3. BIOPOLYMER ORGANIZATION OF THE WALL OF THE FOSSIL SPORES AND POLLEN GRAINS

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Abstract

The transmission electronmicroscopical data of the laboratory prepared from 1969 on fossil spores and pollen grains were reinvestigated from the point of view of the degree of the degradation of the sporoderm. This work taxonomically includes the following: 23 form-species of *Pteridophyta* spores, 16 form-species of *Gymnospermatophyta,* and 75 form-species of *Angiospermatophyta* pollen grains. During the evaluation of the TEM data the following points of view were taken into consideration: Locality, geological age, embedding rock, resolution power of the used TEM instrument, presence of the basic biopolymer unit, highly organized globular units and the superficial biopolymer differentiations. The following was established: 1. The wall of the *Pteridophyta* spores is extremely resistant, 2. *Gymnospermatophyta* pollen grains are heterogeneous in this respect. The basic and highly organized biopolymer system was observed on the ectexine and endexine of *Balmeiopsis limbatus.* Saccate pollen grains are extremely resistant after a fossilization process. 3. The biopolymer systems of *Angiospermatophyta* pollen grains are much more complex in contrast to the previous ones. The exines of *Longaxones* pollen grains as the early types are more resistant than the more developed *Brevaxonate* ones. Typical regular pentagonal basic units and highly organized globules are simultaneously observed at the exines of *Thomsonipollis* and *Restioniidites* from the Eocene layers of the *Mississippi,* USA.

Key words: Palynology, fossil, transmission electron microscopy, biopolymer structure.

Introduction

Our transmission electronmicroscopical investigations on the fossil spores and pollen grains started in 1969, the first results appeared in 1970a, b (KEDVES and PÁRDUTZ). Several publications followed with the evaluation from the point of view of the ultrastructure phylogeny (e.g.: KEDVES, 1988a). A monographical elaboration of the TEM data was also planned. The first monography on the fossil angiosperm pollen grains appeared in 1990. The second ones about the fossil spores and gymnosperm pollen grains is just before completing the manuscript for publication.

In 1974 KEDVES, STANLEY and ROJIK published the macromolecular units of the partialy degraded exines of *Restioniidites hungaricus,* and *Thomsonipollis magnificus* from the Lower Eocene layers of Mississippi, USA. Later several experimental studies started on recent sporomorphs, with the aim to investigate the biopolymer structure of the sporoderm, with different kinds of methods.

The discovery of the quasi-crystalloid biopolymer structure of the sporoderm (KEDVES, 1988b) induced new directions of researches.

The biopolymer structure can be investigated by the TEM method on partially degraded biological structures. This partial degradation can be in vitro and natural, during the sedimentation process.

To get fundamental information about the fossil biopolymer structures it is necessary to evaluate and synthetize all the obtained fossil TEM data from the point of view of partial degradation and biopolymer structure. This is the aim of this contribution.

Methods

The sporomorphs investigated by the TEM method came from the following localities, and embedding rocks, in order to their geological age.

Jurassic

Liassic, Hungary, Úrkút, carbonaceous manganese ore; HU., J., Urk.
Egypt, Kharga Oasis, lower part of the Nubia Sandstone, carbonaceous clay; EG., J., Kh.
Egypt, Farafra Oasis, lower part of the Nubia Sandstone, clay; EG., J., Fa.

Cretaceous

Upper Cenomanian, Portugal, Vila Flor, carbonaceous clay; PORT., Cr., Vila F.
Upper Cenomanian – lower Turonian, Portugal, Fermentelos, carbonaceous clay; PORT., Cr., Fer.
Lower Turonian, Portugal, Carrajão, carbonaceous clay; PORT., Cr., Car.
Turonian, Portugal, Marmeleira do Botão, carbonaceous clay; PORT., Cr., M. do Bot.
– Portugal, Oia, dark bitumenous clay; PORT., Cr., Oia.
Santonian – Campanian, Portugal, Aveiro, carbonaceous clay; PORT., Cr., Av.
Upper Cretaceous, Hungary, Ajka, brown coal; HU., Cr., Aj.
Hungary, Herend, brown coal; HU., Cr., Her.
Maestrichtian, Egypt, Farafra Oasis, upper part of the Nubia Sandstone, carbonaceous clay; EG., Cr., Fa.
Maestrichtian, Kazakhstan, Bet-pak-dala; KAZ., Cr.

Eocene

Lower Eocene, USA, Mississippi, brown coal; USA, Eoc., Miss.
– France, Paris Basin, brown coal; FR., Eoc., P.B.
– Hungary, Úrkút, carbonaceous clay; HU., Eoc., Urk.
Middle Eocene, Hungary, Balinka, carbonaceous shale; HU., Eoc., Bal.
– Hungary, Oroszlány, brown coal; HU., Eoc., Or.
– Hungary, Zirc, black, slightly sandy clay; HU., Eoc., Zi.

