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Review of the late Westphalian – early Stephanian macrofloras of the Dobrudzha Coalfield, Bulgaria

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Кристофер Клил, Янаки Тенчов, Ирвин Зодроу — Обзор поздневестфальской — раннестефанской макрофлоры Добруджанского каменноугольного бассейна, Северо-Восточная Болгария. Макрофлора позднего вестфала — раннего стефана в Добруджанском каменноугольном бассейне имеет ряд общих особенностей с современными сообществами Южной Англии и Канадских прибрежных районов, но в них устанавливаются также некоторые таксоны, которые нормально ассоциируются с флорой более высоко расположенных бассейнов как Саарско-Лотарингский и Центрально-богемский. Эти данные хорошо согласуются с фактом, что Добруджанский бассейн находился на окраине варисийского форланда, хотя может быть он и был расположен сравнительно выше других, более западных каменноугольных бассейнов. Оказалось, что в нем можно провести те основные биозональные границы, которые были первоначально установлены и в Западной Европе, и в Северной Америке. *Laveineopteris garinervis* подзона проходит в углях m_5 Македонской свиты. Основа зоны *Linopteris bunburii* (т.е. основа вестфала D) находится в углях n_3 Крупенской свиты. Подзона *Lobatopteris micromiltoni* видимо отсутствует в связи с нарушением седиментационной последовательности, но подзона *Dicksonites plueckenetii* выявлена в Гурковской свите. Данные о наличии зоны *Odonopteris cantabrica* (граница вестфала и стефана) находятся в углях p_7 — в верхних отделах Гурковской свиты.

Abstract. The late Westphalian – early Stephanian macrofloras of the Dobrudzha Coalfield show many similarities with the contemporaneous lowland assemblages from southern Britain and the Canadian Maritimes, but there are also present some taxa normally associated with more upland basins such as Saar-Lorraine and Central Bohemia. This is in agreement with the Dobrudzha Coalfield occupying a marginal position on the Variscan Foreland, perhaps at higher altitudes than the more western coalfields. It has been possible to identify the main biozonal boundaries that were originally established in western Europe and eastern North America. The base of the *Laveineopteris garinervis* Subzone occurs at coal m_5 in the Makedonka Formation. The base of the *Linopteris bunburii* Zone (indicating the base of the Westphalian D Stage) is at coal n_3 in the Krupen Formation. The *Lobatopteris micromiltoni* Subzone seems to be absent due to a non-sequence, but the *Dicksonites plueckenetii* Subzone is in the Gurkovo Formation. Evidence of the *Odonopteris cantabrica* Zone (indicating the Westphalian – Stephanian boundary) occurs at coal p_7 in the upper Gurkovo Formation.

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Key words: Bulgaria, Dobrudzha Carboniferous, macroflora, floristics, biostratigraphy.

Introduction

The Dobrudzha Coalfield in northeastern Bulgaria (Fig. 1) has a succession spanning most of the Westphalian Series. There is no surface exposure nor has there been any underground working that could provide access to these strata; our knowledge of these deposits stems exclusively from a series of boreholes drilled during the 1960s (Nikolov, 1988). It might be expected, therefore, that our knowledge of the palaeobotany of this coalfield would be limited. However, the large number of boreholes drilled, and the fact that they were cored and sampled has meant that there is in fact a very detailed plant-fossil record for the coalfield. This record was reviewed by Tenchov (in Spassov et al., 1978; in Nikolov, 1988) and there have been studies on specific plant group from here (Tenchov, 1987; Tenchov and Popov, 1987a, 1987b, 1991).

The present paper represents a summary of the Dobrudzha Coalfield macrofloras from the upper part of the succession. It is a result of a collaborative study between the three authors, as part of a wider investigation into vegetation change across the Variscan Foreland during the late Westphalian Epoch (Cleal et al., 2002). It is not intended to be a detailed monograph of the flora; systematic revisions of particular groups will be published separately. It also does not deal with the entire macroflora, being restricted to pteridosperm, marattialean- and tedelacean-fern, and sphenophyll foliage (a paper reviewing the Do-

brudzha lycophytes by Thomas and Tenchov is given elsewhere in this volume). Our aim is to provide a summary of the biodiversity and distribution of the those parts of the macrofloras that are most useful for biostratigraphical and floristic analysis. It will address two problems in particular: (1) do the macrofloras give any support to the idea that the Dobrudzha Coalfield was formed on an eastern extension of the Variscan Foreland; and (2) can the macrofloras be assigned to similar biozones to those used in western Europe and eastern North America?

