Plant reproductive organs from the Mecsek Coal Formation

THESES OF THE PHD DISSERTATION

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Introduction and objectives

Studying Mesozoic plant reproductive organs has a long tradition. In the Mecsek Coal Formation the vegetative plant material has been studied (BARBACKA 2011) but only a few from the reproductive organs have been investigated so far (BARBACKA & BÓKA 2000b, BARBACKA & BÓKA 2014).

The prior aim of this thesis is to describe, classify and interpret the little known plant reproductive structures - mainly gymnosperm cones and dispersed seeds of the Mecsek Coal Formation.

Objective morphometrics have played an increasing role during the last few years, however, no algorithm for statistical evaluation of classical measured data was available. Therefore the aim of my PhD was to test the well-known geostatistical and biostatistical approaches to process an analytical method for morphometrics.

All of the studied specimens were found on waste-dumps, therefore thin section studies were important to describe the sedimentary environment. The fossiliferous layers are waste-racks for coal mining and thus less investigated. Recent studies can provide additional information about the development of the geologically well-known formation.

For wider paleobiogeographic connections the flora of the Mecsek Coal Formation was compared to other Jurassic localities of Europe (BARBACKA & BODOR et al. 2014).

Material and methods

The studied material is hosted in the Hungarian Natural History Museum Department of Botany. More than 800 seeds were found on 315 hand specimens, and other reproductive organs (mainly/such as cones and scales) on 282 hand specimens. The plant fossils from the Mecsek Coal Formation in the Hungarian Natural History Museum are outstanding in Europe according to the number of reproductive organs. The bad preservation made detailed studies impossible in many cases and the cuticles are usually missing.

First macroscopic and microscopic morphological studies and photo documentation were carried out. The specimens for morphometrics and cuticle preparation were selected during this process. Cuticles were prepared by the modified dry Schulze method. Scanning electron microscopic (SEM) studies were made when the palaeobiological questions necessitatedit. In the case of one cone (*Palissya*), a micron punctuality acrystal duplicate was made for the SEM studies. Oriented sections and cuticle dissections of *Cycas revoluta* seeds were used as recent comparative material.

For the sedimentological studies embedded thin sections were made from the six macroscopically different rock types.

Morphometrical proceedings were expanded where mono– and multivariate analytical methods were taken into consideration. The geostatistical and biostatistical literature about grouping was summarised up. After this, the feasibilities, limits and possible interpretations of the methods were determined based on case studies of more independent fossil groups (BODOR et al. 2014; PRONDVAI et al. 2014).

For the palaeoenvironmental studies I used widely applied statistical methods. The background factors were determined by principal component analysis (PCA) and the connections between the different European Jurassic localities were explained by cluster analysis.

Theses

1. Only the combined application of mono– and multivariate statistical methods can give reliable answer in morphometrics for the interpretation of differentiated groups. The separation of different taxa means grouping in statistical point of view. However, the significantly different groups do not necessarily represent different taxa. Based on recent studies the use morphometrics can be expanded not only for taxonomical problems but also ontogenetic and maturation processes can be identified with this tool.

2. Different maturation stages were identified by the two morphotypes of *Nilssonia* seeds with morphometrical analysis. The irregular form is the unripe, less sclerenchymatised, while the regular, rounded forms are the ripe, strongly ligneous specimens. It was not possible to differentiate species by macroscopic or microscopic studies. This is the first case when morphometrics as a tool was used to interpret the maturation process in Mesozoic seeds.

3. The outer surface emergences on *Nilssonia* seeds were proved to be the appearance of the unequal thickness of the sclerenchymatic layer based on cuticle studies and investigations of recent *Cycas revoluta* seeds. The former interpretation of representing resin bodies (HARRIS 1932) was refuted.

4. The macrosporophyll of *Dioonitocarpidium* was first described form Jurassic. Earlier it was known only from the Triassic (KUSTATSCHER et al. 2004; WACHTLER 2010). Based on former studies, the *Dioonitocarpidium* can be the reproductive organ of *Bjuvia* (WACHTLER 2010).

5. Not only the bennettite leaves are smaller in the Mecsek Coal Formation than the corresponding species in other localities (BARBACKA 2000) but the seeds also.

6. Based on morphological, cuticle and epidermis patterns, the occurrence of *Hirmeriella muensteri* was proved.

7. Based on the Mecsek samples the possibility of the inaccurate reconstruction (AXSMITH et al. 2004) of *Pseudohirmerella* was suggested. It is more probable that the cone are formed by ovuliferous dwarf shoots and not scales. However, the Hungarian material cannot be used as strong proof because their classification into *Pseudohirmerella* is doubtful.

