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Palynostratigraphy and palynofacies of the Permian-Triassic transitional sequence in the Żary Pericline (SW Poland)

One spore-pollen assemblage representing the *Lundbladispora obsoleta–Protohaploxypinus pantii* Zone was recognized within the lowermost Buntsandstein deposits in the Żary Pericline. For the first time possible fresh water algae were found in Early Triassic sediments of Poland. Moreover, four palynofacies were distinguished, which together with sedimentological features of the studied deposits, indicate deposition in a playa environment. The palaeoclimatic model used in this study shows warm (tropical) dry climate during the Early Triassic in SW Poland.

INTRODUCTION

The Permian-Triassic sequence in the Żary Pericline has a transitional character. Its lower part (complex I) can be correlated with the Zechstein Top Terrigenous Series (Pzt). The middle part (complex II) represents boundary beds, within which at the boundary between Pzt Series and Lower Buntsandstein deposits is drawn at various positions on the basis of lithological, sedimentological as well as environmental features. In some sections (Bronków M27 or Lubiatów M20 borehole) this boundary lies at the top of complex II whereas in others (Nowa Wieś P1) at the base of complex II or within it (Kosierz M25). The upper part (complex III) represents the Lower Buntsandstein (G. Czapowski *et al.*, in preparation). This approach corresponds generally to the characteristics of the Pzt Series presented by G. Pieńkowski (1987, 1989, 1991) and R. Wagner (1987, 1988, 1991, 1994). The boundary complex II consisted of mostly aleuritic-pelitic heterolithes is especially interesting. The appearance of heterolithes in the lithological Permian-Triassic succession of the Polish Basin is generally connected with the Lower Buntsandstein (G. Pieńkowski, 1989, 1991) but a detailed analysis of the heterolithes from the Żary Pericline, carried out

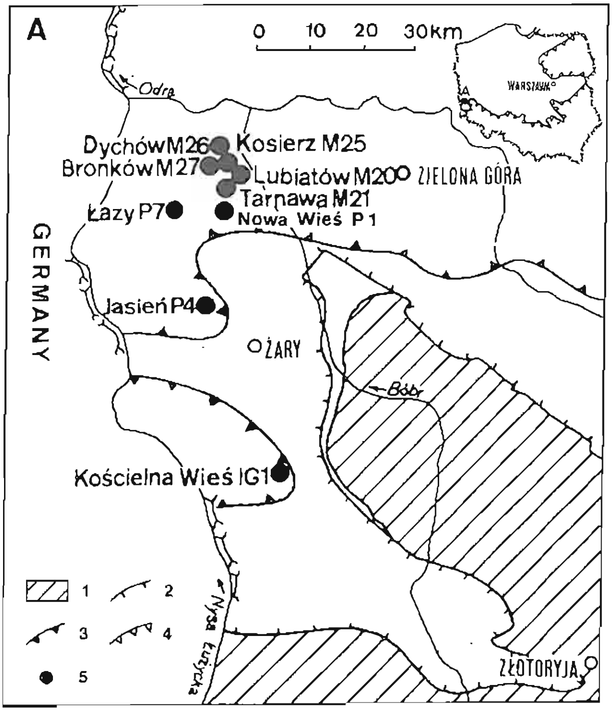

Fig. 1. Location of studied boreholes and present limit of Zechstein and Lower Buntsandstein deposit in the Żary Pericline and North Sudetic Trough (after G. Czapowski *et al.*, in preparation)

1 — areas without Zechstein deposits, 2 — present limit of Lower Buntsandstein deposits, 3 — present limit of PZ4 evaporites, 4 — present limit of Zechstein deposits in Poland, 5 — studied boreholes

Lokalizacja badanych otworów wiertniczych oraz obecny zasięg utworów cechsztynu i dolnego pstrego piaskowca w peryklinie Żar i niecce północnosudeckiej (według G. Czapowskiego i in., w przygotowaniu)

1 — obszary pozbawione utworów cechsztynu, 2 — obecny zasięg utworów dolnego pstrego piaskowca, 3 — obecny zasięg ewaporatów cyklu PZ4, 4 — obecny zasięg utworów cechsztynu w Polsce, 5 — otwory wiertnicze

by G. Czapowski *et al.* (in preparation), made an attempt to divide them into those formed in a continental environment genetically connected with the Pzt Series and those deposited in marine environments, belonging to the Buntsandstein sequence.

Palynological studies of the Permian-Triassic sequence from the Żary Pericline were carried out in 1992–1994. Their aim was definition of microfloral characteristics and working out the palynostratigraphic scheme. In addition, a few palynofacies were recognized which were applied to palaeoenvironmental reconstruction.

Palynological investigation of the Permian-Triassic succession in Poland were started by S. Dybova-Jachowicz, D. Laszko (1976, 1978, 1980). They concerned the Holy Cross Mts. area, where a pore-pollen spectrum A was distinguished within the upper part of the Middle Buntsandstein. Later T. Orłowska-Zwolińska (1984, 1985) presented the first palynostratigraphical zonation of the Lower Buntsandstein, based on borehole sections from western Poland (among other Dachów M24 borehole in the Żary Pericline). The microfloral studies of the Permian-Triassic deposits in the Holy Cross Mts. and SW Poland were continued by the author (G. Czapowski, A. Fijałkowska, 1993; A. Fijałkowska, 1990, 1991, 1992, 1993, 1994*a*, *b*; A. Fijałkowska, A. Trzepierczyńska, 1990). They resulted in reworking the palynostratigraphical scheme of the Zechstein and Buntsandstein deposits in the Holy Cross region as well the Lower Buntsandstein in the Żary Pericline. Moreover, palynofacial analysis of the uppermost Zechstein and Buntsandstein in the mentioned areas was started by author (G. Czapowski, A. Fijałkowska, 1993; A. Fijałkowska, 1994*a*; A. Fijałkowska, M. Kuleta, 1994*a*, *b*; M. Kuleta, A. Fijałkowska, 1995).

METHODS AND MATERIALS

Palynological data for this study were gathered and compiled from 8 boreholes, located in the Żary Pericline: Lubiatów M20 (1096.3–1140.0 m), Tarnawa M21 (985.1, 986.0 m), Kosierz M25 (1100.5–1239.6 m), Dychów M26 (1304.2–1314.9 m), Bronków M27 (980.5–983.2 m), Nowa Wieś P1 (632.8–681.5 m), Jasień P4 (601.2–624.8 m) and Łazy P7(913.5–913.8, 938.6–938.7 m) (Fig. 1).

In total, 70 samples were taken from a variety of lithologies although black, grey and greenish shales were preferred (Fig. 2).

The maceration process was based on the HF method.

In total, 51 species of miospores from 39 genera, as well as 4 genera of acritarchs, fungal spores and 5 types of planktonic possibly fresh water algae were recognized (Appendix 1, Tab. 1).

Organic matter was classified according to the "Amsterdam Organic Matter Classification 1993", where four main groups of organic particles are proposed: palynomorphs, structured matter, unstructured (amorphous) matter and indeterminate matter. Four palynofacies were distinguished within the Permian-Triassic transitional sequence on the basis of the organic matter relative frequency (Fig. 3).

GENERAL CHARACTERISTICS OF THE STUDIED LITHOSTRATIGRAPHICAL COMPLEXES

The first detailed lithostratigraphical characteristics of the Zechstein-Buntsandstein succession in the Żary Pericline was presented by J. Sokołowski (1967), who divided deposits between the Red Upper Clay of the PZ4 Cyclothem and the Lower Buntsandstein beds into four lithological complexes (18–21).

