

Miospore associations as indicators of the origin of coal seams in the Intrasudetic Basin (southwest Poland)

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ABSTRACT – Palynological profiles of coal seams of the Żacler Formation (Westphalian A) in the Intrasudetic Basin (southwest Poland) have been studied. Two palynological assemblages are recognizable in profiles of seam 430 in the northwestern part of the basin. In the first, very monotonous assemblage, *Lycospora* exceeds 60%. The second, much more diverse assemblage includes as its main components *Lycospora*, *Calamospora*, *Cyclogranisporites*, *Savitrissporites*, *Raistrickia*, and *Lophotriletes*. In the first assemblage, the abundance of *Lycospora* reflects a vegetation composed of arborescent lycopsids. The second assemblage reflects a mixed plant community, including arborescent lycopsids, calamitaleans (sphenopsids), and ferns. Seams 409 and 412/413 in the southeastern part of the Lower Silesian Coal Basin host quite different miospore assemblages with *Densosporites* and related crassicingulate genera being the main components. They were produced by herbaceous and/or sub-arborescent lycopsids. These coal palynological assemblages enable recognition of three distinct floral associations: the arborescent lycopsids and mixed associations, occurring in seam 430; and the herbaceous and/or sub-arborescent lycopsid association of seams 409 and 412/413. Coals representing the first two associations are believed to have been deposited in conditions of planar rheotrophic mire; the herbaceous and/or sub-arborescent lycopsid association developed in an ombrotrophic domed mire situation.

RIASSUNTO – [Associazioni di miospore, come indicatori della genesi di letti carboniferi nel Bacino Intrasudetico (Polonia sudoccidentale)] – Sono stati studiati alcuni profili palinologici di letti carboniferi della Formazione di Żacler (Westfaliano A) del Bacino Intrasudetico (Polonia sudoccidentale). Due diversi tipi di associazioni palinologiche sono stati riconosciuti nel profilo del letto 430, nella parte nordoccidentale del bacino. Il primo tipo di associazione è assai monotono e la percentuale di *Lycospora* supera il 60%. Il secondo tipo di associazione è molto più diversificato ed i suoi principali componenti sono *Lycospora*, *Calamospora*, *Cyclogranisporites*, *Savitrissporites*, *Raistrickia* e *Lophotriletes*. Nella prima associazione, l'abbondanza di *Lycospora* riflette una vegetazione composta da licopsidi arborescenti, mentre l'associazione diversificata della seconda associazione è connessa con una comunità paleofitologica mista con licopsidi arborescenti, calamitidi (sphenopsidi) e felci. I letti 409 e 412/413 della parte sudorientale del Bacino carbonifero della Bassa Slesia contengono una associazione palinologica assai diversa, con dominanti *Densosporites* e correlati generi crassicingulati. Queste associazioni sono state prodotte da licopsidi erbacei e/o sub-arborescenti. Queste associazioni palinologiche dei letti carboniferi sono la base per distinguere tre tipi di associazioni paleofloristiche: associazioni a licopsidi arborescenti e associazioni miste che si trovano nel letto 430; associazioni erbacee e/o sub-arborescenti, trovate nei letti 409 e 412/413. I carboni che rappresentano la prima di queste associazioni si sono depositi in ambiente di palude reotrofica, mentre quelli della associazione a licopsidi erbacei e/o sub-arborescenti si sono sviluppati nella parte centrale di una ampia palude ombrotrofica.

