLOGY OF LAMINITES AND TILLITES FROM THE LATEST FAMENNIAN OF THE PARNAÍBA BASIN, BRAZIL

Maurice STREEL[1], Mario V. CAPUTO[2], Stanislas LOBOZIAK[3], José Henrique G. MELO[4] & Jacques THOREZ[1].

(5 figures & 3 plates)

1. *Université de Liège, laboratoires de Paléontologie et de Géologie des argiles, Sart Tilman, Bât. B 18, B-4000 LIEGE, Belgium.*
2. *Universidade Federal do Pará, Geologia, Campus Universitário do Guamá, Av. Perimetral S/N, BELÉM-PA, Brazil.*
3. *U.S.T.L., UPRESA 8014 du C.N.R.S., Sciences de la Terre, F-59655 VILLENEUVE d'ASCQ Cedex, France.*
4. *Petrobrás/Cenpes/Divex/Sebipe, Cid. Univ., I. Fundão, 21949-900 RIO DE JANEIRO-RJ, Brazil.*

ABSTRACT. Varvelike rhythmites, usually laminated siltstones and shales with scattered clasts, are known from outcrops and well cores of the upper Cabeças Formation in the Parnaíba (Maranhão) Basin, Brazil, with sediments laid down under glacial and periglacial conditions. Palynological study from different lithologies, indicates a latest Famennian age (LN Zone). Sedimentological approach of one rhythmite indicates that the grain-size contrast clearly separate between silt and sand layers but that all layers, even the dark silty ones, show features characteristic of sediment-gravity flows. Lateral influx was permanent during the deposition of the sediment. Clay analyses reveal the predominance of kaolinite probably originated from Middle Devonian rocks. Latest Famennian miospores and acritarchs are present and confirm the marine character of the depositionnal environment but a large part (70%) of the palynological material is reworked from Givetian / Frasnian rocks. No reworked miospores from early to late Famennian can be demonstrated. At least two distinct source-areas of the reworked material, Givetian (or older) and Frasnian, can be recognized. Contemporaneous miospores are significally less present in the tillites and associated shale than in the laminites which suggest that they are produced locally, the glacial tongue, carrying the reworked part of the material, only partially overlapping adjacent environments. The rythmites are presumed to be true varves, the sandy layers being first settled after the local seasonal melting of the ice cover and the rush of fresh water supply into the sea, the silty layers being deposited when the spring water run-off decreases. The *Vallatisporites* mother-plant, believed to live in a swamp margin environment, might have been the first to produce spores immediately after the melting of the ice cover.

KEYWORDS: Famennian, laminites, Brazil, Parnaíba Basin, Cabeças Formation, miospores, reworked palynomorphs

1. Introduction

A latest Famennian ice age is recorded in large intracratonic basins of northern Brazil. Available evidence includes diamictites with striated, faceted and polished peebles, rhythmites with dropstones, erratic boulders, and striated pavements.In the Parnaíba (Maranhão) Basin (Fig. 1), sediments laid down under glacial and periglacial conditions make up the upper Cabeças Formation which displays massive polymict diamictites with subrounded to angular, striated and polished outsized clasts immersed in silty and clayey matrix. Varvelike rhythmites, usually laminated siltstones and shales with scattered clasts, are known from outcrops (Malzahn, 1957) and well cores (Carozzi *et al.* , 1975) and are documented by Caputo (1985, Fig. 13) and Caputo & Crowell (1985, Fig. 11).

Palynological study (Loboziak *et al.*, 1993) of the Cabeças Formation made in boreholes 2-PM-1-MA, 1-PA-1-MA and 1-TM-1-MA (Fig. 1), from different lithologies, indicates a latest Famennian age (Zone LN).

The present paper aims to focus on tillites and associated sediments.

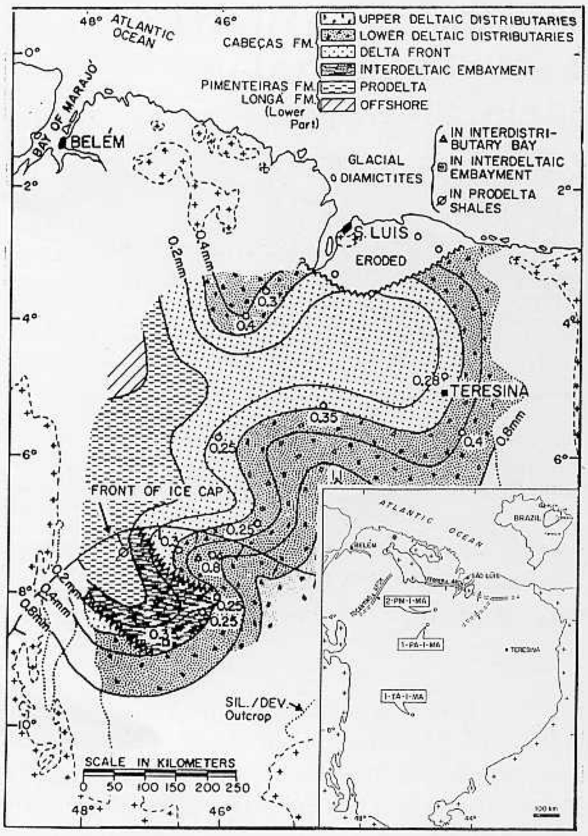


Figure 1. The Parnaíba (Maranhão) Basin with the localisation of boreholes 2-PM-1-MA, 1-PA-1-MA and 1-TM-1-MA and paleoenvironmental map of Famennian time (reproduced from Carozzi 1980, Fig. 15 modified, after Carozzi *et al.* 1975, Fig. 32.) 0.2 to 0.8mm represent the average clasticity.