The most recent proposed lithostratigraphical division of these deposits was produced by G. Czapowski, who distinguished 3 lithofacies complexes (G. Czapowski, A. Fijałkowska, 1993; G. Czapowski *et al.*, in preparation). Complex I can be correlated with the Zechstein Pzt Series. The detailed sedimentological as well as geochemical analyses of complex II showed that the environmental change from continental into marine shore facies, identified with the Zechstein-Buntsandstein boundary, occurs in a different position within this complex (A. Gąsiewicz, G. Czapowski, 1995). In some sections this boundary lies at

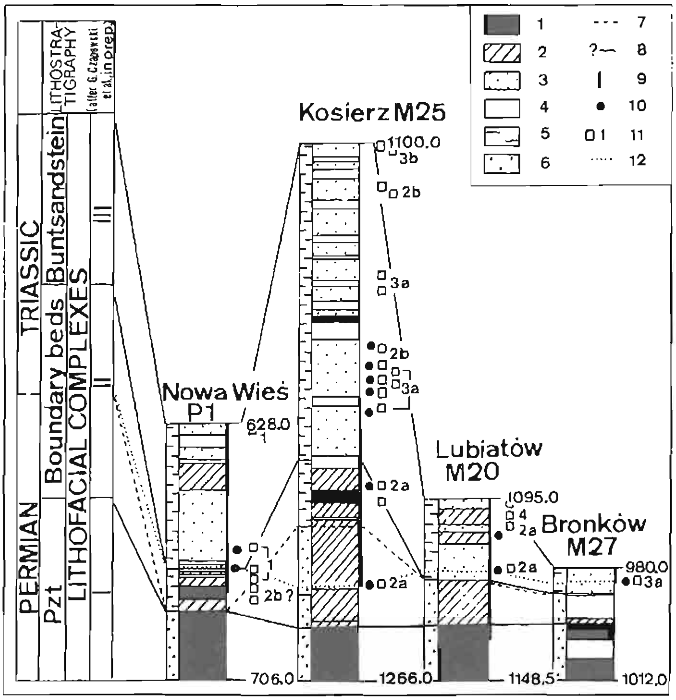

Fig. 2. Correlation of the selected Permian-Triassic sections in the Żary Pericline (after G. Czapowski *et al.*, in preparation)

L i t h o f a c i e s : 1 — pelites, 2 — aleuritic-pelitic heterolithes, 3 — psammitic-aleuritic-pelitic heterolithes, 4 — core lacking; e n v i r o n m e n t: 5 — marine shore, 6 — continental, 7 — Pzt–Buntsandstein boundary based on lithological criteria, 8 — boundary between environments based on palynological criteria; p a l y n o - l o g y : 9 — studied intervals of cores, 10 — palynomorph occurrence, 11 — palynofacies, 12 — Permian-Triassic boundary based on palynological criteria

Korelacja wybranych profili permsko-triasowych z perykliny Żar (według G. Czapowskiego i in., w przygotowaniu)

L i t o f a c j e : 1 — pelity, 2 — heterolity aleurytowo-pelitowe, 3 — heterolity psamitowo-aleurytowo-pelitowe, 4 — brak rdzenia; ś r o d o w i s k o : 5 — morskie brzegowe, 6 — kontynentalne, 7 — granica Pzt–pstry piaskowiec wyznaczona na podstawie kryteriów litofacjalnych, 8 — granica między środowiskami wyznaczona na podstawie kryteriów palinologicznych; p a l i n o l o g i a : 9 — badane odcinki rdzeni, 10 — wystąpienia palinomorf, 11 — palinofacje, 12 — granica perm-trias wyznaczona na podstawie kryteriów palinologicznych

the top of the complex, whereas in others at its base or in the middle part. Therefore the name of "boundary complex" is suggested for these deposits. Complex III represents the Lower Buntsandstein and can be correlated with the Baltic Formation distinguished by R. Wagner (1987, 1991, 1994) in northern Poland.

Complex I (a few to a dozen metres in thickness) consists of structureless red-brown claystones with numerous anhydrite nodules and intercalations. Sometimes thicker interbeds of sandstone occur.

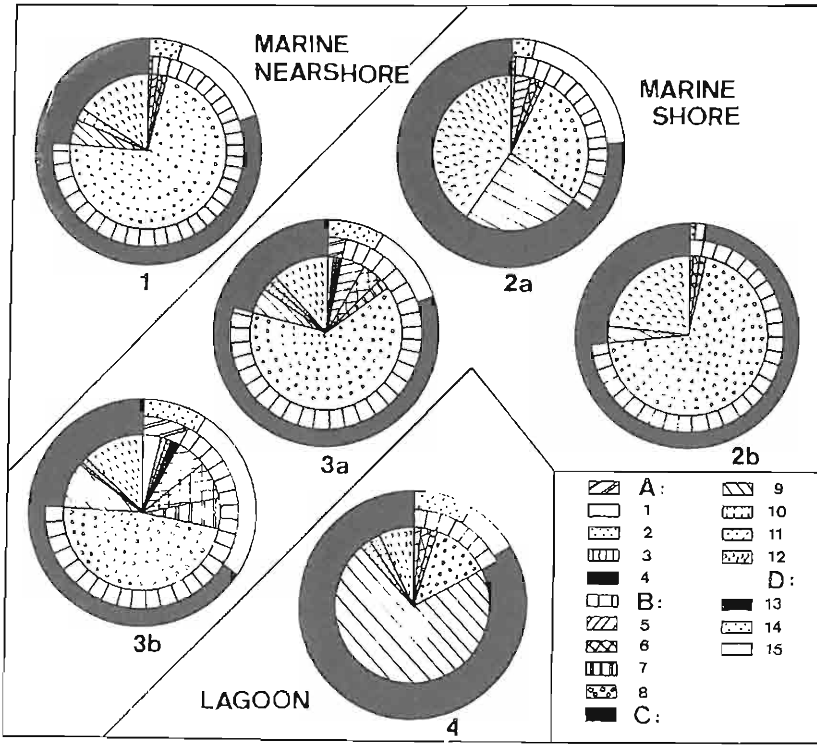

Fig. 3. Palynofacies and palaeoenvironment

1, 2a, 2b, 3a, 3b, 4 — types and subtypes of palynofacies; A — organic matter: palynomorphs: 1 — pollen, 2 — spores, 3 — fungal spores, 4 — acritarchs and algae; B — structured matter: 5 — "woody", 6 — plant epiderm and cuticle, 7 — plant tissue, 8 — indeterminate; C — unstructured (amorphous) matter: 9 — finely dispersed, 10 — homogeneous, 11 — heterogeneous, 12 — indetermine; D — organic matter colour: 13 — dark brown and black, 14 — light brown, 15 — yellow

Palinofacje i paleośrodowisko

1, 2a, 2b, 3a, 3b, 4 — typy i podtypy palinofacji; A — materia organiczna: palinomorfy: 1 — ziarna pyłku, 2 — spory, 3 — spory grzybów, 4 — akritarchy i glony; B — materia strukturalna: 5 — "drewno", 6 — nabłonki roślinne i kutikule, 7 — tkanki roślinne, 8 — fragmenty nieokreślone; C — materia bezstrukturalna: 9 — drobno rozproszona, 10 — homogeniczna, 11 — heterogeniczna, 12 — nieokreślona; D — barwa materii organicznej: 13 — ciemnobrązowa i czarna, 14 — jasnobrązowa, 15 — żółta

Complex II (1.5 to 49.8 m in thickness) is composed of dark brown and motley aleuritic-pelitic heterolithes, locally with sandstone or carbonate/oolitic interbeds, structureless or with horizontal, wavy or ripple bedding. Dessication and syneresis cracks as well as convolutions are common here whereas sulphate nodules and bioturbation are scarce.

Complexes I and II correspond to the Upper Red Clays and three (19–21) complexes of the Lower Buntsandstein, distinguished by J. Sokołowski (1967).

Complex III (2.5 to over 102.3 m) is built of dark brown to greenich sandy-clayey heterolithes with clayey and carbonate interbeds, diagonal, wavy, ripple or horizontal bedding. Dessication and syneresis cracks as well as wash-out structures are common here. It can be referred to complex 18 of J. Sokołowski (1967).

Table 1

Stratigraphic distribution of palynomorphs in the Upper Permian and Lower Triassic of the Żary Pericline and North Sudetic Trough

SPECIES	LITHOSTRATIGRAPHY (after G. Czapowski *et al.*, in preparation)			
	ZECHSTEIN		BUNTSANDSTEIN	
	PZ4	Pzt	Lower Buntsandstein	
		I	II	III
1	2	3	4	5
Lueckisporites virkkiae NA	—			
Lueckisporites virkkiae NB	▬			
Lueckisporites virkkiae NE	—			
Jugasporites delasaucei	—			
Jugasporites paradelasaucei	—			
Jugasporites parvus	—			
Jugasporites lueckoides	—			
Jugasporites NB	—			
Illinites unicus	—			
Protohaploxypinus latissimus	—			
Vittatina vittifera	—			
Vittatina subsaccata	—			
Klausipollenites schaubergeri	▬			
Limitisporites moersensis	—			
Limitisporites rectus	—			
Limitisporites parvus	—			
Gardenasporites leonardii	—			
Gardenasporites moroderi	—			
Gardenasporites oberrauchii	—			
Gardenasporites heisseli	—			
Vesicaspora sp.	—			
Triadispora visscheri	—			
Chordasporites sp.	—			
Lycospora cf. *permica*	—			
Perisaccus granulatus	—			
Nuskoisporites klausi	—			
Endosporites hexarecticulatus	—			
Trizonaesporites grandis	—			
Crustaesporites globosus	—			
Guttulapollenites sp.	—		—	—
Falcisporites zapfei	—		—	—
Nuskoisporites sp.	—		—	—
Trizonaesporites sp.	—		—	—
Lunatisporites multiplex	—		—	—
Gnetacaepollenites steevesii	—		—	—
Lueckisporites sp.	—		—	—
Gardenasporites sp.	—		—	—
Platysaccus niger	—		—	—
Protohaploxypinus samoilovichii	—		—	—
Klausipollenites staplinii	—		—	—
Triadispora crassa	—		—	—
Calamospora tener	—		—	—
Cycadopites coxii	—		—	▬—
Cycadopites follicularis	—		—	▬—
Lunatisporites noviaulensis	▬		—	▬—
Klausipollenites minimus	—			—
Lunatisporites labdacus	—			—
Lunatisporites alatus	—			—
Lunatisporites gracilis	—			—