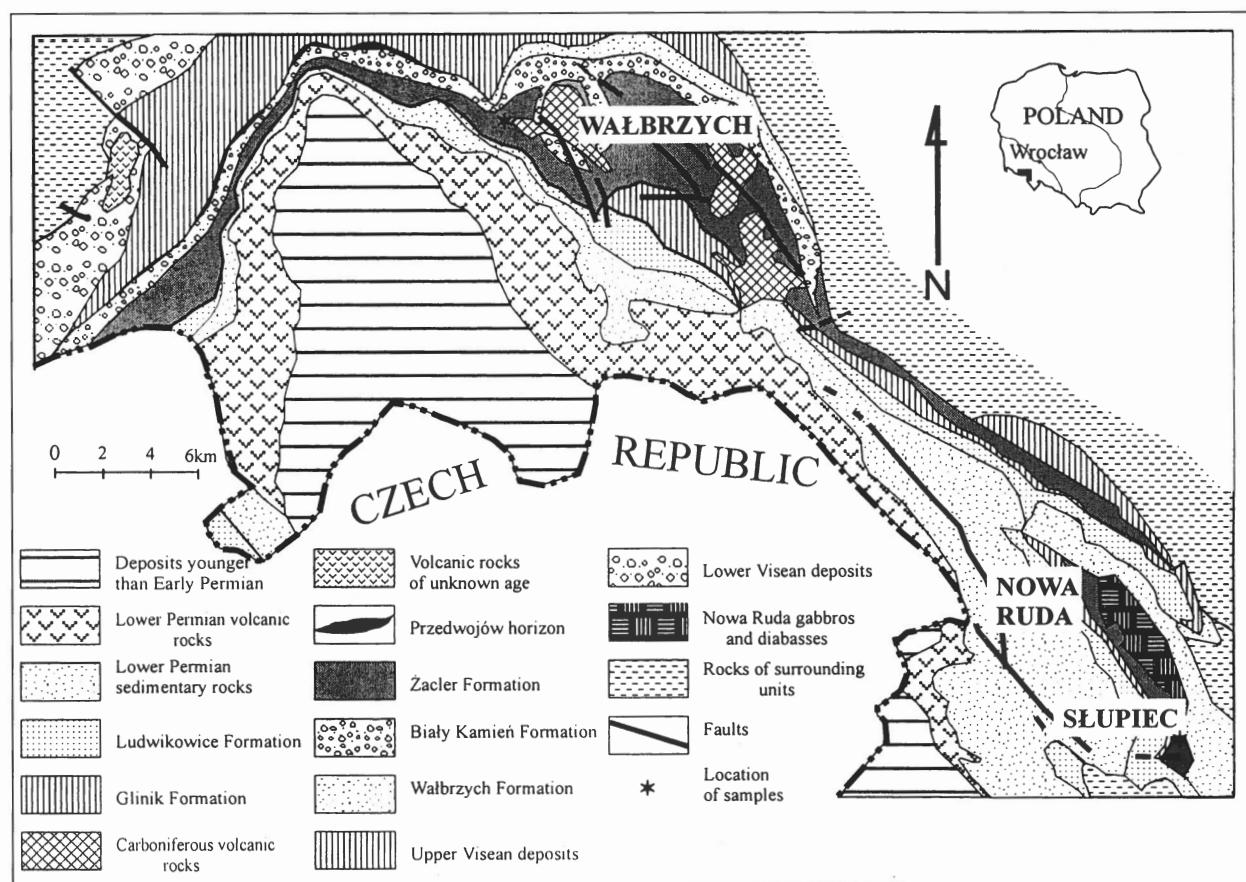
INTRODUCTION

Peat is generally considered as precursor material for coal. Palaeopeat-forming environments are commonly characterized in such terms as swamp, bog, mire, moor, or marsh. Moore (1987) defined major categories of peat-forming systems; the most general term he used was mire. Moore's classification of mire types was based largely on hydrology, especially the source of water and ionic composition and concentration. Rheotrophic mires mostly receive recharge from both ground water and rainfall. In contrast, ombrotrophic mires are solely rain-fed. For the ombrotrophic type, Moore (1987) adopted the term bog; rheotrophic mires were divided into fens and swamps, depending on the range of flooding with respect to the mire surface. Marshes are another type of rheotrophic mire in which peat accumulation is minimal or absent. In this study, mire (or palaeomire) is

used to denote peat-forming environments in the Intrasudetic Basin.

Many palaeodepositional models of coal formation have been described in the literature (e.g., Stach *et al.*, 1982; McCabe, 1984, 1987; Diessel, 1992; Di Michele & Phillips, 1994) and different methods for the reconstruction of the original environmental conditions have also been used. Coal petrography, palynology, palaeobotany, and organic geochemical studies are usually applied in defining the features of a coal depositional environment. This paper utilizes palynological data in reconstructing coal-depositional environments in the Intrasudetic Basin.

With respect to stratigraphic terminology, the term Westphalian is used herein, with subdivisions Westphalian A, B, and C. These subdivisions are traditionally applied in Central Europe as respective equivalents of Langsettian, Duckmantian, and Bolsavian.



Text-fig. 1 - Geological map of the Intrasedimentary Basin (slightly modified from Augustyniak, 1970).

GEOLOGICAL SETTING AND STRATIGRAPHY

The origin of the Intrasedimentary Basin, the largest structural unit in the Middle Sudetes (Text-fig. 1), is related to the Variscan orogeny and owes its final configuration to late Alpine movements. The basin is infilled with Carboniferous, Permian, Triassic, and Upper Cretaceous strata (Nemec *et al.*, 1982). The Upper Carboniferous coal measures of the Intrasedimentary Basin comprise two main lithostratigraphic units, the Wałbrzych and Żacler Formations (Text-fig. 2) of Namurian and Westphalian age respectively (Augustyniak, 1970; Dziedzic, 1971; Górecka & Górecka-Nowak, 1990; Górecka-Nowak, 1995, 1997). Deposition of the Upper Carboniferous strata was not uniform throughout the basin; clastic and organic materials accumulated in some localized sub-basins or troughs. Correlation of coal seams in these different troughs is not possible, because of the lack of marker horizons in the profiles of the coal-bearing strata.