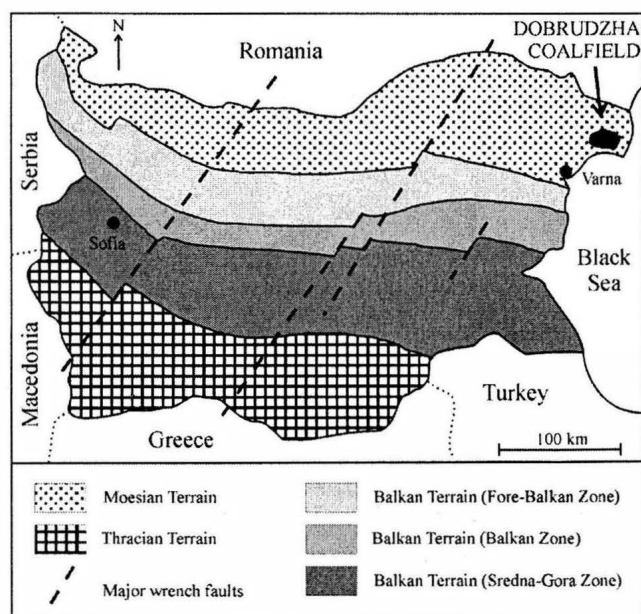


Fig. 1. Position of the Dobrudzha Coalfield within the main palaeogeographical units in Bulgaria

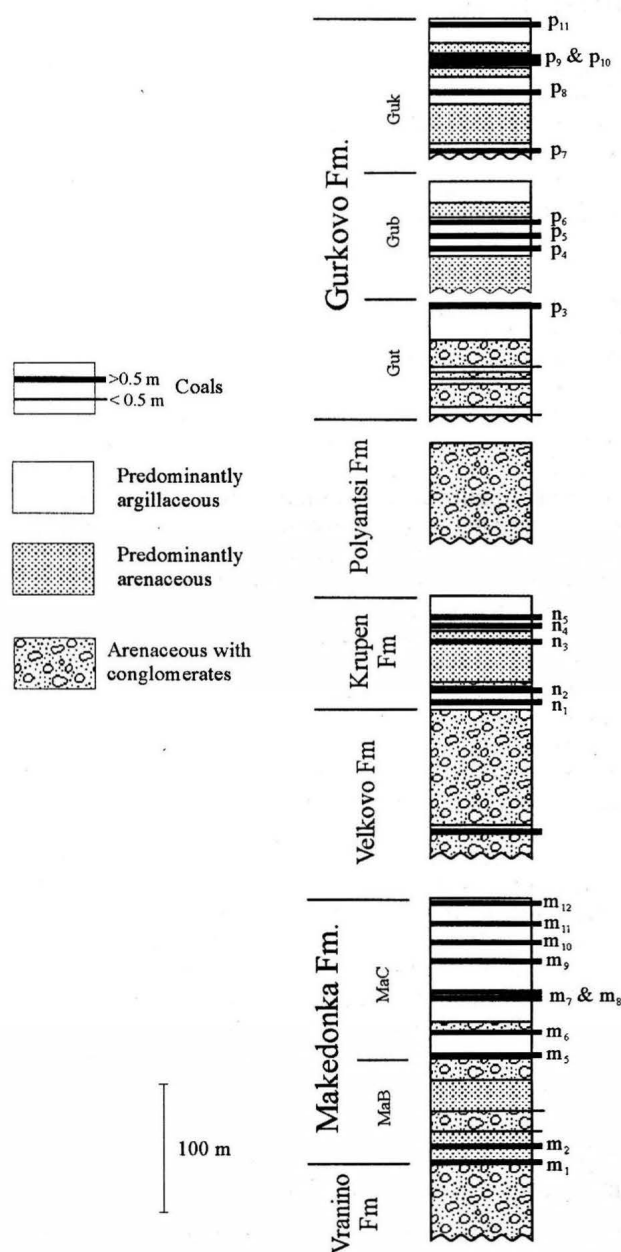


Fig. 2. Lithostratigraphical subdivisions of the upper part of the Dobrudzha Coalfield succession, based partly on data from Tenchov and Kulaksuzov (1972)

Stratigraphical context

The lithostratigraphical classification of the Dobrudzha Coalfield developed by Tenchov and Kulaksuzov (1972) remains in use today. This divided the sequence into four coal-bearing intervals (in ascending order, the Mogilishte, Makedonka, Krupen and Gurkovo Formation) separated by arenaceous barren intervals (the Vranino, Velkovo and Polyantsi Formations). The Mogilishte, Makedonka and Gurkovo Formations are each divided into two or three members (Fig. 2). This paper deals with that part of the succession upwards from the upper Makedonka Formation (MaC Member).

Review of macrofloras

Table 1 gives a list of the pteridosperm, marattialean- and tedelacean-fern and sphenophyll foliage species that we have recognised in the upper part of the Dobrudzha sequence. The following comments on certain of the species are not meant to be comprehensive, but merely clarifications of some of the records.