Tab. I continued

1	2	3	4	5
Strotersporites richteri			—	—
Sphaeripollenites balmei			—	▬
Lunatisporites microsaccatus			—	—
Lundbladispora brevicula			—	—
Lundbladispora obsoleta			—	—
Kraeuselisporites apiculatus			—	—
Kraeuselisporites cuspidus			—	—
Baculatisporites sp.			—	—
Deltoispora minima			—	—
Densoisporites cf. *nejburgii*			—	—
Densoisporites playfordii			—	▬
Protohaploxypinus pantii			—	—
Duplicisporites granulatus			—	—
Klausipollenites decipiens			—	—
Punctatisporites triassicus			—	—
Cyclotriletes microgranifer			—	—
Angustisulcites gorpii			—	—
Angustisulcites klausii			—	—
Endosporites papillatus			—	—
Aculeisporites variabilis			—	—
Klausipollenites forma Y				—
Cyclotriletes oligogranifer				—
Apiculatisporis sp.				—
Lophotriletes sp.				—
Guttatisporites elegans				—
Densoisporites holospongia				—
Striatoabietites balmei				—
Cycadopites hartii				—
Lunatisporites hexagonalis				—
Lunatisporites obex				—
Lunatisporites transversundatus				—
Lunatisporites pellucidus				—
Dulhuntyispora sp.				—
Protosacculina sp.				—
Platysaccus papilionis				—
Lundbladispora willmotti				—
Playfordiaspora sp.				—
Proprisporites pocockii				—
Naumovaspora sp.				—
Klausipollenites vestitus				—
Sphaeripollenites scissus				—
Platysaccus leschiki				—
Striatoabietites aytugii				—
Striatopodocarpites sp.				—
Lycospora sp.				—
Vitreisporites koenigswaldii				—
REDEPOSITED CARBONIFEROUS SPORES			—	—
REDEPOSITED PERMIAN MIOSPORES			—	—
ACRITARCHS			—	—
ALGAE			—	—
FUNGAL SPORES			—	—
PALYNOLOGIAL ZONES	L. virkkiae Bc		?	L. obsoleta-P. pantii

Frequency of palynomorph occurrence: — single, — seldom, ▬ common; samples containing the Upper Permian miospores were taken from the Kościelna Wieś IG 1 borehole in the North Sudetic Trough

PALYNOSTRATIGRAPHY

Presence of palynomorphs was stated within the complex II in the Bronków M27 borehole (at a depth of 983.2 m), Jasień P4 (601.2–618.7 m) and Kosierz M25 (1209.1–1239.6 m) as well as within complex III in the following boreholes: Kosierz M25 (1161.3–1184.2 m), Lubiatów M20 (1108.8, 1116.5–1117.0 m) and Nowa Wieś P1 (668.0, 675.0–678.5 m) (Fig. 2). They belong to one spore-pollen assemblage which represents the *Lundbladispora obsoleta–Protohaploxypinus pantii* Zone.

The assemblage is dominated by pollen grains (58.1% of the spectrum) whereas spores make up 11.5%, planktonic algae 15.4%, fungal spores 10.5%, acritarchs and prasinophyta 2.8%. Comparatively abundant are reworked Permian and Carboniferous miospores (1.7%).

Striatite pollen of conifers predominates among pollen grains. They belong mainly to *Lunatisporites*: *L. noviaulensis* (Leschik) Scheuring (Pl. II, Fig. 1), *L. multiplex* (Visscher) Scheuring, *L. gracilis* (Jansonius) Fijałkowska (Pl. II, Fig. 7), and *Protohaploxypinus*: *P. pantii* (Jansonius) Orłowska-Zwolińska (Pl. I, Fig. 11), *P. samoilovichii* (Jansonius) Hart (Pl. I, Fig. 13). Specimens of *Strotersporites* (Pl. I, Figs. 15, 17) and *Striatoabietites* are less frequent.

Non-striatite pollen of conifers are represented by *Klausipollenites* (*K. decipiens* Jansonius, *K. staplinii* Jansonius, *K. minimus* Góczán), *Platysaccus*, *Angustisulcites* (*A. gorpii* Visscher (Pl. II, Fig. 3), *A. klausii* Freudenthal) and *Triadispora*.

Cycadales pollen are abundant (10.6% of the spectrum) and the Moncolpates group is represented by *Sphaeripollenites* and *Duplicisporites* (Pl. II, Fig. 8).

Spores are dominated by fern taxa of *Cyclotriletes* (2.6% of the spectrum): *C. microgranifer* Mädler, *C. oligogranifer* Mädler, and *Endosporites*: *E. papillatus* Jansonius (Pl. I, Fig. 5), as well as *Kraeuselisporites* (Pl. I, Figs. 8–10). Lycopod spores of *Densoisporites*: *D. playfordii* (Balme) Dettmann (Pl. I, Fig. 1), and *Lundbladispora*: *L. obsoleta* Balme (Pl. I, Figs. 6, 7), *L.* cf. *obsoleta* Balme (Pl. I, Fig. 3), *L. brevicula* Balme (Pl. I, Fig. 2) are less frequent.

The reworked Permian miospores are represented mainly by *Lueckisporites virkkiae* Potonié et Klaus (Pl. II, Figs. 11, 12), *Klausipollenites schaubergeri* (Potonié et Klaus) Jansonius, *Jugasporites delasaucei* (Potonié et Klaus) Leschik and *Nuskoisporites dulhuntyi* Potonié et Klaus. The Carboniferous forms belong to the *Tripartites* sp. (Pl. II, Fig. 6) and *Triquitrites* sp. (Pl. II, Fig. 9). Both the Permian and Carboniferous specimens show features of reworking, which means they have a darker colour and are more strongly altered (very often their exoexine is torn off) than younger Triassic forms which are comparatively well preserved.

Planktonic possible fresh water uni- and multicellular algae are a signifacant element of this spectrum. Their content varies from a few to more than 50% in the single samples. The most abundant are unicellular algae of type A, whereas the multicellular forms of *Actinastrum* occur less frequently.

Fungal spores are mainly represented by the *Microsporonites* (al. *Tympanicysta*) sp. (Pl. II, Fig. 19) and aff. *Polyadosporites* sp.

Single acritarchs belong to *Baltisphaeridium* whereas prasinophyta belong to *Leiosphaeridia*. This assemblage represents the *Lundbladispora obsoleta–Protohaploxypinus pantii* Zone, distinguished in the lowermost Buntsandstein by T. Orłowska-Zwolińska

(1984, 1985). A similar assemblage was described by A. Fijałkowska (1991, 1992, 1994*a*) from the lowermost Buntsandstein of the Holy Cross Mts. This assemblage can also be correlated with the LT1-1 Zone of the scheme proposed by W. A. Brugman (1983) for the lowermost Buntsandstein in Western and Southern Europe.

PALYNOFACIES

Palynofacies analysis deals with the total acid-resistant organic residuum which can be observed under a transmitted-light microscope. The isolated particulate organic matter represents either whole organisms (such as miospores or acritarchs) or fragments (cuticles, "woody"). For the last decade, palynofacies analysis has been successfully applied to palaeoenvironmental studies (R.V. Tyson, 1995). The idea of using organic matter particles for this purpose comes from D. Habib (1979). Although it was developed and widely applied to sediments of a different age (*inter alia* D. J. Batten, 1982; T. J. A. Blondel *et al.*, 1993; M. C. Boulter, A. Riddick, 1986; K. Dybkjaer, 1991; C. C. Parry *et al.*, 1981; M. Prauss, 1989; A. Singh *et al.*, 1992; R.V. Tyson, 1984, 1989, 1993; C. J. Van Der Zwan, 1990), there are still only a few papers concerning older Palaeozoic and early Mesozoic deposits (T. K. Al-Ameri, 1993; J. B. Richardson, S. M. Rasul, 1990; P. F. Van Bergen, J. H. F. Kerp, 1990; H. G. M. Van De Laar, W. J. J. Fermont, 1990). This is due to the fact that in older sediments, generally containing highly matured organic matter, using palynofacies analysis is very often limited.