The lower part of the Upper Carboniferous succession, the Wałbrzych Formation, accumulated in two discrete troughs; viz., the Wałbrzych trough and

the Wolibórz trough in the Nowa Ruda region. The Wałbrzych Formation consists mainly of sandstones, siltstones, and claystones intercalated with numerous coal seams and, locally, conglomerates. The latter occur mainly in the lower part of the formation. In the Wałbrzych region, the formational thickness exceeds 250 m; in the Nowa Ruda region, thickness is up to 320 m (Text-fig. 2). The age of the Wałbrzych Formation was determined palynologically as Namurian A and early Namurian B (Krawczyńska-Grocholska, 1960, 1966; T. Górecka, 1969).

Barren deposits of the Biały Kamień Formation occur between the Wałbrzych and Żacler Formations (Text-figs. 1, 2). The lower part of the Biały Kamień Formation consists of coarse conglomerates; the upper part is mainly of sandstones. Palynostratigraphic studies (T. Górecka, 1968, 1969) have dated the formation as Namurian B-early Westphalian A.

The Biały Kamień Formation passes upwards into the thick complex of coal-bearing sediments known as the Żacler Formation. This unit reaches maximum thickness (900 m) in the Wałbrzych area. In the Nowa Ruda area, which is complicated structurally, accumulation took place mainly in the Nowa Ruda

THE WAŁBRZYCH REGION

STRATIGRAPHY			LITHO- STRATIGRAPHY (FORMATIONS)	THICKNESS (m)	SEAM NUMBER	LITHOLOGY
UPPER CARBONIFEROUS	PER- MIAN	AUTUNIAN	C	LUDWIKO- WICE	100- 440	
	STEPHANIAN	B	A	GLINIK	300- 850	
	WESTPHALIAN	C	B	ŻACLER	500- 900	
	NAMURIAN	C	B	BIAŁY KAMIEŃ	150- 380	

A

THE SŁUPIEC REGION

STRATIGRAPHY			LITHO- STRATIGRAPHY (FORMATIONS)	THICKNESS (m)	SEAM NUMBER	LITHOLOGY
UPPER CARBONIFEROUS	STEPHANIAN	C	B	GLINIK	140- 320	
	WESTPHALIAN	D	C	ŻACLER	20- 160	
	NAMURIAN	A	B	WALB- RZYCH	0- 40	

B

Text-fig. 2 - Lithostratigraphic sections of the Upper Carboniferous deposits of the Intrasudetic Basin. A) Wałbrzych region. B) Słupiec region.

trough (with maximum Żacler thickness of 430 m) and in the Słupiec trough (>160 m of Żacler Formation). The sedimentary package in this area coarsens upward. The lower part comprises mostly fine clastic sediments and includes up to 26 coal seams. The upper part is of coarser deposits, with 22 coal seams (Text-fig. 2).

Biostratigraphy of the Żacler Formation is based on palynological studies (Górecka-Nowak, 1995, 1997). The formation's lower part corresponds to the *Radiiizonates aligerens* miospore zone (Clayton *et al.*, 1977) of Westphalian A age. Presence of *Schulzospora* spp., *Punctatisporites sinuatus* (Artüz) Neves, 1961, *Leiotriletes tumidus* Butterworth & Williams, 1958, and *Bellisporites nitidus* (Horst) Sullivan, 1964 is characteristic of this zone. At the base of the upper Żacler Formation, *Microreticulatisporites nobilis* (Wicher) Knox, 1950, *Florinites junior* Potonié & Kremp, 1956, and *Punctatosporites granifer* (Potonié & Kremp) Alpern & Doubinger, 1973 are introduced, thereby signifying the lower boundary of the *Florinites junior*-*Microreticulatisporites nobilis* miospore

zone (Clayton *et al.*, 1977; Górecka-Nowak, 1995, 1997). The uppermost Żacler Formation conforms to the *Torispora securis*-*T. laevigata* miospore zone (Clayton *et al.*, 1977; Górecka-Nowak, 1995, 1997), with first appearances of *Torispora*, together with *Microreticulatisporites sulcatus* (Wilson & Kosanke) Smith & Butterworth, 1967 and *Vestispora magna* (Butterworth & Williams) Spode, 1969. This zone is Westphalian C in age.

Stratigraphically succeeding the coal-bearing strata are thick, barren deposits consisting of sandstones, conglomerates, and mudstones of the Glinik Formation (uppermost Westphalian) and Ludwikowice Formation (Stephanian) (Text-fig. 2). These complete the Upper Carboniferous sequence in the Intrasudetic Basin, but are poorly documented biostratigraphically.

Palaeoclimatic interpretation of Westphalian palynological data from the Intrasudetic Basin indicates slight changes in humidity during this interval (Górecka-Nowak, 1996). The Westphalian A was probably more humid than the Westphalian B and C.