Neuropteris ex group obliqua (Brongniart) Zeiller

We here include the complex of morphospecies *Neuropteris obliqua* (Brongniart) Zeiller, *N. parvifolia* Stockmans, *N. semireticulata* Josten and *Reticulopteris muensteri* (Eichwald) Gothan. These are widely recognised to represent closely related forms, probably belonging to the same biological species (Josten, 1962; Tenchov and Popov, 1991).

Neuropteris resobae Cleal

Laveineopteris tenuifolia (Sternberg) Cleal et al. is comparatively rare in the Dobrudzha macrofloras, with only a few isolated fragments occurring in the upper Makedonka Formation. However, there are other specimens in the Makedonka Formation that have similar-shaped pinnules to *L. tenuifolia*, but with a venation that is quite different, being much denser and more oblique to the pinnule margin. These bear a striking resemblance to *Neuropteris resobae* Cleal, 1981, which has hitherto only been reported from the middle Westphalian of Palencia. Despite their resemblance to *L. tenuifolia* in pinnule shape, there was an absence of cyclopterids associated with the Spanish types and so Cleal and Shute (1995) retained the species within *Neuropteris*.

Laveineopteris nicolausiana (Gothan) Cleal and Shute

Laveineopteris rarinervis (Bunbury) Cleal et al. occurs abundantly in the Makedonka and Krupen Formations, and occasionally in the Gurkovo Formation. The specimens include both pinnate foliage with pinnules showing the characteristic shape and venation, and cyclopterid leaves. Also in the Ma are examples of pinnate foliage with similar-shaped pinnules, but with a venation that is less widely forking and more oblique to the pinnule margin. They compare closely with the specimens found in the upper Duckmantian and lower Bolsovian of Saar-Lorraine, Upper Silesia and Central Bohemia that has been variously identified as *L. nicolausiana* (Gothan) Cleal and Shute and '*Neuropteris*' *bohemica* Ettingshausen.

Alethopteris lonchitica Sternberg

We interpret this species in the same sense as Zodrow and Cleal (1998) to include the pinnule morphotypes known as *A. densinervosa* Wagner, *A. westphalensis* Wagner, *A. lonchitifolia* Bertrand and *A. missouriensis* White.

Alethopteris pseudograndinioides Zodrow and Cleal

This species is very rare in Dobrudzha and the type variety, normally found in the middle and late Westphalian D, is absent. Only the Cantabrian variety (var. *subzeilleri*) has been seen, in the upper Gurkovo Formation.

Mariopteris carnosa Corsin

This species is characterised by very triangular pinnules, often with an apical prolongation, and with a coarse venation somewhat reminiscent of *M. nervosa* (Brongniart) Zeiller. Boersma (1972) regarded these two species as conspecific, interpreting the more triangular aspect of the pinnules to enrolment of the margin. However, the Dobrudzha specimens do not appear to have enrolled margins, and in our view they represent quite distinct species. There are some specimens found in the Dobrudzha Coalfield that are more typical of *Mariopteris nervosa* (Brongniart) Zeiller, but they are relatively rare.

'*Mariopteris*' *sarana* Huth

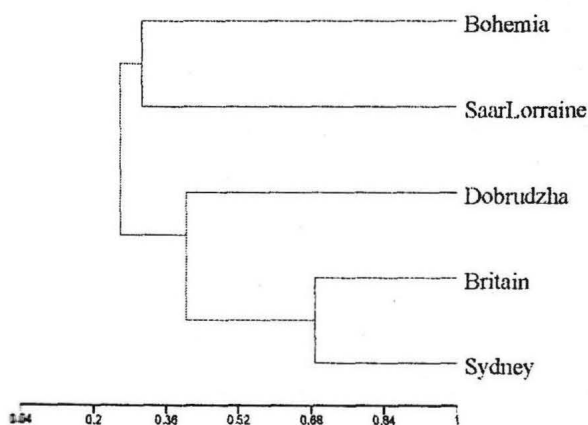
This species occurs mostly in the Krupen Formation. They have sphenopteroid pinnules often with a dentate margin, which compare closely with Corsin's (1932) originals. They are quite different from *Fortopteris latifolia* (Brongniart) Boersma (syn. *Mariopteris leharlei* Corsin) which has more ovate pinnules. One of the Do-

Table 1

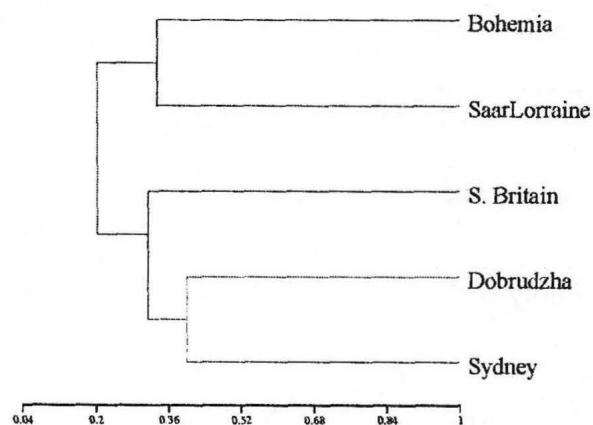
Species of pteridosperm, marattialean fern and sphenophylls present in the upper part of the Dobrudzha Coalfield sequence