Oligocene

Upper Oligocene, Hungary, Fehérvárcsurgó, carbonaceous clay; HU., Olig., Feh.

Results are summarized in the order of morphographical taxa. After the form-species name, the shortened data of the localities and geological ages are indicated. The resolution power in this respect is indicated with + or –, similarly the presence or absence of the different kinds of biopolymer structures; basic biopolymer unit, open polygon, superficial differentiations.

Results

SPORES

	resolution power	basic biopolymer unit	open polygon	superficial differentiations
Leiotriletes				
– *adriennis triplanoid*, HU., Eoc., Zi.	–	?	+	–
– *pseudodorogensis*, HU., Eoc., Zi.	–	?	+	–
– ex gr. *maxoides maximus*, PORT., Cr., Vila F.	+	+	+	–
– asp. *sinuosoides*, PORT., Cr., Vila F.	+	+	–	–
– *fsp.*, PORT., Cr., Vila F.	+	+	+	–
Undulatisporites				
– *undulapolus*, PORT., Cr., M. do Bot.	+	+	+	–
Dictyophyllidites				
– *eocaenicus*, HU., Eoc., Zi.	–	?	+	–
Paraconcavisporites				
– *nubiensis*, EG., J., Kh.	+	–	–	–
Saadisporites				
– *aegyptiaca*, EG., J., Kh.	+	–	+	+
Hydrosporis				
– *farafraensis*, EG., Cr., Fa.	+	–	–	–
Echinatisporis				
– cf. *fsp.*, EG., J., Fa.	+	–	+	–
Foveotriletes				
– *subtriangularis*, EG., Cr., Fa.	–	–	–	?
Vadaszisporites				
– *sacali*, EG., Cr., Fa.	–	–	+	–
Cicatricosisporites				
– *baconicus*, PORT., Cr., Vila F.	+	–	–	+
Zlivisporis				
– *blanensis*, EG., Cr., Fa.	+	±	–	–
Appendicisporites				
– *erdtmanii*, PORT., Cr., M. do Bot.	+	–	+	–
– *tricuspidatus*, HU., Cr., Her.	–	–	+	–
Ariadnaesporites				
– *lusitanicus*, PORT., Cr., Vila F.	+	–	–	–
Hymenoreticulisporites				
– *altimurornatus*, EG., J., Kh.	+	–	–	–
Polypodiaceoisporites				
– *fsp.*, PORT., Cr., Vila F.	+	–	–	–
Hamulatisporis				
– *insignis*, EG., Cr., Fa.	+	–	–	–
Microfoveolatosporis				
– *pseudodentatus*, HU., Eoc., Zi.	–	–	–	–
– *fsp.*, PORT., Cr., Vila F.	+	–	+	–

POLLEN GRAINS
Gymnosperms

	resolution power	basic biopolymer unit	open polygon	superficial differentiations
Pityosporites				
– *singularis*, PORT., Cr., Oia, M. do Bot., Vila F.	+	–	–	–
– *microalatus*, HU., Olig., Feh.	–	–	–	–
Parvisaccites				
– *radiatus*, PORT., Cr., Fer.	+	–	–	–
Inaperturopollenites				
– ex gr. *hiatus*, PORT., Cr., Fer.	+	+	–	–
Araucariacites				
– *balinkaense*, EG., Cr., Fa.	–	–	–	–
– *australis aegypticus*, EG., Cr., Fa.	–	–	+	–
– *hungaricus*, PORT., Cr., Oia.	+	+	–	–
Balmeiopsis				
– *limbatus*, EG., J., Fa.	+	+	–	–
Spheripollenites				
– *scabratus*, HU., J., Urk.	–	–	–	–
Classopollis				
– *classoides*, HU., J., Urk., EG., J., Kh.	+	+	–	–
– *minor*, EG., J., Kh.	+	+	+	–
Classoidites				
– *glandis*, PORT., Cr., Av.	–	–	–	–
Ephedripites				
– *virginiaensis*, EG., Cr., Fa.	–	–	–	–
– *multicostatus*, EG., Cr., Fa.	+	+	–	–
Cycadopites				
– *minimus*, HU., J., Urk.	+	–	–	–
– *fsp.*, PORT., Cr., Fer.	+	+	–	–