2. Investigated material

The material comes from well 1-TM-1-MA, core 16 : three samples (N° 1, 3 and 4) are from interval 674,10-678,40 m and one sample (N° 2) from interval 678,40-683,81 m. Sample N° 3 (pl. 1A) is a laminite (varvelike rhythmite) composed of white sandy and dark silty layers, each half a millimeter thick, each layer being in turn very finely laminated. Eight layers (pl. 1A and pl. 2: 1A to 4B) have been macerated separately. Sample N° 1 and N° 4 were in contact with sample N° 3. Sample N°1 is a shale (pl. 3B), sample N° 4 is a diamictite/ tillite with clasts of laminites and dropstones (pl. 3A). Sample N° 2 is a homogeneous tillite (pl. 1B).

3. Depositional conditions

According to Carozzi (1980), well 1-TM-1-MA was cored through the Cabeças Formation characterized by marine interdeltaic sediments (Figs. 1 and 2). Deposits accumulated in subaqueous fan turbidites and were generated from the calving of icebergs ; they are represented by fine graywackes and "varvites" with numerous rafted pebbles. Fine-grained moderate to well-sorted quartzose to feldspathic arenites with some quartzose subgraywackes correspond to delyaic deposits. Through a northward shift, a glacial tongue developed, crosscutting a major interdeltaic embayment and induced the partial overlapping of adjacent deltas. This hypothesis is well supported by the occurrence and distribution of diamictites and lithic graywackes interbedded with silty shales and shales. The latter sediments were genetically connected to interdistributary bays, interdeltaic embayments and prodeltas. The paleoenvironmental reconstruction (Fig. 1) points to a major deltaic supply from the south-east. Four samples (1 to 4) were analysed for their sedimentological characters.

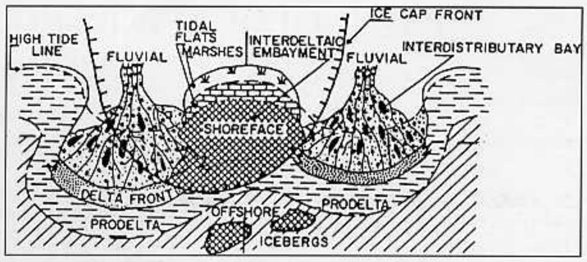
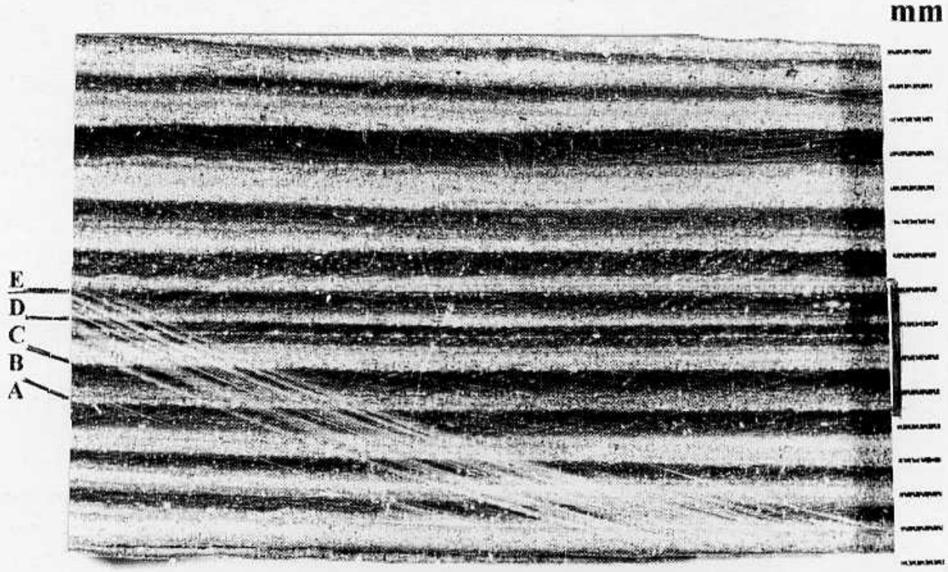


Figure 2. Depositional model of glacial interference with a deltaic system (reproduced from Carozzi 1980, Fig. 4 modified, after Carozzi *et al.* 1975, Fig. 5)