Taxa	MaC/lower Krupen Fm	Upper Krupen Fm	Gurkovo Fm
<i>Alethopteris lonchitica</i> Sternberg	X	X	X
<i>Alethopteris</i> aff. <i>distantinervosa</i> Wagner	X		
<i>Alethopteris ambigua</i> Lesquereux			X
<i>Alethopteris pseudograndinioides</i> Zoderow and Cleal			X
<i>Lonchopteris silesica</i> Gothan	X		
<i>Lonchopteridium karvinensis</i> Purkyňová	X		
<i>Neuropteris ovata</i> Hoffmann		X	X
<i>Neuropteris</i> ex gr. <i>obliqua</i> (Brongniart) Zeiller		X	X
<i>Neuropteris resobae</i> Cleal	X		X
<i>Macroneuropteris scheuchzeri</i> (Hoffmann) Cleal et al.	X	X	X
<i>Odontopteris brardii</i> Brongniart			X
<i>Laveineopteris rarinervis</i> (Bunbury) Cleal et al.	X	X	X
<i>Laveineopteris nicolausiana</i> Cleal and Shute	X		
<i>Laveineopteris loshii</i> (Brongniart) Cleal et al.	X		
<i>Laveineopteris tenuifolia</i> (Sternberg) Cleal et al.	X		
<i>Callipteridium armasii</i> (Zeiller) Wagner			X
<i>Paripteris gigantea</i> (Sternberg) Gothan	X	X	X
<i>Paripteris schuetzii</i> (Potonié) Daber	X	X	X
<i>Paripteris pseudogigantea</i> (Potonié) Gothan	X		X
<i>Linopteris brongniartii</i> (Gutbier) Potonié	X	X	X
<i>Linopteris neuropteroides</i> (Gutbier) Zeiller	X	X	X
<i>Linopteris neuropteroides</i> var. <i>minor</i> Bertrand	X	X	X
<i>Linopteris havlenai</i> Tenchov	X	X	X
<i>Mariopteris muricata</i> (Brongniart) Zeiller	X		
<i>Mariopteris nervosa</i> (Brongniart) Zeiller	X	X	X
<i>Mariopteris carnosa</i> Corsin	X		X
<i>Mariopteris sarana</i> Huth	X	X	
<i>Eusphenopteris neuropteroides</i> (Boulay) Novik	X		
<i>Eusphenopteris striata</i> (Gothan) Novik	X		
<i>Eusphenopteris trigonophylla</i> (Artis) Novik	X		
<i>Eusphenopteris obtusiloba</i> (Brongniart) Novik	X		
<i>Eusphenopteris nummularia</i> (Gutbier) Novik	X		
<i>Dicksonites plueckenetii</i> (Sternberg) Sterzel			X
<i>Senftenbergia plumosa</i> (Artis) Stur	X	X	X
<i>Pecopteris</i> cf. <i>huchetii</i> Corsin	X	X	X
<i>Lobopteris micromiltoni</i> (Corsin) Wagner		X	X
<i>Lobopteris vestita</i> (Lesquereux) Wagner			X
<i>Acitheca polymorpha</i> (Brongniart) Schimper			X
<i>Ptychocarpus unitus</i> (Brongniart) Zeiller		X	X
<i>Sphenophyllum majus</i> (Bronn) Bronn	X		
<i>Sphenophyllum emarginatum</i> Brongniart	X	X	X
<i>Sphenophyllum cuneifolium</i> Crépin	X	X	X
<i>Sphenophyllum zwickaviense</i> Storch	X	X	X
<i>Sphenophyllum saarensense</i> Remy	X	X	X
<i>Sphenophyllum</i> cf. <i>saxonicum</i> Remy and Remy			X
<i>Sphenophyllum costae</i> Sterzel			X
<i>Sphenophyllum oblongifolium</i> (Germar and Kaulfuss) Unger			X

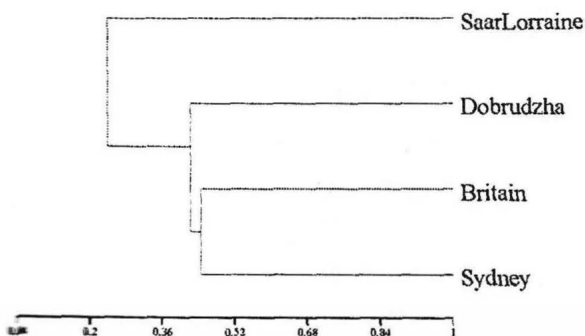
Medullosales - upper Westphalian D/
lower Cantabrian