8. Based on microscopic an SEM studies, the *Palissya* is a female organ contrary to the former pollen organ hypothesis (SCHWEITZER & KIRCHNER 1996). This is proved by the fan-like fingerprint pattern on the seeds which was only once depicted (NATHORST 1908). This character was later destroyed on the type material. The Mecsek specimen is the only sample of the species where this character can be studied according to our present knowledge. The surface pattern and the fact that pollen was never isolated from the cones (PARRIS 1995) confirm the female hypothesis of *Palissya sphenolepis*.

9. More differences were observed between the reconstruction of *Palissya* and the well preserved Mecsek material. There is no aril on the seeds based on SEM studies. There is no micropyle like structure on the adaxial surface of the seeds. On the abaxial surface an inhomogenity was observed that might represent the hylum. The presence of hylum is an additional proof for the female origin of the *Palissya sphenolepis* cones. Based on the Hungarian specimen,s the *Palissya* cones were loose and their structure is similar to the reconstruction of *Metridiostrobus palissyaeoides* (DELEVORYAS & HOPE 1981).

10. The presence of *Elatides* was proved in the macroflora by the presence of attached scones and shoots.

11. The angiosperm origin of *Schmeissneria* (WANG et al. 2010) was refuted based on the Mecsek material and the gymnosperm origin was reinforced.

12. The plant fossil containing rock types were identified and based on thin sections paired with sedimentary environments. These studies show that these rocks were formed in upland areas, floodplain units, lacustrine, swamp and fluvial environments. The information of the plant containing rocks were implemented with the petrological studies. These results agree the former geological knowledge.

13. One of the aims of this PhD was to compare the flora of the Mecsek Coal Formation to the other Jurassic floras of Europe. A complete database was formed based on the literal data (BARBACKA & BODOR et al. 2014) and a database was built on reproductive organs only and was completed with proper observations. General decrease in diversity was discovered during the Jurassic. This was explained by the decrease of the stable continental areas in Europe.

14. The autochton localities were grouped according to palaeoenvironmental point of view with multivariate analysis of European Jurassic floras. This way the palaeoenvironmental

conditions were estimated for the related allochton floras. Based on this analysis Stonesfield, Jura, Veneto, Sardinia and Solnhofen localities are more related to lagoon environment while Brent and Bearreraig are fluvial or deltaic.

15. Based on the whole flora analysis, the Mecsek Coal Formation is related to the other fluvial and deltaic localities independent of their age. Based on the reproductive organs the Mecsek is more related to the localities where gymnosperms are diverse and appear in high numbers.

Summary and conclusions

In the first part of the dissertation a detailed morphometrical method was developed which is not only suitable to define the morphotypes but also give the background factors playing the major role in classification. With this method, taxonomical variability as well as maturation stages can be recognised.

In the second part of the dissertation a detailed taxonomical description of the seeds and cones from the Mecsek Coal Formation is given. Some reproductive organs were identified from all higher gymnosperm groups. From the cycads seeds (*Nilssonia*), female cone (*Beania* sp.) and macrosporophyll (*Dioonitocarpidium* sp.) were determined and described. From the Bennettites (cf. *Bennetticarpus wettsteinii*) and ginkgoes (*Allicospermum* sp.), seeds were identified. From the conifers the Cheirolepidiaceae is represented by the ovuliferous dwarf shoots of *Hirmeriella muensteri* and cf. *Pseudohirmerella*. *Palissya sphenolepis* and *Sachyotaxus* cf. *septentrionalis* cones were described from the Palissyaceae which traditionally belongs to conifers although recent studies do not confirm this hypothesis. The Elatides sp. male cone and *Elatides williamsonii* female cone belongs to the sensu lato Cupressaceae. In the case of cones at *Pagiophyllum* shoot endings the taxonomical affinity was not determinable. The taxonomical affinity of *Schmeissneria* is debated.

In the third part the sedimentological and taphonomical observations were given about the most common plant containing rock types. Most of the cones were found in grey mudstone. This rock type most probably represent low energy environment. These fossils were preserved presumably in floodplain areas or in moderately wet canopies.

In the fourth part the flora and the plant reproductive organs of European Jurassic localities and the Mecsek Coal Formation was compared. Based on the whole flora analysis the Mecsek is in closest relation to the lower Jurassic fluvial - delta locality of Scoresby and clearly different from all lagoonal localities (BARBACKA & BODOR et al. 2014). Based on the analysis of the reproductive taxa, the palaeoenvironments cannot be distinguished. The Mecsek is closest to the late Jurassic Sutherland locality. At both areas more gymnosperm groups appear but none of

them is highly diverse. On the contrary, the reproductive organs of Bennettites is highly diverse in the Romanian Resita basin (POPA 2014).