Four palynofacies were distinguished within the Permian-Triassic transitional sequence in the Żary Pericline (Fig. 3).

TYPE 1

C h a r a c t e r i s t i c s. The contents of palynomorphs oscillates between 1 and 20% (average 1–2%). Both spores and pollen grains occur in the same quantity. Planktonic algae are common. The palynofacies is dominated by the black structured matter among which "woody" particles are the most frequent whereas plant epiderms and tissue are less abundant. Unstructured matter is dominated by the black homogeneous particles (Pl. IV, Fig. 1).

Varied contents of organic matter as well as its comparatively good state of preservation suggest a short transport and deposition not far from the source area. Characteristics of organic matter and sedimentary features of sediment indicate deposition in a playa near-shore environment.

O c c u r r e n c e : Kosierz M25 borehole (1209.1–1213.8 m), Lubiatów M20 (1096.3 m), Nowa Wieś P1 (632.8–642.1, 668.0–677.1, 681.5 m) and Jasień P4 (601.2, 610.0–612.6 m).

TYPE 2

Type 2 is dominated by the black structured matter (mainly "woody" and indetermine particles). The palynofacies characteristics and sedimentological features of the sediment suggest deposition in marine shore environments. This type can be divided into two subtypes.

Subtype 2a is characterized by a comparatively high share of finely dispersed particles (Pl. IV, Figs. 2, 3).

O c c u r r e n c e: Kosierz M25 (1225.6–1228.0, 1233.0, 1239.0–1239.6 m), Lubiatów M20 (1104.0–1117.0 m) and Jasień P4 (605.0–605.2, 615.0 m).

Subtype 2b differs from subtype 2a in higher content of black unstructured particles (Pl. IV, Fig. 7).

O c c u r r e n c e: Kosierz M25 (1115.5, 1168.5–1176.1 m), Nowa Wieś P1 (678.5 m).

TYPE 3

C h a r a c t e r i s t i c s. The contents of palynomorphs is 1–10% and they are dominated by pollen grains. Acritarchs occur sporadically or are absent. Fungal spores and algae are scarce. Deposits containing this palynofacies originated in marine shore lakes. This palynofacies can be divided into two subtypes.

Subtype 3a is characterized by lower contents of palynomorphs which make up 1–5% of the organic matter and they are dominated by pollen grains. Acritarchs occur sporadically or are absent. Fungal spores and algae are scarce. The palynofacies is strongly dominated by the black structured matter (mainly "woody" and indeterminate particles) which share is 50–94% of total organic matter. The black homogeneous particles are the most abundant among unstructured matter (Pl. IV, Fig. 4).

O c c u r r e n c e: Kosierz M25 (1143.3–1152.0, 1176.7–1185.2 m), Bronków M27 (983.2 m).

Subtype 3b contains more palynomorphs (6–10% of organic matter); among them, pollen grains are the most abundant (Pl. IV, Figs. 5, 6). The palynofacies is strongly dominated by the black structured matter.

O c c u r r e n c e: Kosierz M25 (1100.5–1102.5, 1156.2 m).

TYPE 4

C h a r a c t e r i s t i c s. This type does not contain palynomorphs and is dominated by finely dispersed unstructured matter. "Woody" particles are the most abundant among the structured matter (Pl. IV, Fig. 8). The deposits containing this palynofacies may represent a lagoonal environment.

O c c u r r e n c e: Kosierz M25 (1118.1–1130.5, 1141.0 m), Lubiatów M20 (1102.3 m), Jasień P4 (609.1, 617.3–627.8 m) and Dychów M26 (1340.2–1341.9 m).

A sample taken from complex II of the Lubiatów M20 borehole (1140.0 m) does not contain organic matter at all.

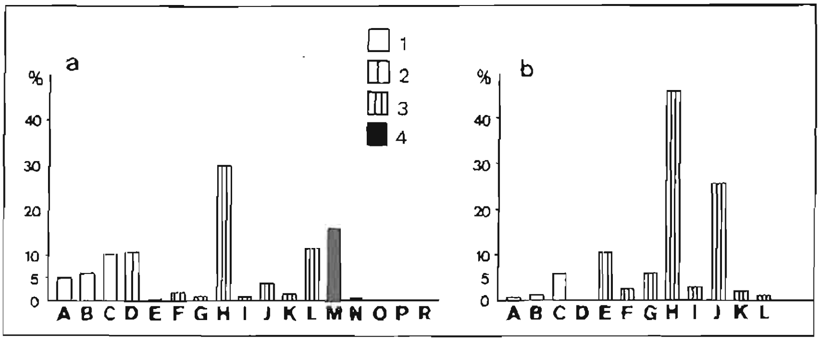

Fig. 4. Application of palaeoenvironmental model to the Permian and Triassic microfloral assemblages from the Żary Pericline and North Sudetic Trough; a — Early Triassic assemblage, b — Late Permian assemblage

1 — hygrophytic elements, 2 — fungal spores, 3 — xerophytic elements, 4 — microphytoplankton; palynomorphs groups: A — trilete, acavate, laevigate spores, B — trilete, cingulate and zonate spores, C — monosulcate pollen, D — fungal spores, E — bisaccate, monolete pollen, F — bisaccate, trilete pollen, G — bisaccate, alete pollen, H — bisaccate, striatite pollen, I — *Triadispora* group, J — vesicate pollen, K — monosulcate pollen, L — circumpollen group, M — chlorophyceae algae, N — *Baltisphaeridium*, O — *Micrhystridium*, P — *Veryhachium*, R — *Leiosphaeridia*

Zastosowanie modelu paleośrodowiskowego do permskich i triasowych zespołów mikroflorystycznych z perykliny Żar i niecki północnosudeckiej; a — zespół wczesnotriasowy, b — zespół późnopermski

1— elementy hygrofilne, 2 — spory grzybów, 3 — elementy kserofilne, 4 — mikrofytoplankton; grupy palinomorf: A — spory ze znakiem trilet, gładkie bez „cavy", B — spory ze znakiem trilet z pierścieniem lub zoną, C — ziarna pyłku monosulcate, D — spory grzybów, E — dwuworkowe ziarna pyłku ze znakiem monolet, F — dwuworkowe ziarna pyłku ze znakiem trilet, G — dwuworkowe ziarna pyłku bez znaku, H — dwuworkowe, prążkowane ziarna pyłku, I — grupa *Triadispora*, J — ziarna pyłku vesicate, K — jednoworkowe ziarna pyłku, L — grupa circumpollen, M — glony zielone, N — *Baltisphaeridium*, O — *Micrhystridium*, P — *Veryhachium*, R — *Leiosphaeridia*

PALAEOCLIMATIC AND PALAEOENVIRONMENTAL ASPECTS

A combination of the H. Visscher, C. J. Van Der Zwan (1981) and G. Jerenič, B. Jelen (1991) models, based on the statistical analyses of xerophytic and hygrophytic elements in microfloral assemblages, was used for palaeoclimatic reconstructions (Fig. 4).

The xerophytic elements (47.3% of the spectrum), belonging to conifers, are represented by striatite pollen grains of the *Lunatisporites* and *Protohaploxypinus* (group H). They predominate over the hygrophytic forms (22.3% of the spectrum) — mainly spores of ferns (*Cyclotriletes*, *Endosporites*) and lycopods (*Densoisporites*, *Lundbladispora*) (groups A and B). Pollen of cycadales are abundant (group C).

Planktonic, chlorophyceae algae (group M) are comparatively frequent whereas acritarchs (groups N–R) occur seldom.

The similar rates between hygro- and xerophytic elements are observed also in the Early Triassic assemblage from the Holy Cross Mts. (A. Fijałkowska, 1994*a*) where xerophytic forms make up 53% of the spectrum.

A distinct difference in the quantity of hygro- and xerophytic components as well their character indicates a dry, warm tropical or subtropical climate during the Early Triassic

(Griesbachian) in southern Poland. A slight increase of humidity is observed in comparison with older Zechstein deposits of PZ4 Cyclothem (Fig. 4).