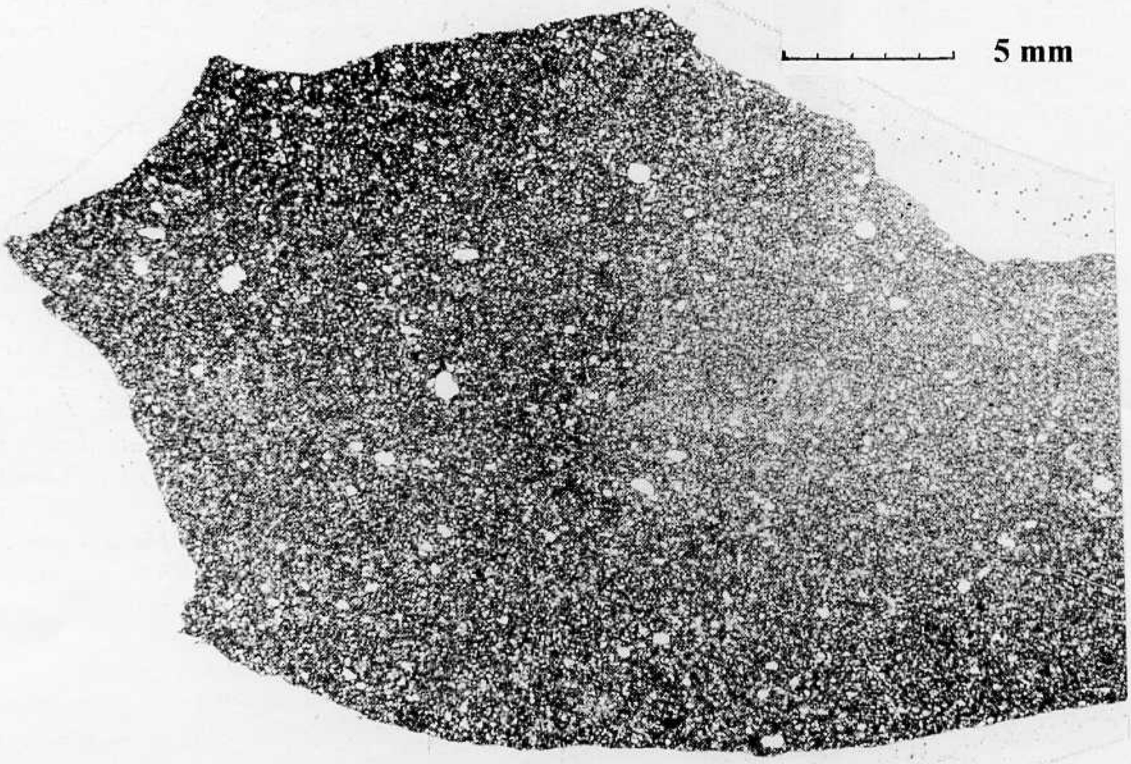
A contrasted grain-size and color readily differentiate silty from sandy layers or laminae with both lithologies. The latter are grouped as doublets or varva-like laminae (at least the pairs B, C and D, on plate 2). These doublets show at the base a sharp erosive-like boundary penetrating into the underlying silty clay whereas the shift from coarse to fine-grained sediments in the upper part of the doublets into the silty sediment is either progressive or sharp; the intradoublet boundary between sand and silty lithologies may be represented by a very thin rich organic discontinuity. These grain-size generally exhibits a fining upward trend. The silty to clayey silt laminae are characterized by a dense horizontal stratification with locally some microdropstones. All layers, even the dark silty ones, were accumulated by lateral gravity flows.

4. Clay mineral analysis

Clay mineral analysis by X-ray diffraction was carries out on the less-than-two micron fraction extracted from selected core samples. The analysed material corresponded to light and dark varvae, tillite and shale (Fig. 3). the clay fraction was extracted after mild grinding with a hand mortar, and prepared as oriented aggregates by sedimentation and centrifugation with demineralized water, but without any chemical pretreatment. Beside the air-dried state, the oriented ag-



A



B

Plate 1. A : sample N° 3: laminites (varvelike rhythmites) (borehole 1-TM-1-MA, core 674.10 - 678.40 m) B : sample N° 2: homogeneous tillite : (borehole 1-TM-1-MA, core 678.40 - 683.81 m).