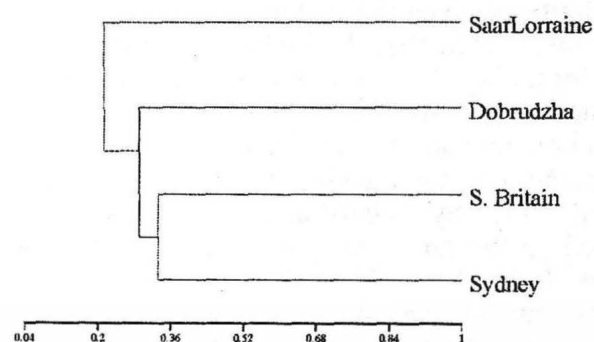
Lagenostomales - upper Westphalian D/
lower Cantabrian



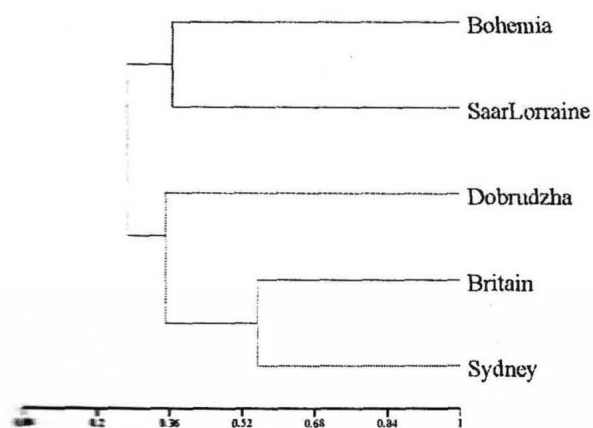
Medullosales - lower Westphalian D



Lagenostomales - lower Westphalian D



Medullosales - Bolsovian



Lagenostomales - Bolsovian

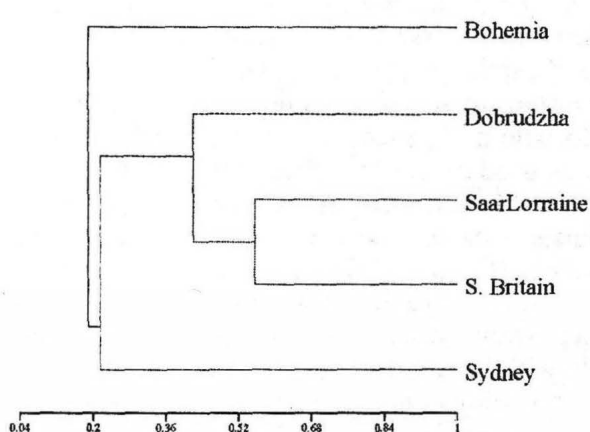


Fig. 3. Relationship of the Dobrudzha Coalfield succession with the coalfields of the lowland Variscan Foreland (Sydney Coalfield and Southern Britain) and upland basins of the Variscan Mountains (Saar-Lorraine and Central Bohemia). For details of the cluster analyses, see text

brudzha Coalfield specimens shows what appears to be the proximal part of a small frond that, with a 'K'-type architecture but with no transverse bars on the rachis.

Pecopteris huchetii Corsin

This is the most widespread marattialean fern in the Makedonka Formation. It is characterised by ultimate pinnae with a gradually tapered apical part, and bearing robust, dentate, slightly oblique pinnules with once forked veins. These compare reasonably well with Corsin's (1951) figures of *Pecopteris huchetii* Corsin.

Floristic analysis of Dobrudzha macrofloras

In the original study on which this paper is based (Cleal et al., 2002) a comparison was made between the macrofloras of the Dobrudzha, British and Sydney Coalfields. This revealed a broad similarity between the assemblages, giving support to the idea that the Dobrudzha succession was formed on the Variscan Foreland. However, to improve the analysis, we have now added data from intramontane basins of Saar-Lorraine (based on species listed in Laveine, 1989, and on unpublished work by Cleal) and central Bohemia (based on the range chart given by Šimůnek in Pešek, 1994).

The medullosaleans and lagenostomaleans were analysed separately. The ferns and sphenophylls were not investigated as we were not as confident about the biodiversity of these groups from the two intra-montane basins. The analyses were done on presence/absence matrices for the species. Three different sets of analysis were performed, on the assemblages from the Bolsovian, lower Westphalian D, and upper Westphalian D/Cantabrian, to see if any chronological trend in the floristic differences could be identified. The analysis used Jaccard Coefficients, which tend to be preferable for this type of work as it gives no emphasis to cases where a species is absent from both areas (Cleal and Shute, 1995). The clustering was done using the Unweighted Paired Group Average strategy, which tends to give preferable results with binary data sets.

