acta geologica polonica

Vol. 30, No. 4 Warszawa 1980

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Stratigraphy and palaeogeography of Lower Triassic in Poland on the bassis of megaspores

ABSTRACT: The study deals with stratigraphy and correlation of Buntsandstein in the Polish Lowland and in the Tatra Mts on the basis of megaspores. Three key (for Buntsandstein) assemblage megaspore zones were distinguished: Otynisporites eotriassicus, Trileites polonicus — Pusulosporites populosus and Trileites validus. Two new species (*Echitriletes validispinus* sp. n. and *Nathorstisporites cornutus* sp. n.) were described. An influence of tectonic movements of Pfälzic and Hardegsen phases on sedimentation of Buntsandstein was discussed.

INTRODUCTION

In the paper a lithostratigraphy, a biostratigraphy and a palaeogeography of Lower Triassic in the Polish Lowland and in the Tatra Mts are presented. The material for the analyses came from cores of 18 boreholes of Geological Institute, Warsaw and of petroleum exploration firms at Wołomin and Piła (Fig. 1); among them 11 boreholes were cored in full. Besides, the random samples of nine other boreholes of petroleum exploration firms were used. In the Tatra Mts the samples were taken from exposures of High-tatric Triassic by Żółta Turnia and in the valley of Stare Szałasiska as well as from Sub-tatric Triassic in the Jaworzynka valley.

During the analysis of these profiles and the confrontation of literature data the author concluded that within a sequence of Buntsandstein there were almost in the whole area of the Polish Lowlands two oolitic horizons that had originated in result of marine ingressions. Therefore, a previously prepared lithostratigraphical scheme of Poland (Fuglewicz 1973) could be used. On the ground of the same data a map of occurrence of particular Buntsandstein horizons, connected with ingressions (of lower-politic beds, upper-oolitic beds and Röt), could be prepared (Fig. 1).

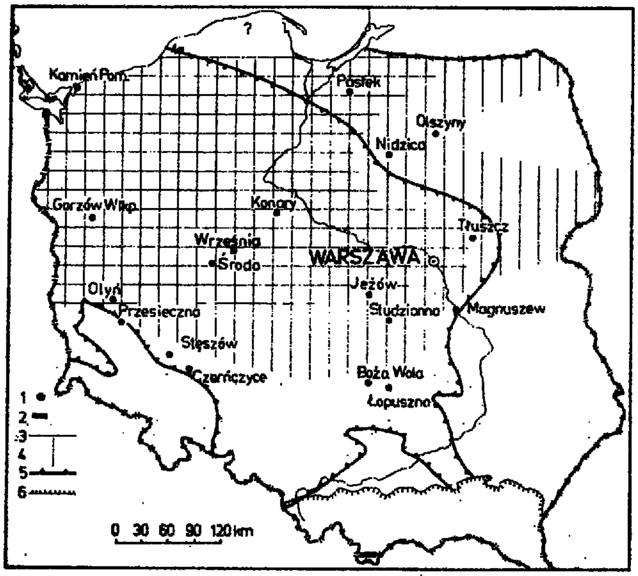

Fig. 1. Localization sketch of analyzed boreholes and exposures and of extent of some Buntsandstein horizons (extent of Röt after Senkowiczowa & Szyperko-Śliwczyńska (1972) with slight modification)

1 — more important of analyzed boreholes, 2 — exposures of the Lower Triassic in the Tatra Mts, 3 — found extent of the lower-oolitic beds, 4 — found extent of the upper-oolitic beds, 5 — extent f Röt, 6 — northern border of the Carpathian overthrust

Systematic author's research of megaspores in Buntsandstein deposits in various regions of Poland, carried through for over ten years has been at first unsuccessful but then, effected in good results — in collecting a rich set of megaspores. About 900 samples were subjected to a megaspore analysis; the samples were macerated by the author's improved method (Fuglewicz 1977a).

In result of the megaspore analyses 46 new megaspore species were palaeontologicaly described (Fuglewicz 1973, 1977, 1979b); among them two species (*Echitriletes validispinus* sp.n. and *Nathorstisporites cornutus* sp.n.) are described in the present paper. Besides, six megaspore species are included in a *„species"* category due to a small number of specimens.

The plates contain mainly the illustrations of these species that have been up to now illustrated in a reflected light only but they were succeeded to be photographed with a use of a scanning microscope.

The collected megaspore data coming the whole Buntsandstein of Poland, allowed to distinguish three megaspore zones: a zone Otynisporites eotriassicus, guide fossil for the Lower Buntsandstein; a zone Trileites polonicus — Pusulosporites populosus, guide fossil for the Middle Buntsandstein, and a zone Trileites validus, guide fossil for the

Upper Buntsandstein. Within a zone O. eotriassicus two subzones were distinguished: lower O. eotriassicus and upper O. eotriassicus subzones. Barren complexes were distinguished as intervals. barren intrazones and interzones (Fig. 20).