This suggestion is confirmed by the palaeogeographical reconstructions and palaeoclimatic models. P. A. Ziegler (1989) placed the Polish area at about 30°N latitude, in the dry tropical/subtropical zone at the end of the Palaeozoic era. Similar climatic conditions, according to L. A. Frakes (1979) as well D. Pollard and M. Schulz (1994), prevailed during the Early Triassic. The Lower Triassic palaeophytogeographic map, presented by A. M. Ziegler *et al.* (1994), shows that the zone of subtropical dry floras of the Europe group continued to North China and this pattern is a holdover from the Late Permian. An important element of this flora is the arborescent lycopod *Pleuromeia*, which seems to have achieved a wide distribution in coastal and lacustrine environments during the Early Triassic (I. A. Dobruskina, 1987; D. Mader, 1990).

The petrographical-sedimentological features of sediment as well as palynofacies analysis allowed G. Czapowski (G. Czapowski, A. Fijałkowska, 1993; G. Czapowski *et al.*, in preparation) to recognized three sedimentary stages with the development of the Permian-Triassic sequence in the Żary Pericline.

S t a g e I (complex I, part or whole complex II) comprises sedimentation in continental lakes and playas. It reflects a regressional phase after the accumulation of the Upper Zechstein evaporites and genetically is connected with the Zechstein sedimentary cycle.

S t a g e II (part or whole complex II) reflects the first phase of the Early Triassic transgression when deposition took place on the marine nearshore.

S t a g e III (complex III) is connected with clastic deposition in a coastal plain, lagoons and locally alluvial fan environments. After this stage a big regression took place and alluvial sedimentation of the Lower Buntsandstein began in the whole marginal area of the Polish Basin.

Similar development of the sedimentary environments is observed in the Holy Cross Mts. area (A. Fijałkowska, M. Kuleta, 1994*a*, *b*; M. Kuleta, A. Fijałkowska, 1995). Stage I comprises here Pzt and Pzt-N lithological complexes of M. Kuleta (1985, 1993, in preparation), stage II — A0, A0-N, A complexes, and stage III — A1 and probably the lowermost part of the B complex.

CONCLUSIONS

1. One spore-pollen assemblage, representing the *Lundbladispora obsoleta–Protohaploxypinus pantii* Zone was identified within complexes II and III of the lowermost Buntsandstein in the Żary Pericline.

2. Four palynofacies were distinguished within the lowermost Buntsandstein deposits, which together with sedimentological features of sediment, indicate deposition in marine nearshore environments.

3. The palaeoclimatic model used in this study suggests a dry, warm, tropical or subtropical climate during the Early Triassic. A slight increase of humidity is observed in comparison with earlier time of the PZ4 Cyclothem deposition. This phenomenon in also known from the Holy Cross Mts.

4. Three stages can be recognized in the environmental evolution of the Permian-Triassic sequence in the studied area; the first one is connected with the end of the Zechstein sedimentary cycle, the second reflects the first Early Triassic transgression and the third is linked with an initial phase of regression which took place later in the whole southern marginal area of the Polish Basin (G. Czapowski *et al.*, in preparation).

5. The biostratigraphic Permian-Triassic boundary lies within complex II and can be well correlated with the boundary determined by G. Czapowski on the basis of sequence stratigraphy.

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Appendix 1

DESCRIPTION OF CHLOROPHYCEAN ALGAE

Planktonic chlorophycean algae of Permian and Early Triassic age from possible fresh water or low-salinity habitats have been very weakly recognized so far. One genus, *Wilsonastrum* n. gen., was described by J. Jansonius (1962) from the Permian-Triassic deposits of Western Canada; two genera: *Syndesmorion* n. gen. and *Botrycoccus* Kützing were identyfied by H. H. Ecke (1986) from the Zechstein and Lower Buntsandstein of Germany and a few taxa: *Schizocystia rara* Playford et Dettmann, *Actinastrum* sp., *Crucigeniella* sp. were found in the Scythian deposits of Australia (W. Brenner, C. B. Foster, 1994). A few algal forms were recognized by the author in the Lower Triassic deposits from the Żary Pericline.

Phylum **Chlorophyceae**
Order **Zygnematales**
Family **Coelastraceae**
Genus *Actinastrum* Lagerheim, 1894

Synonymy: 1986 *Syndesmorion* Ecke.

Actinastrum paulii (Ecke, 1986) Brenner et Foster, 1994
(Pl. III, Figs. 10–12)

1986 *Syndesmorion paulii* n. sp.; H. H. Ecke: p. 73–74, Pl. 10, Figs. 1–3.
1994 *Actinastrum*? sp.; W. Brenner, C. B. Foster: p. 220, Pl. 2, Fig. 3.

D i m e n s i o n s : single cell legth 10–20 µm, width 7–10 µm, coenobium length 40–60 µm, width 17–28 µm (based on 8 specimens).

D e s c r i p t i o n . Multicellular, colonial alga. The coenobium is built of 8–40 (average 16) elongated cells, arranged on one, zigzag axis. Cells lie in one plane, symmetrical to the axis of the coenobium. One cell is at each end of the axis. Single cells are fusiform to elliptical in shape, tipped with a short spine on the outer end. Exine is thin (1 µm), laevigate with secondary folding.

D i s c u s s i o n . Based on morphology (arragement and size of coenobium) W. Brenner and C. B. Foster (1994) tentatively assigned this form to *Actinastrum*.

O c c u r r e n c e . Poland: Żary Pericline, complex III of the Lower Triassic; Germany, Lower Triassic (H. H. Ecke, 1986); Australia: Perth Basin, Lower Triassic (W. Brenner, C. B. Foster, 1994).

Actinastrum stellatum n. sp.
(Pl. III, Fig. 7)

H o l o t y p e : Pl. III, Fig. 7.
T y p e h o r i z o n : Lower Triassic.
T y p e l o c a l i t y : Kosierz M25 borehole, depth 1233.0 m, Żary Pericline.
D e r i v a t i o n o f n a m e : [Lat.] *stella* — star, *stellatum* — starry; coenobium with a radial organization of cells, resembling a star.
D i a g n o s i s : Colonial algae built of 7 elongated cells, radially arranged on one plane.
D i m e n s i o n s: single cell length 8–18 µm (holotype 10 µm), width 7–10 µm (holotype 7 µm); coenobium diameter 30–40 µm (holotype 35 µm) (based on 7 specimens).

D e s c r i p t i o n . Colonial alga built of 7 spindle shaped cells which are radially, in one plane, organized on a zigzag axis. There is a cell only on one end of the axis whereas the second end is empty. Single cells end with short tip in the outer side. Exine is thin (1 µm), laevigate with small secondary folding.

D i s c u s s i o n . It differs from *A. paulii* (Ecke) Brenner et Foster in smaller, constant number of cells in single coenobium (7) and their radial orientation as well as smaller size of single vesicle.

O c c u r r e n c e . Żary Pericline, complex III of the Lower Triassic.

Family ?Scenedesmaceae
Genus aff. *Genicularia*
aff. *Genicularia zwolinskai* n. sp.
(Pl. III, Fig. 6)

H o l o t y p e : Pl. III, Fig. 6.
T y p e h o r i z o n : Lower Triassic.
T y p e l o c a l i t y : Kosierz M25 borehole, depth 1239.6 m, Żary Pericline.
D e r i v a t i o n o f n a m e : from the name of Polish palynologist T. Orłowska-Zwolińska.
D i a g n o s i s : Multicellular, colonial alga of elongate, cylindrical shape, built of elongated, rectangular cells

forming a regular, rhomboidal net.
Dimensions: single cell length 8–10 μm (holotype 9 μm), width 3–5 μm (holotype 3 μm); length of coenobium 15–30 μm (holotype 28 μm), width 15 μm (holotype 15 μm); dimension of fensters of net 6–8 μm.

Description. Multicellular alga built of elongated, rectangular cells which form a cylindrical coenobium in the shape of a regular, rhomboidal net. Exine of vesicles thin (1 μm) and laevigate.

Discussion. This alga shows a morphological similarity to recent alga of the genus *Genicularia*.

Occurrence. Żary Pericline, complex III of the Lower Triassic.

Incertae sedis

Alga type A n. sp.

(Pl. III, Figs. 1–3)

Holotype: Pl. III, Fig. 2.
Type horizon: Lower Triassic.
Type locality: Kosierz M25 borehole, depth 1107.0 m, Żary Pericline.
Diagnosis: Unicellular, circular alga with secondary exinal folding in marginal part.
Size: 45–70 μm (holotype 50 μm).

Description. Circular shaped, unicellular alga. Exine is thin (0.5–1 μm), laevigate with numerous secondary folds concentrated in marginal part of body.