The resulting dendrograms are shown in Fig. 3. Five out of the six analyses show the same general pattern, with the Dobrudzha, British and Sydney floras clustering together, and distinct from the intramontane Saar-Lorraine and Bohemian floras. In all three medullosalean analyses, the Dobrudzha floras appear to occupy an intermediate position between the lowland floras of Britain and Sydney, and the two intramontane basins.

This seems to be the result of the presence in the Dobrudzha floras of some taxa that are more typically found in the upland basins (e.g. *Alethopteris* aff. *distantnervosa*, *Laveineopteris nicolausiana*, *Linopteris neuropteroides* var. *minor*) associated with assemblages that are otherwise more comparable with those of the lowlands. The analyses of the Lagenostomales also mostly show the same clustering of Dobrudzha, Britain and Sydney, although the detailed structure of the cluster is not always the same. The Bolsovian analysis for the Lagenostomales is the only notable exception for this general pattern, which is probably due to the very low diversity of the order in Sydney.

This floristic analysis thus seems to confirm that the Dobrudzha floras are more closely related to those of the Variscan Foreland than to the upland intramontane floras. There are nevertheless some 'upland' elements in the Dobrudzha floras suggesting that this was a marginal part of the Foreland, occupying somewhat higher elevations to the British and Sydney Coalfields. This would be in agreement with the total absence of marine influence in Dobrudzha, even in the Bolsovian where several marine bands occur in western Europe. It is likely that the Dobrudzha floras are closest in affinity to those of Upper Silesian, which also probably occupied somewhat elevated parts of the Variscan Foreland, but this will need to be confirmed by a more detailed comparative analysis.

Biostratigraphy

As the Dobrudzha floras show greatest affinities with the Variscan Foreland floras of western Europe, it should be possible to identify the macrofloral zones established there by Wagner (1984) and subsequently modified by Cleal (1991) and Cleal and Thomas (1994). The ranges of the biostratigraphically most important taxa have been plotted in Fig. 4.

Paripteris linguaefolia Zone

At about the junction between the MaB and MaC members of the Makedonka Formation (m₅ Seam) there is a marked change in the macrofloras, with the appearances of *Sphenophyllum emarginatum*, *Macroneuropteris scheuchzeri*, *Reticulopteris muensteri*, *Laveineopteris rarineris* and *Alethopteris distantnervosa*. This clearly corresponds to the boundary between the *Neuropteris semireticulata* and *Laveineopteris rarineris* Subzones of the *P. linguaefolia* Zone recognised by Cleal (1991) and Cleal and Thomas (1994). This major change in macrofloras has been widely recognised throughout Europe