Angiosperms

	resolution power	basic biopolymer unit	open polygon	superficial differentiations
Retimonocolpites				
– *granulatus*, HU., Eoc., Zi.	–	–	–	–
Liliacidites				
– *barakatii*, EG., Cr., Fa.	–	–	–	–
Transdanubiaepollenites				
– *magnus*, HU., Eoc., Urk.	–	–	–	–
Cupuliferoidaepollenites				
– cf. *quisqualis*, PORT., Cr., Av.	–	–	–	–
– *liblarensis*, HU., Eoc., Zi.	–	–	–	–
Polycolpites				
– *viesenensis*, HU., Eoc., Zi.	–	–	–	–
Betpakdalina				
– ex gr. *protuberantis*, KAZ., Cr.	–	–	–	–
– ex gr. *tetrabarbata*, KAZ., Cr.	–	–	–	–
– ex gr. *minuta*, KAZ., Cr.	–	–	–	–
Retitricolporites				
– cf. *microreticulatus*, FR., Eoc., P.B.	–	–	–	–

	resolution power	basic biopolymer unit	open polygon	superficial differentiations
Araliaceoipollenites				
— *euphorii,* HU., Eoc., Urk.	–	–	–	–
Nyssapollenites				
— *kruschii,* HU., Eoc., Urk.	–	–	–	–
Cupuliferoidaepollenites				
— *pusillus,* HU., Eoc., Urk.	–	–	–	–
Intrabaculitricolporites				
— *sooi,* HU., Eoc., Urk.	–	–	–	–
Granotricolporites				
— *semiglobosus,* HU., Eoc., Bal.	–	–	–	–
— *miniverrucatus,* FR., Eoc., P.B.	–	–	–	–
Ilexpollenites				
— *margaritatus medius,* FR., Eoc., P.B.	–	–	–	–
Striatricolporites				
— *solé de portai,* HU., Eoc., Zi.	–	–	–	–
Teixeraipollenites				
— *globosus,* PORT., Cr., Vila F.	–	–	–	–
Pentapollenites				
— *laevigatus,* HU., Eoc., Zi., Bal.	–	–	–	–
Bolchovitinaepollenites				
— *punctatus,* PORT., Cr., Vila F.	+	–	–	+
— *microreticulatus,* PORT., Cr., Vila F.	+	–	–	–
Samoilovichaepollenites				
— *concavus,* PORT., Cr., Vila F.	+	–	–	–
Vilaflorpollenites				
— *concavus,* PORT., Cr., Vila F.	+	–	–	–
— *magnus,* PORT., Cr., Vila F.	+	–	–	–
— *pflugii,* PORT., Cr., Vila F.	+	–	–	–
— *rugulatus,* PORT., Cr., Vila F.	+	–	–	–
— *ibericus,* PORT., Cr., Vila F.	+	–	–	–
— *minor,* PORT., Cr., Vila F.	+	–	–	–
Complexiopollis				
— *praeatumescens,* PORT., Cr., Car.	+	–	–	–
— *vancampoae,* PORT., Cr., Vila. F.	+	–	–	–
— *helmigii,* PORT., Cr., Vila. F.	+	–	–	–
Atlantopollis				
— *reticulata,* PORT., Cr., Fer., Car.	+	+	–	–
— *microreticulata,* PORT., Cr., Fer.	+	+	–	–
— *variabilis,* PORT., Cr., Vila F.	+	–	–	–
— *vilaflorensis,* PORT., Cr., Vila F.	+	–	–	–
— *microrugulata,* PORT., Cr., Vila F.	+	–	–	–
— — PORT., Cr., Fer.	+	+	–	–
— *grootii,* PORT., Cr., Fer.	+	+	–	–
— *choffatii,* PORT., Cr., Fer.	+	+	–	–
— *convexa,* PORT., Cr., Fer.	+	+	–	–
— *verrucosa,* PORT., Cr., Fer.	+	+	–	–
— *lusitanica,* PORT., Cr., Vila F.	+	–	–	–
Limaipollenites				
— *triangulus,* PORT., Cr., Vila F.	+	+	–	–