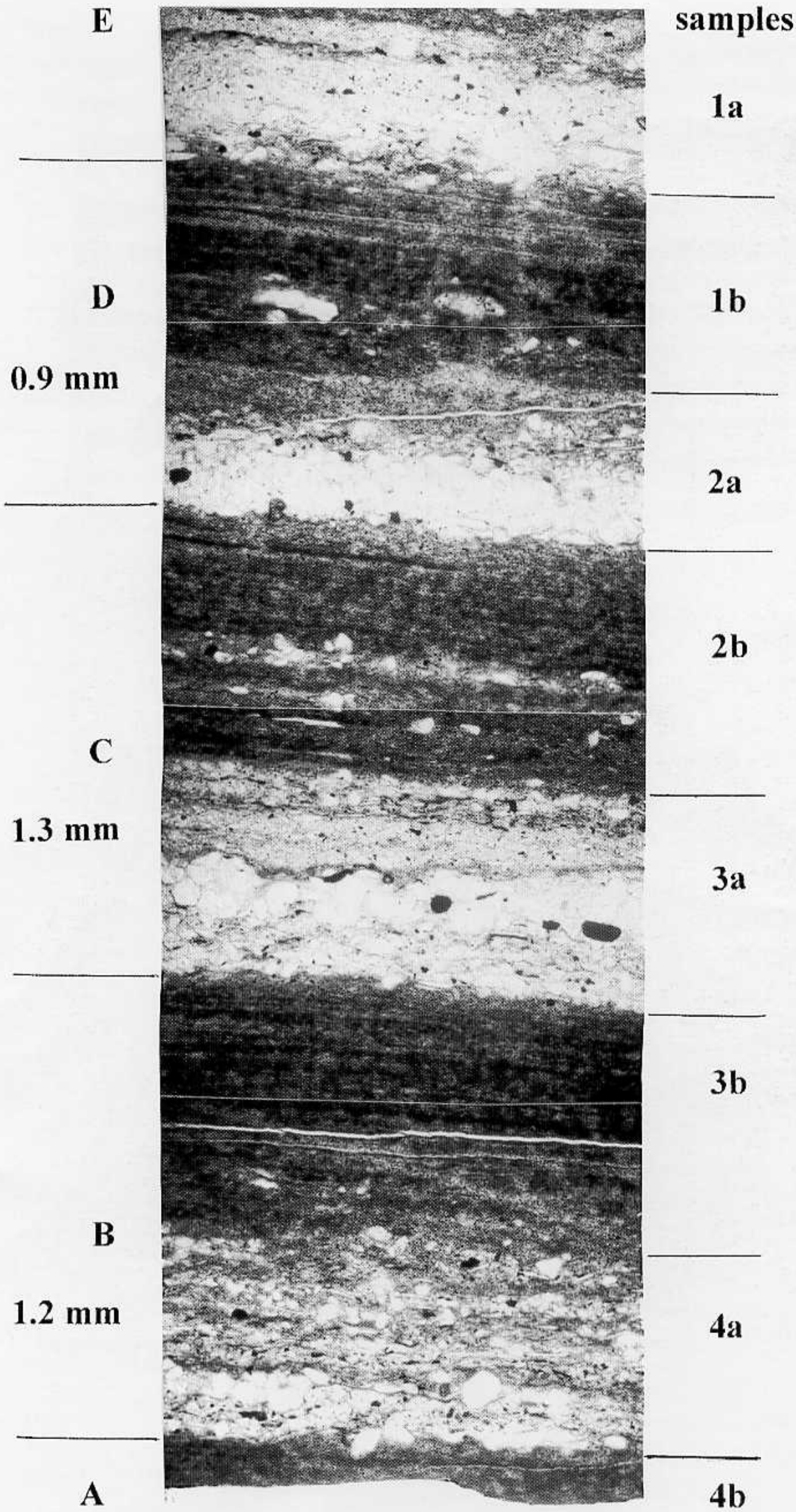


Plate 2. sample N° 3: laminites (1a to 4b) sampled separately for analysis.

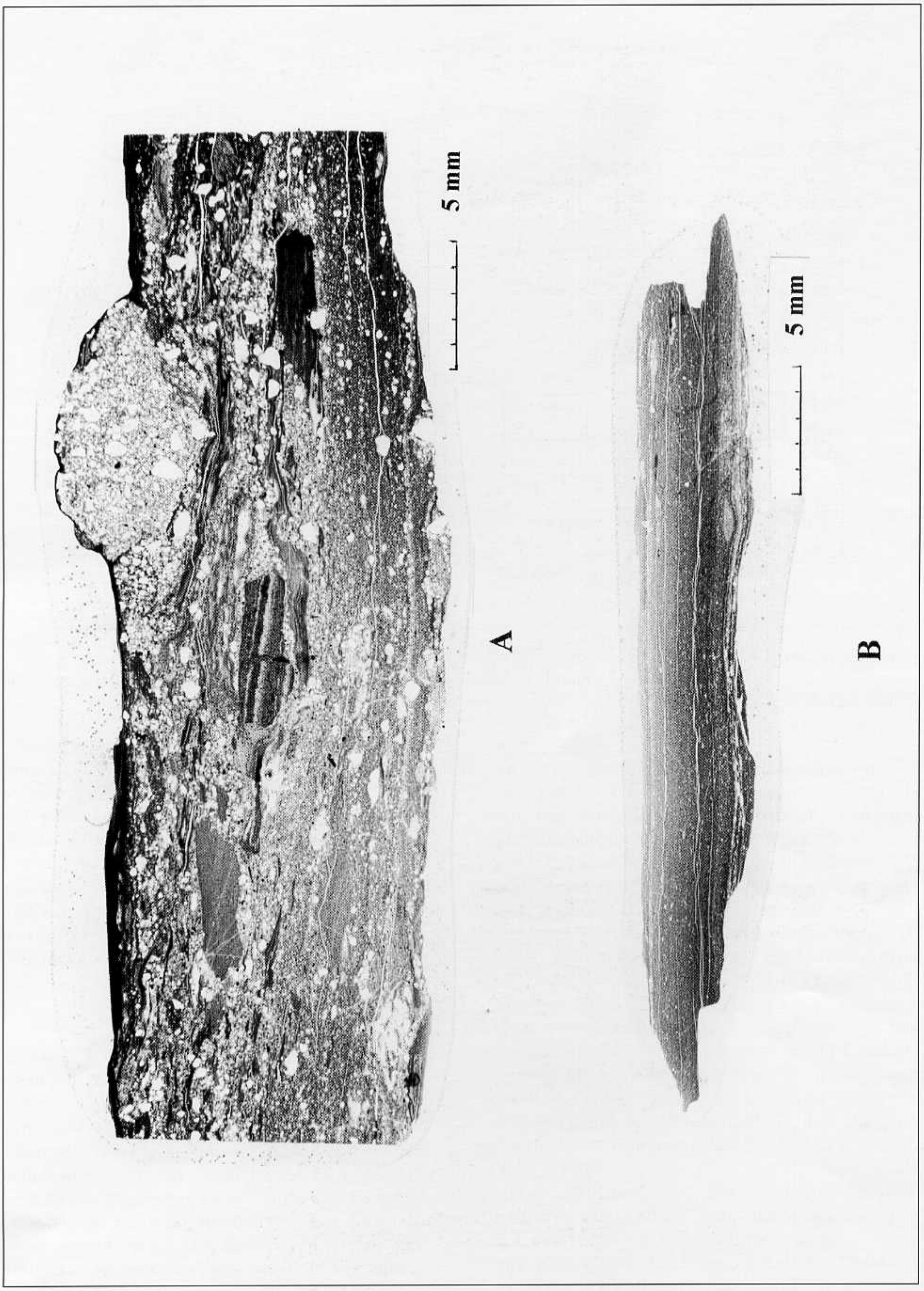


Plate 3. samples in contact with the laminites of sample N° 3. A : sample N° 4: diamictite/tillite with clasts of laminites and dropstones. B : sample N° 1: shale.