Based on the results of the dissertation, the Mecsek Coal Formation is the fourth diverse Jurassic locality of Europe in plant reproductive organs.

Literature

AXSMITH , B. A. , ANDREWS F. M., FRASER N. C. 2004: The structure and phylogenetic significance of the conifer *Pseudohirmerella delawarensis* nov. comb. from the Upper Triassic of North America. — *Review of Palaeobotany and Palynology*, 129, 251–263

BARBACKA M. 2000: Bennettitales from the Mecsek Mountains Liassic, Hungary. — *Acta Palaeobot.*, 40 (2), 111–127.

BARBACKA M. 2011: Biodiversity and the reconstruction of Early Jurassic flora from the Mecsek Mountains (southern Hungary). — *Acta Palaeobot.*, 51(2), 127–179.

BARBACKA, M. & BÓKA, K. 2000: The stomatal ontogeny and structure of the Liassic pteridosperm Sagenopteris (Caytoniales) from Hungary. — *International Journal of Plant Sciences*, 161(1), 149–157.

BARBACKA, M. & BÓKA, K. 2014: Ovule–containing cupules belonging to the Early Jurassic pteridosperm, *Komlopteris nordenskioeldii* (Nathorst) Barbacka. — *Review of Palaeobotany and Palynology*, 210, 102–112.

BARBACKA M., BODOR E., JARZYNKA A., KUSTATSCHER E., PACYNA G., POPA M.E., SCANU G.G., THÉVENARD F., ZIAJA J. 2014: European Jurassic floras: statistics and paleoenvironmental proxies. — *Acta Palaeobot.*, 54(2), 173–195.

BODOR, E., KOVÁCS, J., VASILE, S., CSIKI–SAVA, Z., VÁCHOVÁ, Z. 2014: Fossil Insect eggs from the Maastrichtian of the Hateg Basin (Romania) – employment of morphometrics in taxonomical assessment. — *International Zoological Congress of „Grigore Antipa" Museum Abstract Book*. 148.

DELEVORYAS, T., & HOPE, R. C. 1981: More evidence for conifer diversity in the upper Triassic of North Carolina. — *American Journal of Botany*, 68, 1003–1007.

HARRIS T.M. 1932: The fossil flora of Scoresby Sound East Greenland, 2: Description of seed plants incertae sedis together with a discussion of certain Cycadophyte cuticles. — *Medd. Grønland*, 85, 1–114.

KUSTATSCHER, E., WACHTLER, M., VAN KONIJNENBURG – VAN CITTERT, J. H. A. 2004: A number of additional and revised taxa from the Ladinian Flora of the Dolomites, Northern Italy. — *Geo.Alp*, 1, 57-70.

NATHORST, A. G. 1908: Paläobotanische Mitteilungen 7. Über *Palissya*, *Stachyotaxus* und *Palaeotaxus*. — *Kungliga Svenska Vetenskapsakademiens Handlingar*, 43, 3–20.

PARRIS, K. M., DRINNAN, A. N., CANTRILL, D. J. 1995: *Palissya* cones from the Mesozoic of Australia and New Zealand. — *Alcheringa*, 19, 87–111.

PRONDVAI, E., BODOR, E. R., ÖSI, A. 2014: Does morphology reflect osteohistology–based ontogeny? A case study of Late Cretaceous pterosaur jaw symphyses from Hungary reveals hidden taxonomic diversity. — *Paleobiology*, 288–321.

POPA, M. E. 2014: Early Jurassic bennettitalean reproductive structures of Romania. — *Palaeobiodiversity and Palaeoenvironments*, 94(2), 327–362.

SCHWEITZER, H.J. & KIRCHNER, M., 1996. Die rhätojurassischen Floren des Iran und Afghanistan: 9. Coniferophyta. — *Palaeontographica*, *Abt. B.*, 238 (4/6), 77–139.

WACHTLER, M. 2010: About the origin of Cycads and some enigmatic Angiosperm–like fructifications from the Early–Middle Triassic (Anisian) Braies Dolomites (Northern Italy). — *Dolomythos*, 1, 3–55,

WANG, Xin 2010: *Schmeissneria*: An angiosperm from the Early Jurassic. — *Journal of Systematics and Evolution*, 48(5), 326–335.

List of publications related to the dissertation

BARBACKA M. & **BODOR**, E. R. 2008: Systematic and palaeoenvironmental investigations of fossil ferns *Cladophlebis* and *Todites* from the Liassic of Hungary. — *Acta Palaeobotanica*, 48(2), 133–149.