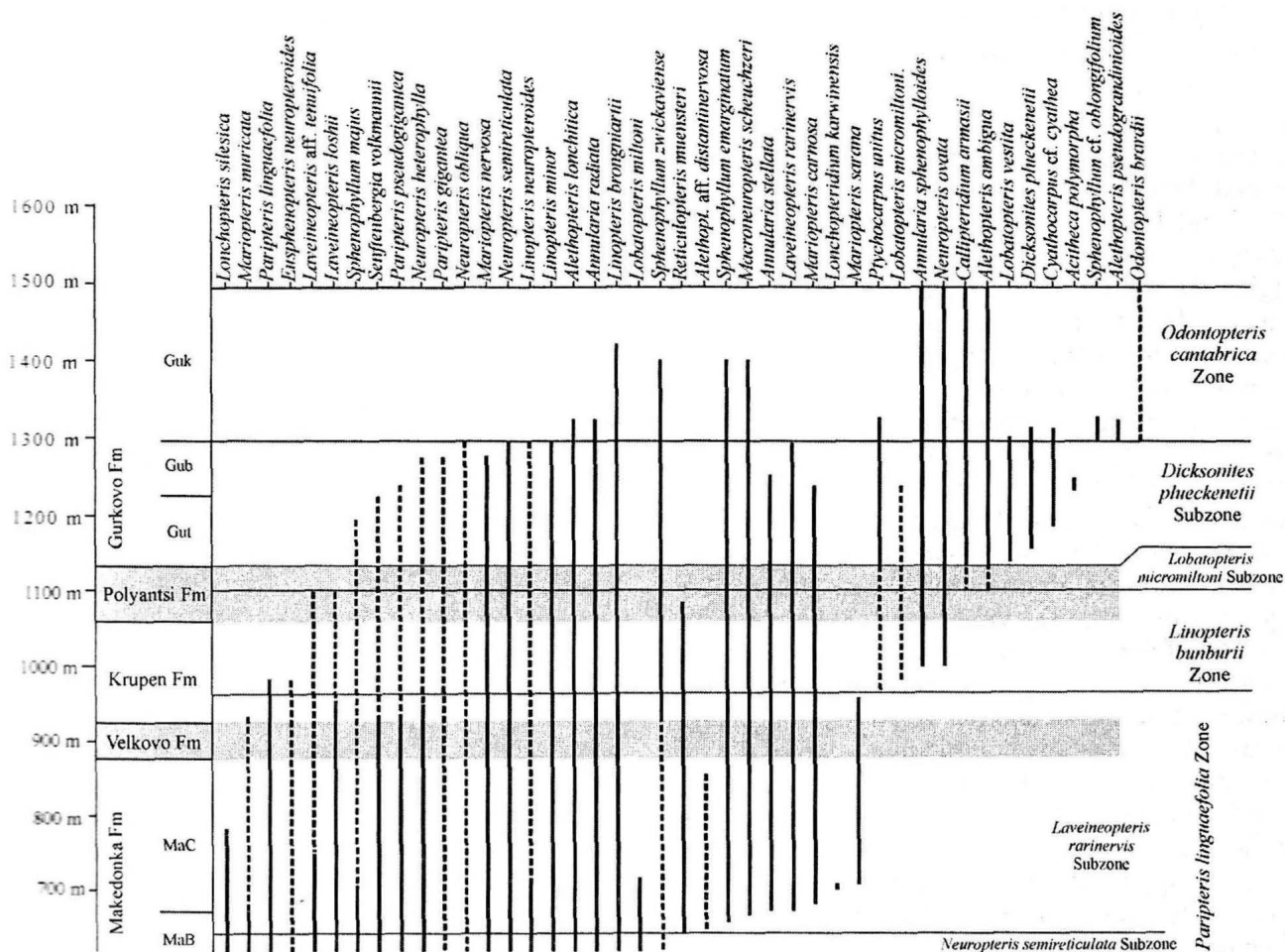


Fig. 4. Macrofloral range chart for the upper Westphalian – lower Stephanian part of the Dobrudzha Coalfield succession, showing the proposed positions of the main biostratigraphical boundaries

and is regarded as an index for the middle Bolsovian Stage.

Although there is no obvious evidence of a non-sequence, the macrofloras from below the m_5 Seam seem to be late Duckmantian in age. This may be because the thick m_5 Seam represents a significant time-span, which swallows the *N. semireticulata* Subzone. Alternatively, the western European biostratigraphy may not fit so well into this eastern European floral sequence.

Linopteris bunburii Zone

This zone is principally marked by the appearance of *Neuropteris ovata* Hoffmann, although Laveine (1977) has shown that there are other macrofloral and palynological changes at about this level, which can help with its identification. The biohorizon has been extensively studied and has been identified in the upper South Bar Formation in Cape Breton (Zodrow and Cleal, 1985), the Rhondda Member in South Wales (Cleal, 1978), the base of the Faisceau de Du Souiche in Nord-Pas-de-Calais (Laveine, 1977), the Luisenthaler Schichten/Faisceau de Pettite-

Rousselle in Saar-Lorraine (Laveine, 1977; Cleal 1984), and the Central Asturian Coalfield (Wagner and Alvarez-Vázquez, 1991). In the Dobrudzha sequence, this biohorizon is placed at the n_3 coal in the middle Krupen Formation, where *Lobatopteris micromiltoni* and '*Pecopteris*' *unita* have their stratigraphically lowest occurrences. *N. ovata* occurs a little higher in the sequence at the n_4 coal, but this is of doubtful significance as this species is often rare low in the zone (Thomas and Cleal, 2001).

Laveine (1977) noted that *Paripteris* disappears and *Annularia stellata* appears a short distance below the biohorizon at the base of the *L. obliqua* Zone. The distribution of *Paripteris* broadly corroborates this view; except for some rare examples from the Gurkovo Formation, the stratigraphically highest specimens are from the lower Krupen Formation, about 20 m below the n_3 coal. However, *A. stellata* first appears significantly lower in the Dobrudzha sequence, down to near the base of the MaC Member, but only rarely.

Lobopteris vestita Zone

The base of this zone is marked by the appearances of *Alethopteris ambigua*, *A. pseudograndinoides* and *Callipteridium armasii*, and marked increase in abundance of *Lobopteris micromiltoni* and *Ptychocarpus unitus*. Cleal (1991) and Cleal and Thomas (1994) divided this zone into a lower *Lobopteris micromiltoni* Subzone and a higher *Dicksonites plueckenetii* Subzone. The base of the upper subzone is marked by the appearances of *Dicksonites plueckenetii*, *Acitheca polymorpha* and *Lobopteris vestita*. These intervals have been recognised in Cape Breton (Zodrow and Cleal, 1995), South Wales (Cleal, 1978), Saar-Lorraine (Cleal, 1984) and Central Asturias (Wagner and Alvarez-Vázquez, 1991).