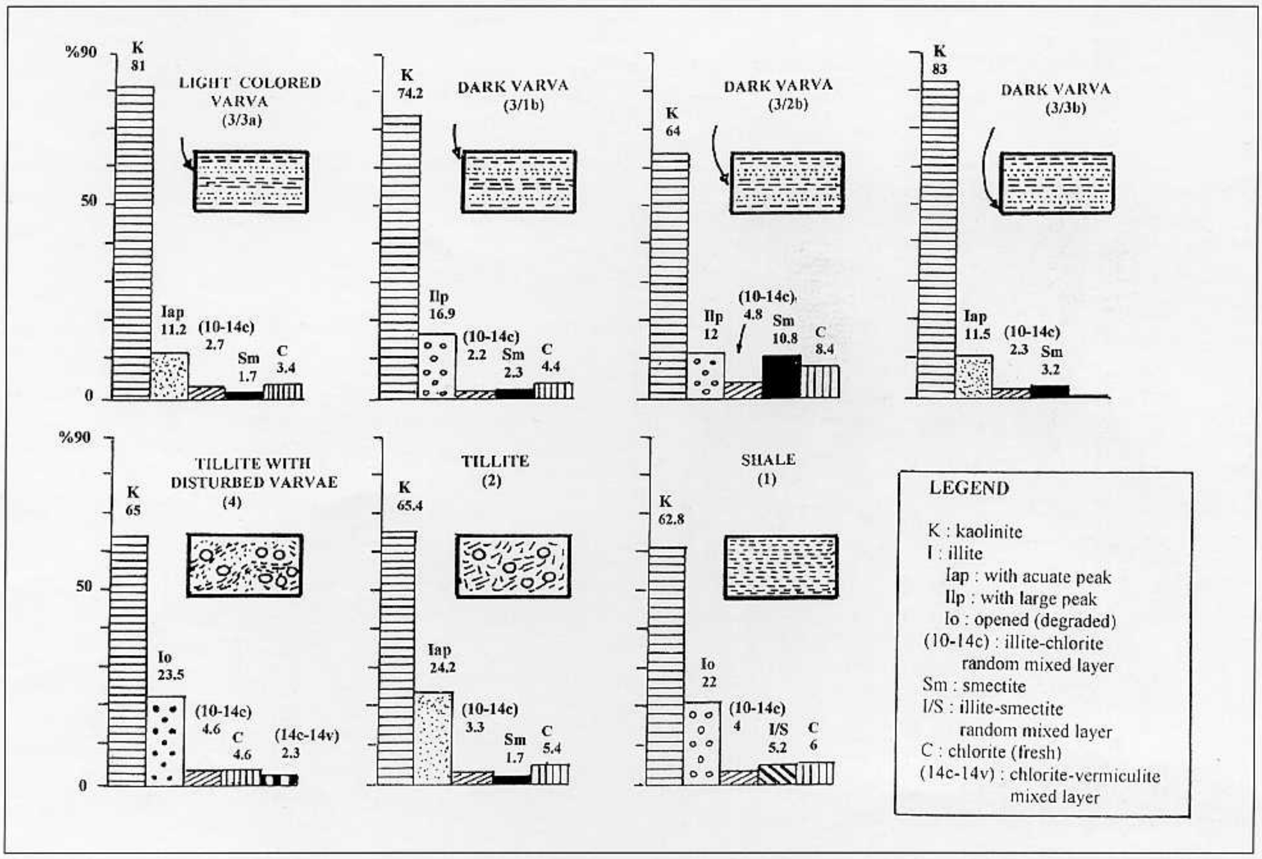


Figure 3. Clay analyses
Large dominance of kaolinite and illite with a ratio K/K+I ranging from 87 % (N° 3/sand layer) to 63 % (Tillite N° 2 and 4). Illite is often degradated. Other clays (Chlorite, Smectite, ...) are poorly represented.

gregates were submitted afterwards to solvation with ethylene glycol vapors (check for swelling clay minerals) and to heating to 500 °C. The quantitative distribution of the clay minerals, directly obtained from the measurement of the intensity of the basal (001) spacings without application of a correction factors unravel the large predominance of kaolinite (62.3 to 93%) in all samples. The remaining clay minerals comprise in decreasing order : illite, a random mixed layer illite-chlorite (10-14c), a random illite-smectite (10-14sm) mixed layer or a badly crystallized smectite, and in practically all investigated samples, some fresh chlorite. Illite could be structurally discriminated as : a fresh mineral (characterized by a narrow and symetric narrow {001} 10A, characterizing a well-crystallized mineral), a slightly degraded illite (with an enlarged basal peak), a fully degraded material (or open illite).

The predominance of kaolinite as found in the investigated samples pointed to a middle or late Devonian source from the southern part of the basin through a south-east supply as proposed by Carrozi (1980). The other clay minerals remained genetically anonymous. Chlorite associated with fresh illite (mica) point to an unweathered material whereas the mixed layers illite-chlorite and illite-smectite could point to a mild physico-chemical weathering having affected prior removal the upper part of the same parent rocks. The co-existence of residual fresh materials with a predominant kaolinite (the latter representing a deep or extended weathering) either points to a mixing of sources or to a substratum which was originally covered by a kaolinic mantle. The latter was recycled by erosion which has also affected the substratum (comprising illite, chlorite, and the mixed layers).

5. Palynological analysis

The quantitative palynological analysis of the subdivided sample 3 (Fig. 4) shows a miospore / miospore + acritarch ratio ranging from 40 % to 70 %. A large part of this material is reworked from Givetian / Frasnian rocks (see below) but latest Famennian miospores and acritarchs are present and also confirm the marine character of the depositionnal environment. The palynomorph concentrations suggest some rythmicity of a higher level, miospores progressively decreasing from 4.000/gr (3/3b) to 2500/gr (3/1b) in the silty layers and from 2500/gr (3/3a) to 1000/gr (3/1a) in the sandy layers.