These changes correspond to the coeval climatic developments in North America and Western Europe (Phillips & Peppers, 1984; DiMichele *et al.*, 1985).

SCOPE AND METHODS OF STUDY

Miospore assemblages - valuable tools in facies analysis - facilitate palaeofloral reconstructions. This is possible because the parent plant affinities of a majority of Carboniferous dispersed miospore taxa are known. The interpretation of miospore successions within the coals rests on the assumption that the constituent miospores are autochthonous and represent a local plant community. In contrast, many of the miospores hosted by siliciclastic sediments are presumably allochthonous (Fulton, 1987).

Palynological studies also provide information on the original edaphic conditions and mire hydrology. Smith (1962, 1968) recognized four main "phases" in the Westphalian A and B coal seams of the Yorkshire Coalfield of England, based on miospore and petrographic analyses. These were termed the Lycospore, Transition, Densospore, and Incursion phases, so named from the dominant miospore taxa and microlithotype composition. These phases may be repeated vertically in a seam, with the Lycospore phase, associated with very wet conditions, always being at least at the base of the coal bed. In contrast, the Densospore phase was interpreted as having developed when the peat became emergent, i.e., raised above the water table. The Transition phase was named from its relative position in the phase sequence (Lycospore, Transition, Densospore), although it may also separate two Lycospore phases. The Incursion phase probably indicates periods of flooding and clastic influx.

Palynological studies have been used very effectively in palaeoecological and palaeoenvironmental reconstructions of Carboniferous peat accumulations. Complementary to such studies are many coal petrographic analyses (e.g., Habib, 1968; Bartram, 1987; Fulton, 1987; Grady & Eble, 1990; Eble & Grady, 1993; Hyde *et al.*, 1991; Pierce *et al.*, 1993, 1995; Eble *et al.*, 1994a, b; Marchioni *et al.*, 1994; Hower *et al.*, 1994; Eble & Hower, 1995).

Clearly, vegetation is very sensitive to even slight environmental changes. Palaeobotanical studies, based particularly on coal balls (Phillips & Peppers, 1984; DiMichele *et al.*, 1985; Phillips *et al.*, 1985; DiMichele & Phillips, 1994), have provided new information on the ecological preferences of various plant groups, as well as on climate and climatic changes during Carboniferous times. Clearly, palynology, as a basis for reconstruction of plant communities, provides a very useful method for environmental and climatic reconstructions, although the limitations of this method, as discussed by DiMichele & Phillips (1994), should be taken into account.

Three coal seams from the Żacler Formation

(Westphalian A) of the Intrasudetic Basin (Text-fig. 2) were selected for facies studies: seam 430 from the Wałbrzych region (northwestern part of the Intrasudetic Basin), and seams 409 and 412/413 from the Słupiec region (southeastern part).

All samples were collected from underground mines. Each profile of seam 430 was subdivided into coal lithotypes (Text-fig. 3). However, the structure of seams 409 and 412/413 did not permit recognition of lithotypes, and, for these, channel samples of whole seams were taken. Clastic partings were also sampled where possible.