Discussion. Both shape and size of this alga make it very similar to the spore *Calamospora plicata* (Luber et Waltz) Klaus from which it differs in thinner, transparent exine and lack of trilete mark.

Occurrence. Żary Pericline, complex III of the Lower Triassic.

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PALINOSTRATYGRAFIA I PALINOFACJE OSADÓW Z POGRANICZA PERMU I TRIASU NA OBSZARZE PERYKLINY ŻAR

Streszczenie

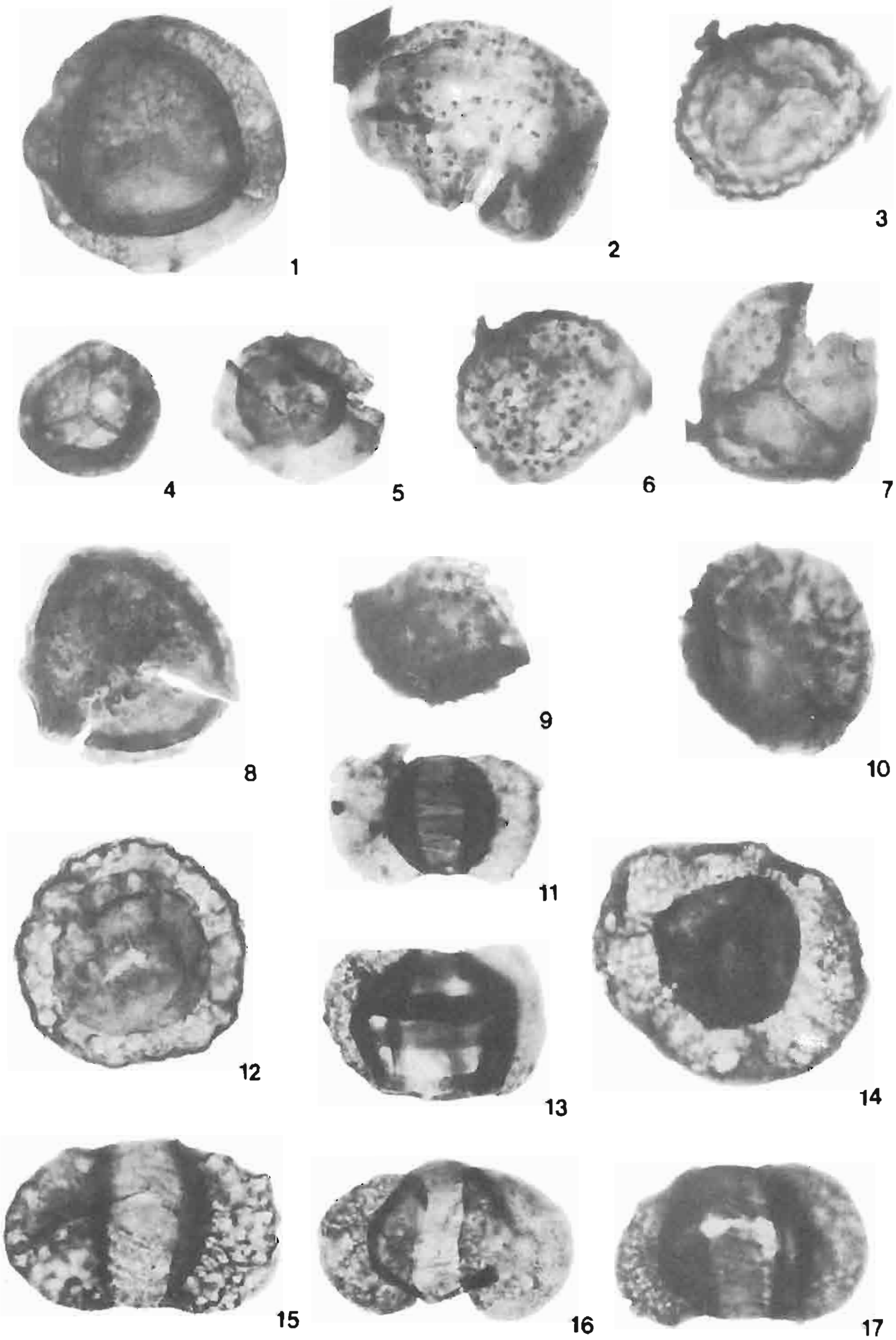
Osady z pogranicza permu i triasu na obszarze perykliny Żar mają charakter przejściowy. Dolna część tej sekwencji, obejmująca kompleks I, stanowi odpowiednik stropowej serii terygenicznej (Pzt), wyróżnionej w osadach górnego cechsztynu na obszarze Polski centralnej i północnej przez G. Pieńkowskiego (1987, 1989, 1991) i R. Wagnera (1987, 1988, 1991, 1994). W środkowej części (kompleks II), w różnym położeniu, przebiega granica między cechsztynem i pstrym piaskowcem, wyróżniana na podstawie kryteriów litologicznych, sedymentologicznych, jak również cech środowiskowych. W niektórych otworach (np. otwór Bronków M27 czy Lubiatów M20) granica ta leży w stropie kompleksu II, natomiast w innych (Nowa Wieś P1) lokalizowana jest w spągu kompleksu II lub w jego obrębie (otwór Kosierz M25). Górna część omawianej sekwencji (kompleks III) należy do dolnego pstrego piaskowca i może stanowić odpowiednik formacji bałtyckiej, wyróżnionej przez R. Wagnera (1987, 1991, 1994) na obszarze Polski północnej. Kompleksy te odzwierciedlają również zmiany środowiskowe i mogą być traktowane jako jednostki izochroniczne w stratygrafii sekwencyjnej.

W badanym materiale (kompleks II i III) wyróżniono jeden zespół sporowo-pyłkowy, reprezentujący najniższy poziom pstrego piaskowca — *Lundbladispora obsoleta–Protohaploxypinus pantii*. Granica biostratygraficzna między permem i triasem, stawiana w obrębie kompleksu II, dość dobrze koreluje się ze zmianami środowisk sedymentacji (od kontynentalnego do morskiego przybrzeżnego).

Zidentyfikowano ponadto 4 palinofacje, które wraz z cechami sedymentologicznymi osadu wskazują na depozycję w środowisku przybrzeża morskiego i playi.

Model paleoklimatyczny, zastosowany w badaniach, pozwolił na określenie klimatu panującego we wczesnym triasie jako suchy, ciepły, o charakterze zwrotnikowym lub podzwrotnikowym. Obserwuje się jednocześnie nieznaczny wzrost wilgotności w porównaniu z wcześniejszym okresem późnego permu. Sugestia ta znajduje potwierdzenie w rekonstrukcjach paleogeograficznych i paleoklimatycznych dla obszaru europejskiego (por. L. A. Frakes, 1979; P. A. Ziegler, 1989; A. M. Ziegler i in., 1994).

PLATE I



Anna FIJAŁKOWSKA — Palynostratigraphy and palynofacies of the Permian-Triassic transitional sequence in the Żary Pericline (SW Poland)

PLATE I

Fig. 1. *Densoisporites playfordii* (Balme) Dettmann
Depth 1107.0 m
Fig. 2. *Lundbladispora brevicula* Balme
Depth 1225.6 m
Fig. 3. *Lundbladispora* cf. *obsoleta* Balme
Depth 1156.2 m
Fig. 4. *Densoisporites playfordii* (Balme) Dettmann
Depth 1156.2 m
Fig. 5. *Endosporites papillatus* Jansonius
Depth 1100.5 m
Fig. 6. *Lundbladispora obsoleta* Balme
Depth 1156.2 m
Fig. 7. *Lundbladispora obsoleta* Balme
Depth 642.1 m
Fig. 8. *Kraeuselisporites apiculatus* Jansonius
Depth 1107.0 m
Fig. 9. *Kraeuselisporites* cf. *cuspidus* Balme
Depth 1151.0 m
Fig. 10. *Kraeuselisporites cuspidus* Balme
Depth 1239.0 m
Fig. 11. *Protohaploxypinus pantii* (Jansonius) Orlowska-Zwolińska
Depth 1151.0 m
Fig. 12. Monosaccites indet.
Depth 1100.5 m
Fig. 13. *Protohaploxypinus samoilovichii* (Jansonius) Hart
Depth 1100.5 m
Fig. 14. *Nuskoisporites* sp.
Depth 1156.2 m
Fig. 15. *Strotersporites richteri* (Klaus) Wilson
Depth 1100.5 m
Fig. 16. *Striatopodocarpites* sp.
Depth 1116.5 m
Fig. 17. *Strotersporites* sp.
Depth 1107.0 m