		Percentage (one = or one > means 10%)			Concentration (one = or one > means 500/gr)		
Cycle	Sample	Miosp.	Sp. acrit.	Leiosph.	Miosp.	Sp. acrit.	Leiosph.
E	1a	>>>>>	>>	>>>	>>	>	>
D	1b	======	===	=	=====	==	=
D	2a	>>>>>>>	>>	>	>>>>	>	>
C	2b	=====	====	=	=======	=====	==
C	3a	>>>>>	>>>	>>	>>>>>	>>>	>>>
B	3b	======	===	=	========	====	===
B	4a	>>>>	>>>>	>>	>>	>>	>
A	4b	======	===	=	=====	===	=

Figure 4 : Quantitative analysis of laminite samples
> : sandy, = : silty
Miosp. : Miospores
Sp. acrit. : Spiny acritarchs
Leiosph. : Leiospheres
For cycles and samples, see Plate 1

The qualitative palynological analysis of all samples (Fig. 5) concerns 41 taxa, 70 % of these taxa being reworked from Givetian and Frasnian sediments. Reworked material, which is very well preserved, is recognizable only by its well known stratigraphic range. The most recent reworked miospores belong to the late Frasnian "IV" Zone, an equivalent of the *acanthaceus - deliquescens* Zone known in Eastern Europe to correspond to the Late *rhenana* conodont Zone (Obukhovskaya et al., 2000). No reworked miospores from early to late Famennian can be demonstrated. Latest Famennian miospores are represented by 12 species and are mainly characterized by the occurrence of *Retispora lepidophyta* and of a complex of *Vallatisporites,* with *V. vallatus* indicating a high stratigraphic position within the latest Famennian (late latest Famennian) i.e. the LN (*lepidophytus-nitidus*) Zone.

Most of the reworked taxa of Givetian (or older) age are only present in the tillites and associated shale (N° 1, 2 and 4). Most of the other reworked taxa originate from Frasnian rocks. They are more numerous in the silty layers (20 taxa) than in the sandy layers (13 taxa) of laminite 3. Thus, all reworked material in tillites can be explained by Givetian and Frasnian source while the reworked material in laminite 3 can be explained mainly by Frasnian source

Tillites and associated shale (N° 1, 2 and 4) contain only few of the characteristic taxa of the LN Zone. On the contrary, in sample N° 3, the *Vallatisporites* complex is present both in the silty and sandy layers.

6. Interpretation and conclusion

Reworked palynomorph occurrences throughout the stratigraphic column have been reviewed by Streel & Bless (1980). In late Pleistocene glacial lacustrine deposits, up to 60 % of Mesozoic and Cenozoic miospores and Dinoflagellates are known in sandy facies with clay flakes (Switzerland : Jan du Chêne, 1975). Reworked Mesozoic and Cenozoic palynomorphs are known in many continental late Pleistocene sediments (Great Britain : Birks, 1970, Turner, 1970 ; The Netherlands : Zagwijn & Veenstra, 1966 ; USA : Davies, 1961). Reworking processes are also known in Quaternary marine glacial deposits (USA : Bartlett, 1928 ; Scandinavia : Fries & Ross, 1950 ; Antarctica : Wilson, 1968, Kemp, 1972a and 1972b). Carboniferous glacimarine rhythmites were recently described in western Argentina (Milana & Lopez, 1998) but no attempt of analysing the miospores of the different layers has been made. The reworking occurrence in glacial pre-Quaternary sediments are poorly recorded emphasizing the interest of our new data.

The present data show that at least two distinct source-areas can be recognized, a Givetian one and a Frasnian one. Paleogeography and clay analysis suggest its origin in the southern part of the basin. Smaller amount of reworked taxa in the sandy layers than in the silty layers of the laminite (sample N° 3) could be explained by a distinctly lower concentration of miospores in the sandy than in the silty layers (see Fig. 4). Indeed, silty layers have more chance than sandy layers to reflect the complete reworked assemblage.

	laminite 3 silty				laminite 3 sandy				tillites			
	4b	3b	2b	1b	4a	3a	2a	1a	4	3	2	1
REWORKED MIOSPORES												
Emsian to Givetian taxa												
Acinosporites apiculatus		•							•			
Grandispora megaformis									•			
Rhabdosporites minutus									•			
Samarisporites praetervisus									•			
Eifelian to Givetian taxon												
Camarozonotriletes? concavus									•	•		•
Emsian to Frasnian taxa												
Acinosporites lindlarensis									•			
Samarisporites eximius		•	•	•					•			•
Eifelian to Frasnian taxa												
Archaeozonotriletes variabilis		•	•	•		•		•	•	•	•	•
Chelinospora timanica	•	•	•	•		•		•	•	•	•	•
Grandispora permulta	•	•				?		?	•	•	•	•
Verrucosisporites premnus	•			•					•	•		
V. scurrus				•					•	•	•	
Givetian to Frasnian taxa												
Cymbosporites catillus		•	•						•			•
C. cyathus	•	•	•	•		•		•	•	•	•	
Chelinospora concinna											•	
C. ligurata		•	•			•				•		•
Geminospora lemurata	•	•	•	•		•	•	•	•	•	•	•
G. punctata	•	•	•	•		•	•	•	•	•	•	•
Samarisporites triangulatus	•	•	•	•			•	•	•	•	•	•
S. sp. E	•	•	•	•			•	•	•	•	•	•
Frasnian to earliest Famennian taxa												
Grandispora daemonii						•		•	•	•	•	•
Geminospora piliformis	•	•	•	•		•	•	•	•	•	•	•
Lophozonotriletes media				•		•			•	•	•	
Verrucosisporites bulliferus	•						•		•		•	