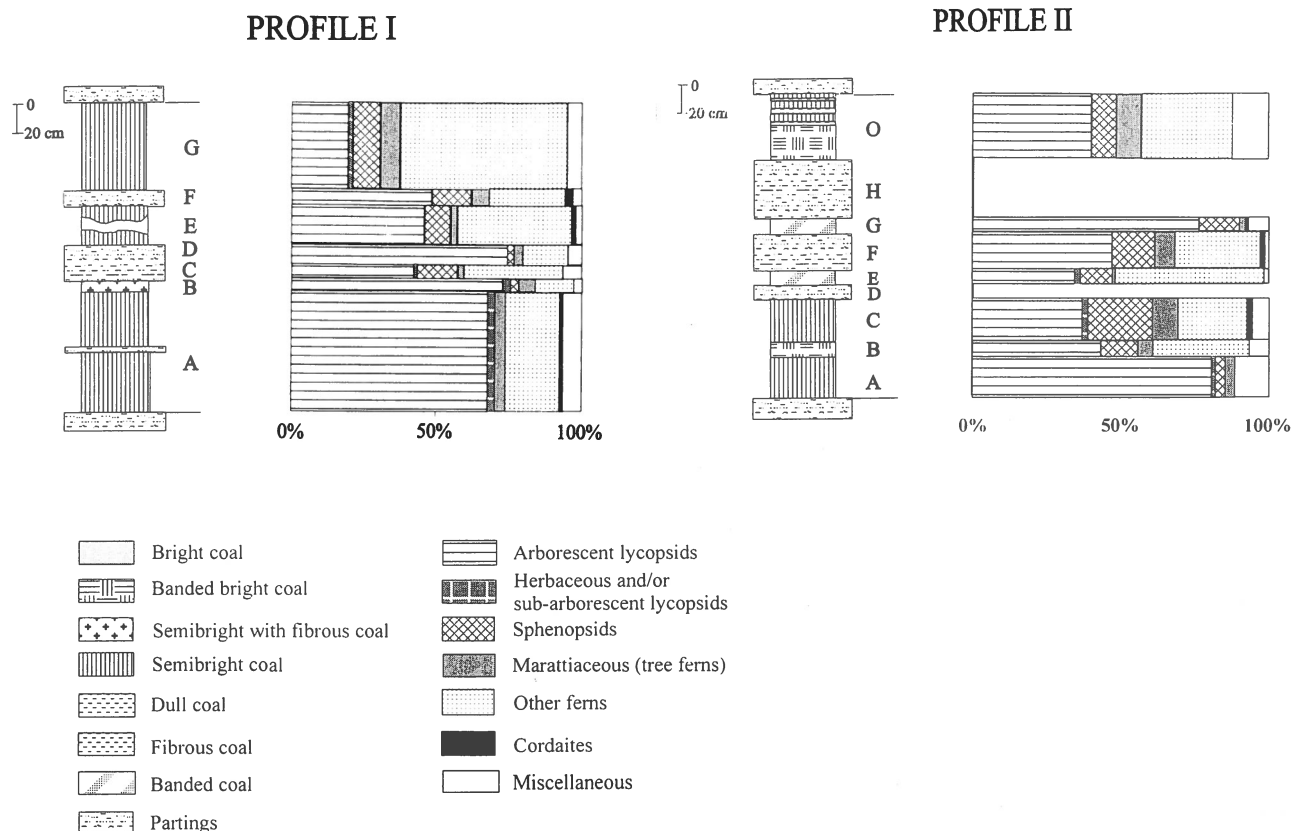
Each sample was examined palynologically and petrographically. This paper focuses on the palynological data. Combined results of the petrographic and palynological analyses are presented by Nowak & Górecka-Nowak (1999).

For palynological examination, the coal samples were macerated in Schulze solution (65% HNO₃ saturated with KClO₃), followed by KOH treatment. Samples of clastic rocks (barren of coal) were processed similarly, following initial, demineralizing HF treatment. Two hundred miospore specimens were counted per sample for quantitative documentation and representation. Assignment of dispersed spores to their respective parental plant groups (e. g., lycopsids, ferns, calamites, etc.) is based herein on compilations by Ravn (1986) and Górecka-Nowak (1995).

PALYNOLOGICAL RESULTS

SEAM 430

Coals and shaly intercalations of this seam yielded well-preserved and diverse miospores (Text-fig. 4). The miospore taxa belong to five major Westphalian plant groups (lycopsids, ferns, seed ferns, calamites, and cordaites) and occur in varying proportions (Text-fig. 3). Three species of *Lycospora* (Schopf, Wilson & Bentall) Potonié & Kremp, 1954 [*L. pusilla* (Ibrahim) Schopf, Wilson & Bentall, 1944, *L. pelucida* (Wicher) Schopf, Wilson & Bentall, 1944, and *L. orbicula* (Potonié & Kremp) Smith & Butterworth, 1967] are most abundant. They represent *Lepidodendron* Sternberg, 1820, *Lepidophloios harcourtii* (Witham) Seward & Hill, 1900, and *Paralycopodites* Morey & Morey, 1977 respectively (DiMichele & Phillips, 1994). These taxa constitute large lycopsid trees, which dominated early Westphalian peat-forming environments. *Granasporites medius* (Dybová & Jachowicz) Ravn, Butterworth, Phillips & Peppers, 1986, which was produced by *Diaphorodendron* DiMichele, 1985 and *Synchysidendron* DiMichele & Bateman, 1992, is rare. *Crassispora kosankei* (Potonié & Kremp) Smith & Butterworth, 1967 is also infrequent. *Densosporites* (Berry) Butterworth, Jansonius, Smith & Staplin, 1964, *Cristatisporites* (Potonié & Kremp) Butter-



Text-fig. 3 - Lithotype (A) and floral associations (B) of the 430 coal seam. Explanations in text.