BARBACKA, M., POPA, M. E., MITKA, J., BODOR, E. R., PACYNA, G. in press: Relationships between ecosystems and plant assemblages as a response to different environmental conditions in Lower Jurassic of Hungary and Romania. — *Acta Palaeobotanica,* 55, xx-xx

BARBACKA, M., PACYNA, G., FELDMAN–OLSZEWSKA, A., ZIAJA, J., **BODOR** E. 2014: Triassic–Jurassic flora of Poland; floristical support of climatic changes. — *Acta Geologica Polonica*, 64(3), 281–309.

BARBACKA, M., PÜSPÖKI, Z., **BODOR**, E. R., FORGÁCS, Z., HÁMOR–VIDÓ, M., PACYNA, G., MCINTOSH R., W. bírálat alatt: Palaeotopography related plant succession stages in a coal forming deltaic succession and their role in comparative interpretations. — *Palaeogeography, Palaeoclimatology, Palaeoecology*

BARBACKA M., **BODOR** E., JARZYNKA A., KUSTATSCHER E., PACYNA G., POPA M.E., SCANU G.G., THÉVENARD F., ZIAJA J. 2014: European Jurassic floras: statistics and paleoenvironmental proxies. — *Acta Palaeobotanica*, 54(2), 173–195.

BODOR E. R. & BARBACKA, M. 2008: Taxonomic implications of Liassic ferns *Cladophlebis* Brongniart and *Todites* Seward from Hungary. — *Palaeoworld*, 17, 207–214.

BODOR E. R. & BARBACKA, M. 2012: The remarkable world of the ferns in the Mecsek Coal Formation with special focus on the genera *Todites* and *Cladophlebis* (SW Hungary). — *e–Acta Naturalia Pannonica*, 3, 1–10.

PRONDVAI, E., **BODOR**, E. R., ŐSI, A. 2014: Does morphology reflect osteohistology–based ontogeny? A case study of Late Cretaceous pterosaur jaw symphyses from Hungary reveals hidden taxonomic diversity. — *Paleobiology*. 288–321.

List of abstracts related to the dissertation

BARBACKA M., PÜSPÖKI Z., **BODOR** E. 2014: Geochemical and lithological proxies of deltaic coal forming facies and their relation to sequence stratigraphy and plant succession. — *9th European Palaeobotany – Palynology Conference Abstract Book*. 12.

BARBACKA, M., PACYNA G., PIENKOWSKI G., **BODOR** E., ZIAJA J., JARZYNKA A. 2014: Floristical changes and plant succession in the early–middle Jurassic localities of the northern margin of the Holy Cross Mountains, Poland. What did Polish dinosaurs like? — *9th European Palaeobotany – Palynology Conference Abstract Book*. 11.

BODOR, E. R. 2012. Cikászok reproduktív képletei a Mecseki Kőszén Formációból. — *15. Őslénytani Vándorgyűlés konferencia kivonatok*, 6–7.

BODOR E., BARBACKA M. 2014: Cheirolepidiaceae–related reproductive structures from the Jurassic Mecsek Coal Formation (Hungary). — *9th European Palaeobotany – Palynology Conference Abstract Book*. 21.

BODOR E., BARBACKA M. 2014: Cheirolepidiaceae szaporító képletek a Mecseki Kőszén Formációból. — *17. Magyar Őslénytani Vándorgyűlés konferencia kivonatok*, 8.

BODOR E., BARBACKA M. 2015: *Nilssonia*–félék reproduktív képletei a Mecseki Kőszén Formációból. — *18. Magyar Őslénytani Vándorgyűlés konferencia kivonatok*, 8.

BODOR E., BARBACKA M., PÜSPÖKI Z., FORGÁCS Z. 2014: A Mecseki Kőszén Formáció őskörnyezet rekonstrukciója paleobotanikai és szedimentológiai adatok alapján. — *17. Magyar Őslénytani Vándorgyűlés konferencia kivonatok*, 8–9.

BODOR, E., KOVÁCS, J., VASILE, S., CSIKI–SAVA, Z., VÁCHOVÁ, Z. 2014: Fossil Insect eggs from the Maastrichtian of the Hateg Basin (Romania) – employment of morphometrics in taxonomical assessment. — *International Zoological Congress of „Grigore Antipa" Museum Abstract Book*. 148.

Popular science related to the dissertation

BODOR E. R. 2011. Mecseki páfránymaradványok csodálatos világa. — *Természet Világa*, 143(1), 18–22.