	laminite 3 silty				laminite 3 sandy				tillites			
	4b	3b	2b	1b	4a	3a	2a	1a	4	3	2	1
Late Frasnian to earliest Famennian taxa												
Cymbosporites acanthaceus						•					•	•
Lophozonotriletes bouckaertii									•	•	•	
Rugospora bricei		•	•							•	•	
Late Frasnian to Tournaisian taxon												
Auroraspora macra			•	•					•	•	•	•
CONTEMPORANEOUS MIOSPORES												
Latest Famennian taxa												
Retispora lepidophyta			◊	♦	◊				♦	♦	♦	
Vallatisporites hystricosus (small spines)	◊	♦		♦	◊	◊				◊		
Latest Famennian to Tournaisian taxa												
Aratrisporites saharaensis		•								•		
Cordylosporites spathulatus										◊		
Gorgonispora convoluta			♦		◊							
Knoxisporites literatus/hederatus				•						•		
Leiozonotriletes insignitus	•	♦	♦	♦					•	•	•	
Spelaeotriletes sp. cf. *S. obtusus*	•	♦	•	•			•	•	♦	•	•	•
Vallatisporites vallatus		♦		♦	◊	•		♦		♦	?	
V. verrucosus	♦	♦	♦	♦	◊		♦	♦		♦		♦
Verrucosisporites mesogrumosus	♦				◊						•	

made by S. Loboziak
• in 1992
♦ in 1992 and repeated in 1997
◊ in 1997

Figure 5 : Qualitative analysis of laminite and tillite samples
All reworked material in tillites can be explained by Givetian and Frasnian sources.
All reworked material in laminite 3 can be explained mainly by Frasnian source

This is partly true also for the miospores presumed to be contemporaneous (late latest Famennian). of the laminite deposit (less miospores in the sandy layers than in the silty layers). But it is obvious that these contemporaneous miospores are significally less present in the tillites and associated shale (Samples N° 1, 2 and 4) than in the laminite (Samples 3), a situation different from that observed in the reworked material. This suggests that the contemporaneous miospores are produced locally, the glacial tongue, carrying the reworked part of the material, only partially overlapping adjacent environments.

If we except sample 3/4a (where several silty thin layers are intercalated in the sandy layer - See plate 2), the rarity of contemporaneous miospore taxa in the sandy layers of laminite N° 3 might be interpreted also as a sort of seasonal effect, with only the *Vallatisporites* complex and *S.* sp. cf. *S. obtusus* escaping the process.
In case of seasonal effect, the rythmites would be true varves, the sandy layers being first settled after the local seasonal melting of the ice cover and the rush of fresh water supply into the sea, the silty layers being deposited when the spring water run-off decreases.

In the late Famennian of eastern North America, *Vallatisporites hystricosus* was demonstrated to occupy a margin of downstream peat swamp (Streel & Scheckler, 1990). Because Streel & Traverse (1978) had come to the conclusion that *V. hystricosus and V. vallatus* were part of a same palynodeme, the first species merging progressively into the second-one with time, Streel (1999) has accepted that, in the late latest Famennian of western Europe, they were sharing the same ecological niche.
Was the *Vallatisporites* mother-plant, living in the swamp margin environment, the first to produce spores immediately after the (spring?) melting of the ice cover?

7. Acknowledgements

The authors are indebted to Petrobas-Petróleo Brasileiro S.A. for the permission to publish this paper.

8. References

AVKHIMOVITCH, V.I., TCHIBRIKOVA, E.V., OBUKHOVSKAYA, T.G., NAZARENKO, A.M., UMNOVA, V.T., RASKATOVA, L.G., MANTSUROVA, V.N., LOBOZIAK, S. & STREEL, M., 1993. Middle and Upper Devonian miospore zonation of eastern Europe. *Bull. Cent. Rech. Expl. Prod.* Elf Aquitaine, 17 (1): 79-147.

BARTLETT, H.H., 1928. Fossils of the Carboniferous coal pebbles of the glacial drift at Ann Arbor. *Pap. Michigan Acad. Sci. Arts*, Lett., 9: 11-28.

BIRKS, H.J.B., 1970. Inwashed pollen spectra at Loch Fada, Isle of Skye. *New Phytol.*, 69: 807-820.

CAPUTO, M.V., 1985. Late Devonian glaciation in South America. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 51: 291-317.

CAPUTO, M.V. & CROWELL, J.C., 1985. Migration of glacial centers across Gondwana during Paleozoic Era. *Geol. Soc. Amer. Bull.*, 96: 1020-1036.

CAROZZI, A.V., 1980. Tectonic control and petroleum geology of the Paleozoic clastics of the Maranhão Basin, Brazil. *Journal of Petroleum Geology*, 2 (4): 389-410.

CAROZZI, A.V., FALKENHEIM, F.U.H., CARNEIRO, R.G., ESTEVES, F.R. & CONTREIRAS, C.J.A., 1975. Análise ambiental e evolução tectônica sinsedimentar da seção siluro-eocarbonífera da Bacia do Maranhão. Petrobrás/Cenpes, Ciência-Técnica-Petróleo; Seção: *Explor. Petrol.*, 7, pp. 1-48 + appendix.

DAVIES, M.B., 1961. The problem of rebedded pollen in the late-glacial sediments at Taunton, Massachusetts. *Am. Journ. Sc.*, 259: 211-222.

FRIES, M. & ROSS, N.E., 1950. Pre-Quaternary pollen grains and spores found in late-glacial and post-glacial clays in Bohuslän, S.W. Sweden. *Arkiv Mineral. Geol.*, 1 (7): 199-210.

JAN DU CHENE, R., 1975. Etude sédimentologique et paléontologique d'une coupe tardiglaciaire des environs de Morat (Fribourg, Suisse). *Arch. Sc. Genève*, 28 (1): 53-66.

KEMP, E.M., 1972a. Recycled palynomorphs in continental shelf sediments from Antarctica. *Antarct. Jour. U.S.*, 72 (7-5): 190-191.