L. vestita and *D. plueckenetii* both appear in the lower Gurkovo Formation, which thus probably belongs to the *D. plueckenetii* Subzone. The position of the Polyantsi Formation is less easy to determine as it unconformably underlies the Gurkovo Formation and has relative poor macrofloras. However, it is notable that none of the index species to the *D. plueckenetii* range down into the Polyantsi Formation. Furthermore, two of the indexes to the base of the *L. micromiltoni* Subzone appear in the middle Polyantsi Formation, suggesting perhaps that the base of that subzone occurs within the formation. This is apparently supported by the palynofloras, as the base of the *Thymospora obscura* Zone, which normally coincides with the base of the *L. micromiltoni* macrofloral subzone, occurs in the middle Polyantsi Formation.

Odontopteris cantabrica Zone

Except in northern Spain, the base of this zone is never particularly well marked (Cleal et al., 2003) and the Dobrudzha sequence is no exception in this. However, the stratigraphically lowest occurrences of rare *Odontopteris brardii* and *Sphenophyllum* cf. *oblongifolium* indicate that the base of the *O. cantabrica* Zone occurs at about the base of the Guk Member (upper Gurkovo Formation).

Chronostratigraphical correlations

Based on this biostratigraphical analysis of the macrofloras, we propose the following chronostratigraphical correlations (Fig. 5).

1. The base of the Bolsovian Stage is at base of the m_5 seam, which divided the Makedonka Formation into MaB and MaC Members.
2. The roof shales of m_5 seam are middle Bolsovian in age. This level is equivalent to the major change in both floras and faunas recog-

Series	Stages	Macrofloras	Palynofloras	Formations/ Members
Stephanian	Cantabrian	<i>O. cantabrica</i>	<i>S. spinosus</i>	Guk
Westphalian	Westphalian D	<i>D. plueckenetii</i>	<i>T. obscura</i>	Gub
		<i>L. micromiltoni</i>		Gut
		<i>L. bunburii</i>	<i>V. laevigata</i>	Polyantsi Fm
	Bolsovian	<i>L. varinervis</i>	<i>T. securis</i> (upper subzone)	Krupen Fm
		<i>H. semireticulata</i>	<i>T. securis</i> (lower subzone)	Velkovo Fm
Duckmantian	Duckmantian	<i>S. majus</i>	<i>F. junior</i>	Makedonka Fm
				Vranino Fm

Fig. 5. Proposed correlation between the upper part of the Dobrudzha Coalfield succession and the series and stages of the Heerlen chronostratigraphical scheme. Palynological evidence provided by T. Kh. Dimitrova (pers. com.)

nised by Dix and Trueman (1937) as marking a fundamental division of what we now call the Westphalian Series, and which they referred to as the Amanian and Morganian Stage boundary.

3. The base of the Westphalian D Stage is at the top of the n_3 seam in the Krupen Formation.
4. If we use the informal division of the Westphalian D Stage based on the three macrofloral divisions recognised by Cleal (1991), the upper Krupen and lower Polyantsi Formations are early Westphalian D in age, the upper Polyantsi Formation middle Westphalian D in age, and the lower Gurkovo Formation (Gut and Gub Members) upper Westphalian D in age.
5. The base of the Cantabrian Stage (and therefore of the Stephanian Series) is at about p_3 seam, at the base of the Guk Member.

Conclusions

Notable features of the Dobrudzha Coalfield macrofloras are that there is a high biodiversity of potonieacean Medullosales (*Paripteris*, *Linopteris*) and the species are often longer ranging than in most other areas; sphenophylls are also diverse; but the marattialean ferns appear to be relatively rare and of low diversity, at least in the

Bolsovian. On the whole, however, the Dobrudzha macrofloras are essentially similar to those of Britain and the Canadian Maritimes, and help corroborate the idea that it was formed on an eastern extension of the Variscan Foreland that has been subsequently become separated by the Carpathian Arc. The pteridosperms in particular show close similarities, although there are some 'intramontane' elements present in Dobrudzha. This indicates that the Dobrudzha Coal Basin was formed on the margin of the Foreland, at somewhat higher elevations to the British and Canadian basins, but not so high as Saar-Lorraine or Central Bohemia.

The standard macrofloral biozones developed mainly in western Europe have been identified in Dobrudzha, and can help locate the bases of the Bolsovian, Westphalian D and Cantabrian Stages. These correlations indicate that none of the stratigraphical hiatuses in the sequence represent significant time-intervals. On the other hand, although the Dobrudzha succession is dominated by arenaceous deposits that would have been rapidly deposited, it is only one-fifth of the thickness of the time-equivalent succession in South Wales. Clearly, some time is missing from the clastic part of the Dobrudzha succession, perhaps hidden in the very thick coal seams that occur at several levels.

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