Figs. 1–6, 8–15, 17 — Kosierz M25 borehole, Fig. 7 — Nowa Wieś P1 borehole, Fig. 16 — Lubiatów M20 borehole; Figs. 3–7, 9–17 — x 500, Figs. 1, 2, 8 — x 750; Lower Triassic

Fig. 1–6, 8–15, 17 — otwór Kosierz M25, fig. 7 — otwór Nowa Wieś P1, fig. 16 — otwór Lubiatów M20; fig. 3–7, 9–17 — 500 x, fig. 1, 2, 8 — 750 x; trias dolny

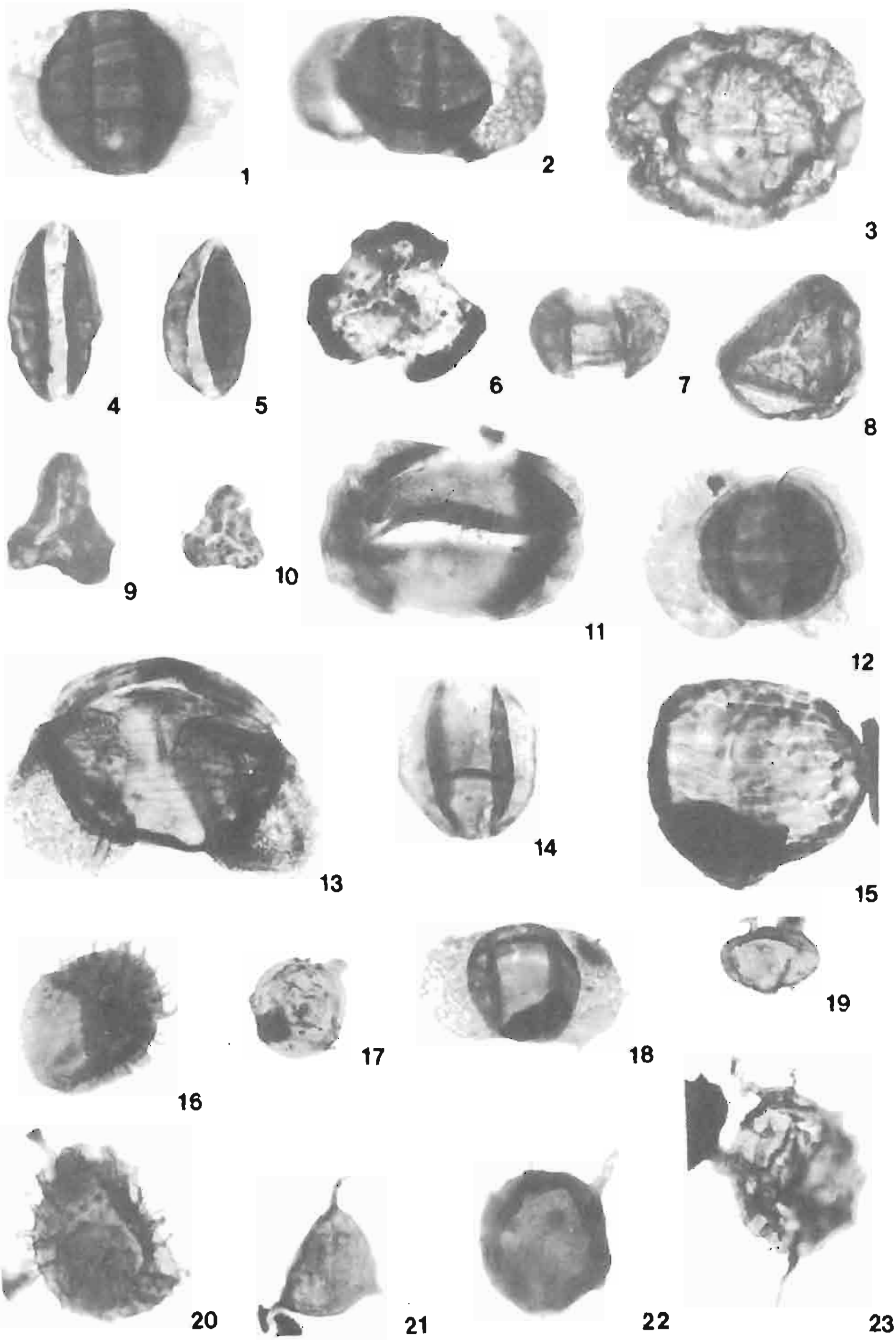


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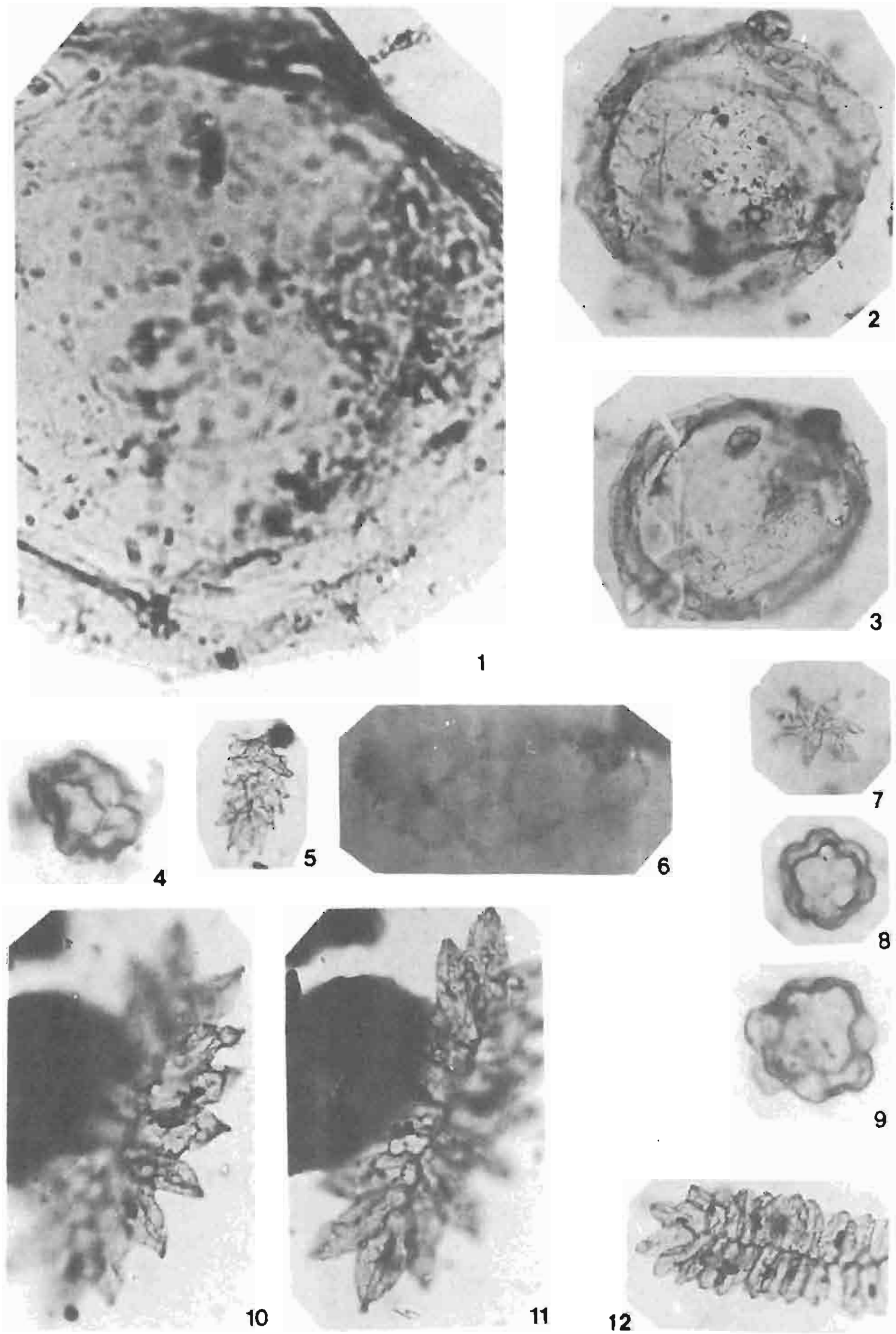
PLATE II