KEMP, E.M., 1972b. Reworked palynomorphs from the west sea shelf area, East Antarctica, and their possible geological and palaeoclimatological significance. *Marine Geol.*, 13: 145-157.

LOBOZIAK, S., STREEL, M., CAPUTO, M.V. & MELO, J.H.G., 1993. Middle Devonian to Lower Carboniferous miospores from selected boreholes in Amazonas and Parnaíba Basins (Brazil): additional data, synthesis, and correlation. *Docum. Lab. Géol. Lyon*, 125: 277-289.

MALZAHN, E., 1957. Devonisches glazial in Piaui (Brasilien), ein neuer Beitrag zur Eiszeit des Devon. *Beih. Geol. Jahrbuch*, 25: 1-31.

MILANA, J.P. & LOPEZ, S., 1998. Solar cycles recorded in Carboniferous glacimarine rhythmites (Western Argentina): relationships between climate and sedimentary environment. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 144: 37-63.

OBUKHOVSKAYA, T.G., AVKHIMOVITCH, V.I., STREEL, M. & LOBOZIAK, S., 2000. Miospores from the Frasnian-Famennian Boundary deposits in Eastern Europe (the Pripyat Depression, Belarus and the Timan Pechora Province, Russia) and comparison with Western Europe (Northern France). *Rev. Palaeobot. Palynol.* 112,4: 229-246.

STREEL, M., 1999. Quantitative palynology of Famennian Events in the Ardenne-Rhine Regions. In: Feist, R., Talent, J.A., Daurer, A., (eds.), North Gondwana: Mid-Paleozoic Terranes, Stratigraphy and Biota). *Abh. Geol. Bundesanstalt*, 54: 201-212.

STREEL, M. & BLESS, M.J.M., 1980. Occurrence and significance of reworked palynomorphs. Meded. Rijks Geol. Dienst, 32 (10): 69-80.

STREEL, M. & LOBOZIAK, S., 1987. Nouvelle datation par miospores du Givétien-Frasnien des sédiments non marins du sondage de Booischot (Bassin de Campine, Belgique). *Bull. Soc. belge Géol.*, 96 (2): 99-106.

STREEL, M. & SCHECKLER, S.E., 1990. Miospore lateral distribution in upper Famennian alluvial, lagoonal to tidal facies from eastern United States and Belgium. *Rev. Palaeobot. Palynol.*, 64: 315-324.

STREEL, M. & TRAVERSE, A., 1978. Spores from the Devonian/Mississippian transition near the Horseshoe Curve section, Altoona, Pennsylvania, U.S.A. *Rev. Palaeobot. Palynol.*, 26: 21-39.

TURNER, C., 1970. The Middle Pleistocene deposits at Marks Tey, Essex. *Philos. Trans. Roy. Soc. Lond.*, B257: 373-437.

WILSON, G.J., 1968. On the occurrence of fossil microspores, pollen grains, and microplankton in bottom sediments on the Ross Sea, Antarctica. *N.Z. Journ. mar. Fresh Wat. Res.*, 2: 381-389.

ZAGWIJN, W.H. & VEENSTRA, H.J., 1966. A pollen-analytical study of cores from the outer silver pit, *North Sea. Marine Geol.*, 4: 539-551.

Appendix : list of taxa

Acinosporites apiculatus (Streel) Streel 1967
Acinosporites lindlarensis Riegel 1968
Aratrisporites saharaensis Loboziak, Clayton and Owens 1986
Archaeozonotriletes variabilis Naumova emend Allen 1965
Auroraspora macra Sullivan 1968
Camarozonotriletes? concavus Loboziak and Streel 1989
Chelinospora concinna Allen 1965
Chelinospora ligurata Allen 1965
Chelinospora timanica (Naumova) Loboziak and Streel 1992
Cordylosporites spathulatus (Winslow) Playford and Satterthwait 1985
Cymbosporites acanthaceus (Kedo) Obukhovskaya *in* Avkhimovitch et al., 1993
Cymbosporites catillus Allen 1965
Cymbosporites cyathus Allen 1965
Geminospora lemurata Balme emend Playford 1983
Geminospora piliformis Loboziak, Streel and Burjack 1988
Geminospora punctata Owens 1971
Gorgonispora convoluta (Butterworth and Spinner) Playford 1976
Grandispora daemonii Loboziak, Streel and Burjack 1988
Grandispora megaformis (Richardson) McGregor 1973
Grandispora permulta (Daemon) Loboziak, Streel and Melo 1999
Knoxisporites hederatus (Ishchenko) Playford 1963
Knoxisporites literatus (Waltz) Playford 1963
Leiozonotriletes insignitus Hacquebard 1957
Lophozonotriletes bouckaertii Loboziak and Streel 1989
Lophozonotriletes media Taugourdeau-Lantz 1967
Retispora lepidophyta (Kedo) Playford 1976
Rhabdosporites minutus Tiwari and Schaarschmidt 1975
Rugospora bricei Loboziak and Streel 1992
Samarisporites eximius (Allen) Loboziak and Streel 1989
Samarisporites praetervisus (Naumova) Allen 1965
Samarisporites triangulatus Allen 1965
Samarisporites sp. E *in* Streel and Loboziak 1987
Spelaeotriletes sp. cf. *S. obtusus* Higgs 1975
Vallatisporites hystricosus (Winslow) Byvsheva 1985 (small spines)
Vallatisporites vallatus Hacquebard 1957
Vallatisporites verrucosus Hacquebard 1957
Verrucosisporites bulliferus Richardson and McGregor 1986
Verrucosisporites mesogrumosus (Kedo) Byvsheva 1985
Verrucosisporites premnus Richardson 1965
Verrucosisporites scurrus McGregor and Camfield 1982

Manuscript received September 13, 2000, accepted January 8, 2001.