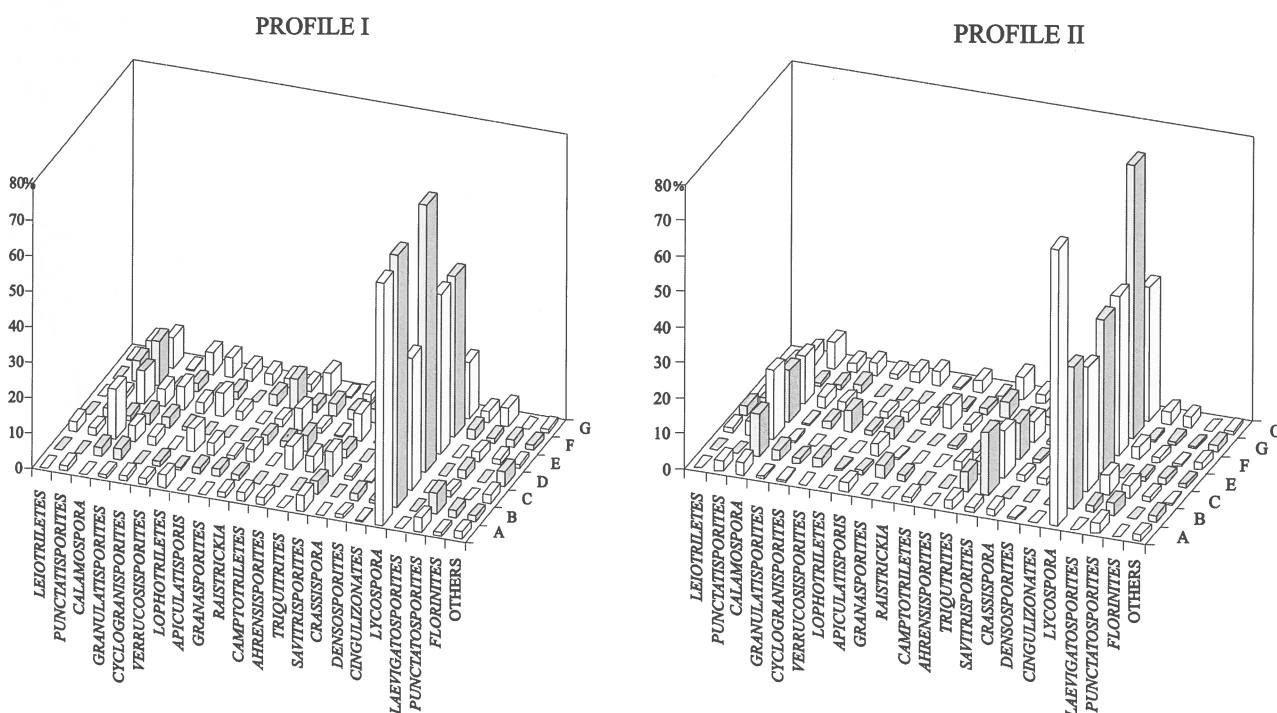
worth, Jansonius, Smith & Staplin, 1964 and *Cingulizonates* (Dybová & Jachowicz) Butterworth, Jansonius, Smith & Staplin, 1964 - spores assignable to herbaceous and/or sub-arborescent lycopsids (e.g., *Bodeodendron* Wagner & Spinner, 1976/*Sporangiostrubus* Bode, 1928; Wagner, 1989) - occur sporadically. An important component is *Calamospora* Schopf, Wilson & Bentall, 1954, which exceeds 20% in certain intervals. This genus, together with some species of *Laevigatosporites* Ibrahim emend. Alpern & Doubinger, 1973, was produced by calamitaleans. Another important floral group represented in the miospore assemblages is the small ferns, which produced *Granulatisporites* Ibrahim emend. Potonié & Kremp, 1954, *Leiotriletes* Naumova emend. Potonié & Kremp, 1954, *Cyclogranisporites* Potonié & Kremp, 1954, *Savitrissporites* Bharadwaj, 1955, *Raistrickia* Schopf, Wilson & Bentall emend. Potonié & Kremp, 1954, *Lophotriletes* Naumova emend. Potonié & Kremp, 1954, and other trilete genera. Tree ferns, as well as cordaitaleans, are quantitatively insignificant in the palynoflora.

In spite of the common features, slight vertical changes in the palaeofloral composition of the seam (Text-fig. 3) enable recognition of two floral assemblages. The first is dominated by arborescent lycopsids, with percentages of *Lycospora* usually >60% and

L. pellucida usually the dominant species. This assemblage is most common in basal parts of the coal seam, but sometimes appears in its middle part, in partings (sample D, profile I), and in some coal intervals near the top of the bed (sample G, profile II). The second floral assemblage occurs in the remaining levels of the seam (coal and parting). Arborescent lycopsids remain the dominant group, but their percentage is lower (ca. 40%). The palynoflora is more diverse, with relatively higher percentages of calamites (represented by *Calamospora* and *Laevigatosporites* spp.) and small ferns, the latter represented by several miospore genera.

SEAMS 409 AND 412/413

A somewhat monotonous miospore suite was identified from these seams (Text-fig. 5); it differs greatly from the palynoflora of seam 430. The main components (totalling at least 80%) are *Densosporites* and related crassicingulate spores (e. g., *Cristatisporites*, *Radiizonates* Staplin & Jansonius, 1964, *Cingulizonates*). These indicate that herbaceous and/or sub-arborescent lycopsids were the dominant peat-forming plants. Ferns (small and arborescent) contributed 10-15% of the miospore assemblage; arborescent lycopsids and sphenopsids were minor contributors.