	resolution power	basic biopolymer unit	open polygon	superficial differentiations
– *vilaflorensis,* PORT., Cr., Vila F.	+	–	–	–
– *minor,* PORT., Cr., Vila F.	+	–	–	–
Trudopollis				
– *mechanicus,* HU., Cr., Her.	–	–	–	–
Pompeckjoidaepollenites				
– *subhercynicus,* FR., Eoc., P.B.	–	–	–	–
Oculopollis				
– *zaklinskaiae,* HU., Cr., Her.	–	–	–	–
– *minoris,* HU., Cr., Aj.	+	+	–	–
Semioculopollis				
– *praedicatus,* HU., Cr., Aj.	+	+	–	–
– *croxtonae,* HU., Cr., Her.	–	–	–	–
– *granulosus,* HU., Cr., Her.	–	–	–	–
Hungaropollis				
– *krutzschii,* HU., Cr., Her.	–	–	–	–
– cf. *medusii,* HU., Cr., Her.	–	–	–	–
Basopollis				
– *basalis,* FR., Eoc., P.B., USA, Eoc., Miss.	+	+	–	+
Nudopollis				
– *terminalis,* FR., Eoc., P.B., USA, Eoc., Miss.	+	+	–	+
Interporopollenites				
– *endotriangulus,* PORT., Cr., Av.	–	–	–	–
Plicapollis				
– *pseudoexcelsus turgidus,* FR., Eoc., P.B., USA, Eoc., Miss.	+	+	–	+
Vacuopollis				
– *orthopyramis,* PORT., Cr., Av.	–	–	–	–
Interpollis				
– *microsupplingensis,* USA., Eoc., Miss.	+	+	+	+
– *messelensis,* USA., Eoc., Miss.	+	+	–	+
Thomsonipollis				
– *magnificus,* USA., Eoc., Miss.	+	+	–	+
Labraferoidaepollenites				
– *rurensis,* HU., Olig., Feh.	–	–	–	–
Plicatopollis				
– *laevigatus,* HU., Eoc., Urk., Zi.	+	–	–	–
Triporopollenites				
– *robustus robustus,* Fr., Eoc., P.B., USA, Eoc., Miss.	+	+	–	+
– *pflugii,* HU., Eoc., Urk.	–	–	–	–
Subtriporopollenites				
– *constans constans,* HU., Eoc., Urk.	+	+	–	–
– *constans magnus* FR., Eoc., P.B.	–	–	–	–
Diporoconia				
– *iszkaszentgyoergyi,* HU., Eoc., Urk.	–	–	–	–
Kopekipollenites				
– *magnus,* HU., Eoc., Or.	–	–	–	–
Platycaryapollenites				
– *miocaenicus,* USA, Eoc., Miss.	+	+	–	+
Alnipollenites				
– *verus,* HU., Olig., Feh.	–	–	–	–

	resolution power	basic biopolymer unit	open polygon	superficial differentiations
Intratriporopollenites				
– *microreticulatus*, Fr., Eoc., P.B.	–	–	–	–
Caryapollenites				
– *triangulus*, USA., Eoc., Miss.	+	+	–	+
Compositoipollenites				
– *rhizophorus*, FR., Eoc., P.B.	–	–	–	–
Restioniidites				
– *hungaricus*, USA, Eoc., Miss.	+	+	–	+

Discussion and Conclusions

SPORES

On the basis of our up-to-date knowledge, the bituminous (dark) clay preserved the best the wall structure. Among the different kinds of biopolymer structures it is the open polygon which occurred as the most frequent in our material. Regarding the geological age, the spores extracted from the Upper Cenomanian layers are in the best preservation. The colour of the embedding rock was dark coloured (coaley or bituminous) and the locality is in Portugal. Basic biopolymer structures occured in 1.7 per cent, open polygons in 52.1%, superficial differences in 6.8% of the investigated material.

GYMNOSPERM POLLEN GRAINS

It is worth of mentioning that at the fossil gymnosperm pollen grains we have not observed superficial differences. To this fact it can be pointed out that during our experiments of the recent saccate gymnosperm pollen grains we have observed and described interesting biopolymer structures (e.g.: KEDVES and PÁRDUTZ, 1992).

The intercalated argillaceous layers of the Nubia Sandstone in Egypt are the best from the point of view of the preservation of the exines.

Basic biopolymer units were observed on Upper Cenomanian and Turonian sediments from Portugal, from the carbonate manganese ore layers of Úrkút, in Hungary (Liassic), and from the lower part of the Nubia Sandstone; Egypt, Jurassic.

Open polygon was observed on the exines extracted from the intercalated argilaceous layers of the Nubia Sandstone from Egypt. Both parts, the Jurassic and the Upper Cretaceous were succesful in this respect.

In resumé, at the investigated fossil gymnosperm exines basic biopolymer structures was observed at the 43.75%, open polygon structure at 12.5% of the totality of the material.

ANGIOSPERM POLLEN GRAINS

In this very interesting and heterogeneous group 55.4% of the investigated material was degraded during the sedimentation processes, in this way a remarkable quantity (44.59%) of the biopolymer system was discovered.

At the fossil material open polygon was not observed during our investigations.

As regards the problem of preservation, carbonaceous clay and brown coal were suitable.

The most important discovery in this respect was made on the Eocene layers of Mississippi, USA on the fossil exines of *Restioniidites hungaricus* and *Thomsonipollis magnificus* (Kedves, Stanley and Rojik, 1974). These observations were the first on the fossil biopolymer structures, and started several new directions of experimental researches on recent and fossil exines.

Finally we must emphasize that the problem investigated in the present contribution is the first attempt to survey an extremely multifactorial question. In this way several questions and problems can emerge. But we hope that this contribution will be useful future researches.

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