Fig. 1. *Lunatisporites noviaulensis* (Leschik) Scheuring
Depth 1178.0 m
Fig. 2. *Lunatisporites hexagonalis* (Jansonius) Scheuring
Depth 1102.5 m
Fig. 3. *Angustisulcites gorpii* Visscher
Depth 1107.0 m
Fig. 4. *Cycadopites follicularis* Wilson et Webster
Depth 1100.5 m
Fig. 5. *Cycadopites coxii* Visscher
Depth 1100.5 m
Fig. 6. *Tripartites* sp. (Carboniferous redeposited form)
Depth 1100.5 m
Fig. 7. *Lunatisporites gracilis* (Jansonius) Fijałkowska
Depth 1102.5 m
Fig. 8. *Duplicisporites granulatus* Leschik
Depth 1152.0 m
Fig. 9. *Triquitrites* sp. (Carboniferous redeposited form)
Depth 1156.2 m
Fig. 10. *Leiotriletes* sp.
Depth 1156.2 m
Fig. 11. *Lueckisporites virkkiae* Potonié et Klaus NAb (Permian redeposited form)
Depth 1143.3 m
Fig. 12. *Lueckisporites virkkiae* Potonié et Klaus NAc (Permian redeposited form)
Depth 1116.5 m
Fig. 13. *Crustaesporites globosus* Leschik (Permian redeposited form)
Depth 1100.5 m
Fig. 14. *Gardenasporites* cf. *leonardii* Klaus (Permian redeposited form)
Depth 1107.0 m
Fig. 15. *Vittatina subsaccata* Samoilovich (Permian redeposited form)
Depth 1100.5 m
Figs. 16, 20. *Micrhystridium* sp.
Depth 1239.6 m
Fig. 17. *Leiosphaeridia* sp.
Depth 1102.5 m
Fig. 18. *Gardenasporites heisseli* Klaus (Permian redeposited form)
Depth 1156.2 m
Fig. 19. *Microsporonites* (al. *Tympanicysta*) sp. (fungal spore)
Depth 1233.0 m
Fig. 21. *Veryhachium* sp.
Depth 1102.5 m
Figs. 22, 23. *Baltisphaeridium* sp.
Depth 1102.5 m

Figs. 1–11, 13–23 — Kosierz M25 borehole, Fig. 12 — Lubiatów M20 borehole; x 500; Lower Triassic
Fig. 1–11, 13–23 — otwór Kosierz M25, fig. 12 — otwór Lubiatów M20; 500 x; trias dolny

PLATE III



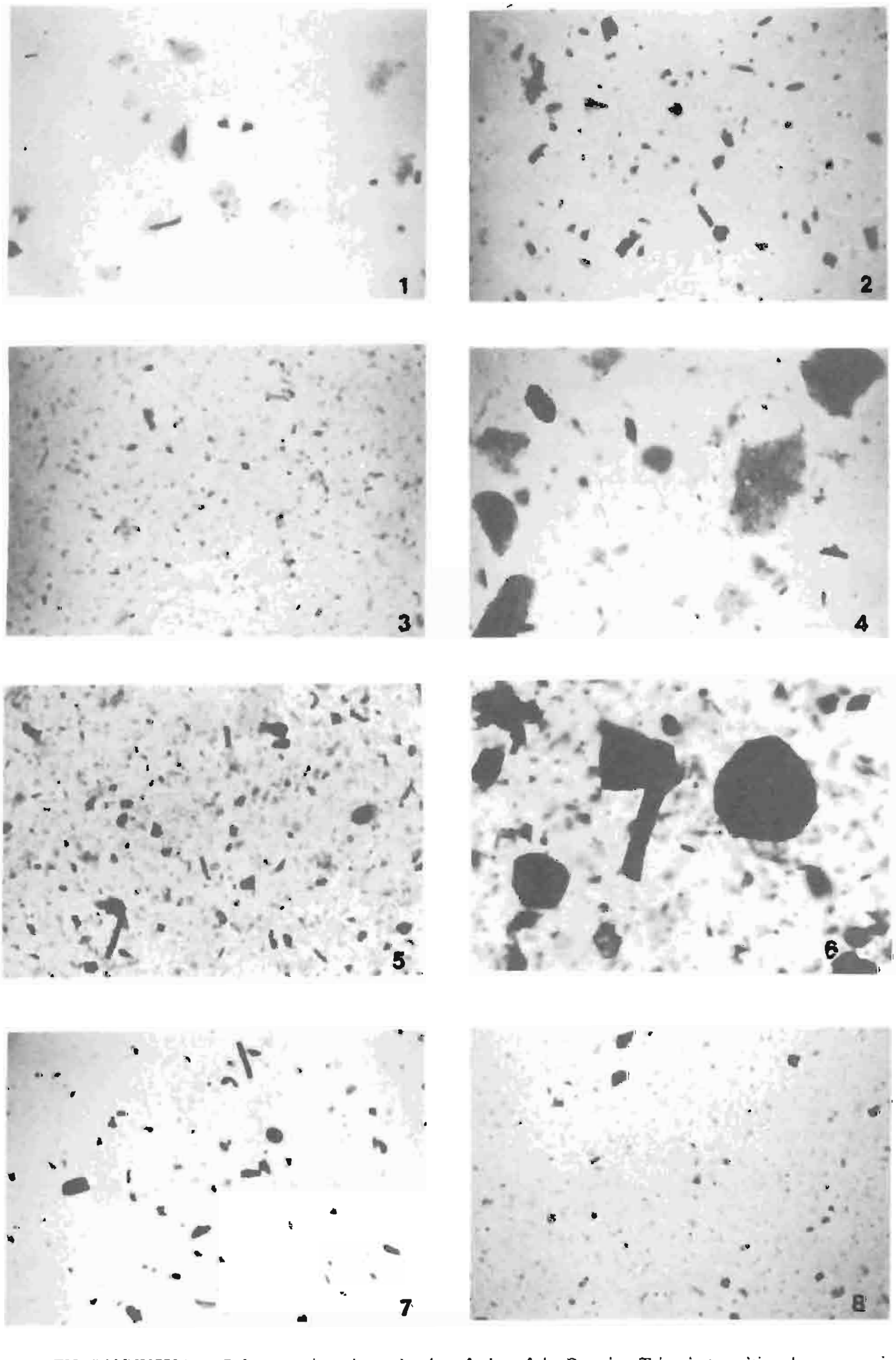
Anna FIJAŁKOWSKA — Palynostratigraphy and palynofacies of the Permian-Triassic transitional sequence in the Żary Pericline (SW Poland)

PLATE III

Fig. 1. Alga type A n. sp.
Depth 1107.0 m
Fig. 2. Alga type A n. sp.
Depth 1107.0 m
Fig. 3. Alga type A n. sp.
Depth 1107.0 m
Fig. 4. aff. *Polyadosporites* sp. (fungal spore)
Depth 1100.5 m
Fig. 5. *Syndesmorion* sp.
Depth 654,3 m
Fig. 6. aff. *Genicularia zwolinskai* n. sp.
Depth 1239.6 m
Fig. 7. *Actinastrum stellatum* n. sp.
Depth 1233.0 m
Figs. 8, 9. aff. *Polyadosporites* sp.
Depth 1102.5 m
Figs. 10–12. *Actinastrum paulii* Ecke
Depth 654,4 m

Figs. 1–4, 6–9 — Kosierz M25 borehole, Figs. 5, 10–12 — Nowa Wieś P1 borehole; Figs. 1, 5, 7, 12 — x 500, Figs. 2–4, 6, 10, 11 — x 750; Pzt Series, Lower Triassic

Fig. 1–4, 6–9 — otwór Kosierz M25, fig. 5, 10–12 — otwór Nowa Wieś P1; fig. 1, 5, 7, 12 — 500 x, fig. 2–4, 6, 10, 11 — 750 x; seria Pzt, dolny trias



Anna FIJAŁKOWSKA — Palynostratigraphy and palynofacies of the Permian-Triassic transitional sequence in the Żary Pericline (SW Poland)

PLATE IV

Fig. 1. Palynofacies type 1
Depth 1209.1 m
Fig. 2. Palynofacies subtype 2a
Depth 1239.6 m
Fig. 3. Palynofacies subtype 2a
Depth 1233.0 m
Fig. 4. Palynofacies subtype 3a
Depth 1183.7 m
Figs. 5, 6. Palynofacies subtype 3b
Depth 1100.5 m
Fig. 7. Palynofacies subtype 2b
Depth 1168.5 m
Fig. 8. Palynofacies type 4
Depth 1126.8 m

Kosierz M25 borehole; Figs. 1–5, 7, 8 — x 160, Fig. 6 — x 250; Lower Triassic
Otwór Kosierz M25; fig. 1–5, 7, 8 — 160 x, fig. 6 — 250 x; dolny trias