Text-fig. 4 - Composition of miospore associations of the 430 coal seam.

PALAEOENVIRONMENTAL INTERPRETATION

Miospore assemblages obtained from the samples studied can be grouped into specific associations, which reflect the nature of the peat-forming flora. The latter may then be regarded as indicative of the conditions that prevailed during peat deposition. Three miospore associations are recognizable: (1) arborescent lycopsid association; (2) mixed association; and (3) herbaceous and/or sub-arborescent lycopsid association. These associations facilitate palaeomire interpretation, because each corresponds to a particular environment.

ARBORESCENT LYCOPSID ASSOCIATION

The palynological data indicate that the most abundant plants in this category were large lycopsid trees, such as *Lepidophloios*, *Lepidodendron*, and *Paralycopodites*; small lycopsid trees occurred in minor abundance. Although *Lepidophloios* and *Lepidodendron* occupied similar habitats with long periods of standing water, *Lepidophloios* is more typical of this assemblage (DiMichele & Phillips, 1994). A flooded environment could be tolerated by arborescent lycopsids due to their specialized growth and reproductive strategies. In this respect, the arborescent lycopsid association probably occupied a rheotrophic mire (Moore, 1987). Petrographic studies support this conclusion: the high vitrinite content in the coal

studied is correlated with standing water cover, which inhibited peat oxidation (Nowak & Górecka-Nowak, 1999).

Cecil *et al.* (1985) introduced the term "planar swamp" to characterize the palaeoenvironment of coal seams of the Appalachian Basin; this may correspond to the type of mire described here. The planar swamp is considered to have a relatively flat surface profile, which allowed easy access of extra-mire waters. Occasional high percentages (up to 15%) of inorganic matter in seam 430 coals are suggestive of river flooding; the mire could have developed near a river, perhaps on a flood plain (Nowak, 1996, 1997a, b). River flooding often results in the emplacement of clastic partings.

MIXED ASSOCIATION

Miospore data indicate that vegetation of this environment was relatively diverse. Arborescent lycopsids were very abundant; calamites and ferns were common. The edaphic conditions apparently did not favour dominance and proliferation of any one plant group, but resulted in a heterogeneity of plant types. Coals of this association may reflect rheotrophic conditions in planar mire.

Predominance of vitrinite in the coals (with telocollinite exceeding desmocollinite) and enrichment in mineral matter indicate peat deposition in marginal parts of the mire, under less acid conditions than

the arborescent lycopsid association (Nowak & Górecka-Nowak, 1999).

HERBACEOUS AND/OR SUB-ARBORESCENT LYCOPSID ASSOCIATION

This association represents a different environment of peat deposition, compared with those discussed above. Coals constituting this association are equivalents of the "Densospore phase" (Smith, 1962, 1968). Palynological data indicate that sub-arborescent plants, *Sporangiostrobus* (= vegetative *Bodeodendron*, *Omphalophloios* White, 1898), were the main floristic components. These plants were ca. 3 m high and ca. 30 cm in basal diameter, with an unbranched columnar trunk (Wagner, 1989). Other plant contributors to this association were rare.

Petrographic analysis of the coals of this association reveals greater destruction of vitrinite precursor material and more conspicuous biodegradation, together with a fluctuating water table and exposure to air and oxygenated rain water (Nowak & Górecka-Nowak, 1999).

The floral composition of the palaeomire implies that the peat formed under subaerial, exposed conditions, with a subterranean water table (Smith, 1957, 1962, 1968; Fulton, 1987). Bartram (1987), who studied the distribution of lycopod megaspores in the Westphalian B Barnsley coal seam of England, also regarded the "Densospore phase" as representing ombrotrophic peat development. A similar interpretation of the Middle Pennsylvanian Appalachian coals was advanced by Eble & Grady (1993) and Eble & Hower (1995). These types of mires developed in areas generally unaffected by river flooding; if such flooding did occur, it merely resulted in thin clastic partings. The low mineral matter content of these coals further supports an ombrogenous peat interpretation.

However, there is no agreement on the significance of *Densosporites*-rich coal as indicator of ombrotrophic mire. Taking account of more recent palaeobotanical data, DiMichele & Phillips (1994) claimed that *Densosporites* could not be used as an ombrogenous-mire indicator, because it has been found in shaly coals and in clastic deposits.

SEQUENCE OF PALAEOENVIRONMENTAL CHANGES

The temporal arrangement of miospore associations in the studied coal seams indicates the sequence of palaeoenvironmental changes during peat deposition.

In profile I of seam 430, the following sequence of associations is recognized (Text-fig. 3): intervals A and B, at the base of the seam, both with an arborescent lycopsid association; higher coal intervals, E and G, with a mixed association. Coals of this profile are intercalated with shaly sediments (intervals C, D, F).

However, in profile II of the same seam a greater variation of associations is observed: the arborescent lycopsid association occurs at the base; intervals B, C, E, and O have a mixed association and are intercalated with coal layers featuring the arborescent lycopsid association (interval G) and parting (F).

It is evident that arborescent lycopsids were the main floral group of the palaeomire during its entire development. The dominance of lepidodendrids in the initial and some later stages of the mire suggests that the peat surface was mostly covered with standing water.

The occurrence, and occasional abundance, of some other plant groups helps trace some environmental changes within the palaeomire during its developmental history. Relatively high percentages of calamitaleans and small ferns at certain levels (mixed association) seem to indicate a fluctuating water table, possibly caused by the migration of mire borders. Brief flooding by extra-mire sediment-bearing water are registered as clastic intercalations in the seam profile.

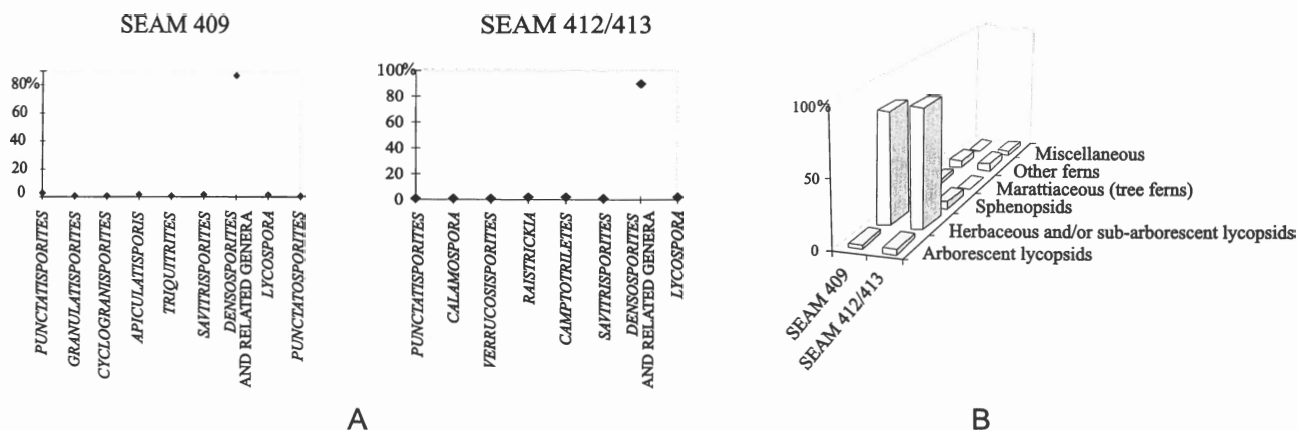
The nature of the mire vegetation, maceral composition, presence of clastic partings, and relatively high mineral content of the coals suggest that seam 430 formed in a rheotrophic forest mire, which was planar throughout its development.

The two coal seams studied from the Supieć region (409 and 412/413) are representative of the herbaceous and sub-arborescent lycopsid association, which is interpreted as having formed in the central part of the domed ombrotrophic mire.

CONCLUSIONS

Palynological analysis of seam 430 reveals two types of miospore assemblages: the first dominated by the arborescent-lycopod spore *Lycospora*; the second with mixed composition (high percentages of *Lycospora*, *Calamospora*, and others). The diverse parental plant community included arborescent lycopsids, calamites, and ferns. Coals from seams 409 and 412/413 display a predominance of *Densosporites* over other miospore taxa, and document vegetation consisting mainly of herbaceous and/or sub-arborescent lycopsids.

Three miospore associations, corresponding to the plant assemblages, are recognizable. The arborescent lycopsid association equates to the "Lycospore phase" (Smith, 1962, 1968) and "arborescent lycopod-dominant group" (Eble & Grady, 1993). This association represents a rheotrophic, planar mire of forest character. The mixed association connotes similar environmental conditions, but was probably in a more marginal part of the palaeomire. The herbaceous and/or sub-arborescent lycopsid association - comparable to the "Densospore phase" (Smith, 1962, 1968) or "herbaceous lycopod and fern group" (Eble & Grady, 1993) - is believed to represent the central



Text-fig. 5 - Composition of miospore (A) and floral associations (B) of 409 and 421/413 coal seams.

part of an extensive mire of ombrotrophic (domed) character.

Coal seam 430 (of the northwestern part of the Intrasudetic Basin) is interpreted as a planar rheotrophic mire. Seams 409 and 412/413 (southeastern Intrasudetic Basin) are envisaged as having formed in the central part of an extensive ombrotrophic mire.

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