Lithology and megaspore content of ten most important (full and of best megaspore documentation) borehole cores are graphicaly presented (Fig. 5—14). In full-cored boreholes the lithostratigraphic and the biostratigraphic borders could be defined in detail whereas in the boreholes of control coring these borders were approximate only.

A use of a biostratigraphic scale for correlation of Buntsandstein profiles enabled to revise the errors in correlations based on a lithologic method only. The latter refers mainly to a correlation of Buntsandstein deposits of south-western and north-eastern Poland (Fig. 4). A megaspore analysis was also useful for interpretation of environmental and palaeogeographic conditions.

A confrontation of lithostratigraphic and biostratigraphic data enabled to find the sedimentary breaks caused by two tectonic phases, Pfälzic and Hardegsen ones, of decisive influence on sedimentation of Buntsandstein deposits. Subsidence, sedimentation and palaeogeography of Buntsandstein in Poland and probably, in the whole Central European Basin were proved to be ruled by the contrastive movements of Palaeozoic and Precambrian platforms (Figs 21, 23).

Acknowledgements. The author thanks from his heart to Professor J. Malinowski, the Head of the Geological Institute, Warsaw and to Docent Dr. A. Witkowski, the chief of Dept. of Regional Geology of Platform Areas for offering the cores for megaspore analyses. I am also indebted to the managers of petroleum exploration firms at Wołomin and Piła.

I wish also to thank very much to Professor J. Znosko, Professor S. Orłowski and Professor J. Kutek for their helpful criticism and discussions. Particular thanks are given to Dr. W. R. Kowalski, for frequent discussions and for a help in preparing the illustrations of this work and to Dr. B. Gaczyński and Mr. A. Iwanow, M.Sc. for their remarks. I would like also to thank Mrs. J. Smoleńska, M.Sc. for a final drawing of the figures. The photographs of megaspores were done with a scanning microscope in the Nencki Institute of Experimental Biology, Polish Academy of Sciences, whereas the photographs of other fossils were taken by Mrs. B. Drozd, M.Sc. and Mrs. S. Zielińska; I thank them both very much. An inappreciable help during preparation of this work was given to me by my wife, Dr. B. Jendryka — Fuglewicz to whom I thank particularly warmly.

PRESENT KNOWLEDGE OF STRATIGRAPHY OF BUNTSANDSTEIN IN POLAND (A REGIONAL DESCRIPTION)

LITHOSTRATIGRAPHIC STUDIES

Until 1965 a traditional subdivision of Buntsandstein (into lower, middle and upper ones) had been applied for the Polish Lowland with regard to exposures as well as for boreholes (Szubin). Buntsandstein, known from exposures, represents a littoral part of the basin, it is much reduced and contains a great content of coarse-detrital rocks; there are also numerous sedimentary breaks (Fig. 3, also Backhaus 1976). On this basis the first lithostratigraphic schemes have been prepared, similarly as in Germany. The data from the boreholes supplied with

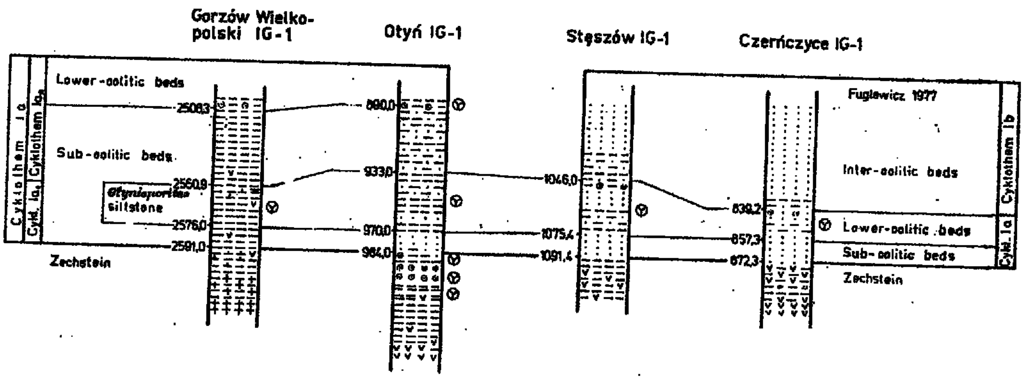

Fig. 2. Correlation of the bottom border of Buntsandstein taking some boreholes from the Fore-Sudetic Monocline as example. Explanations as at Fig. 4

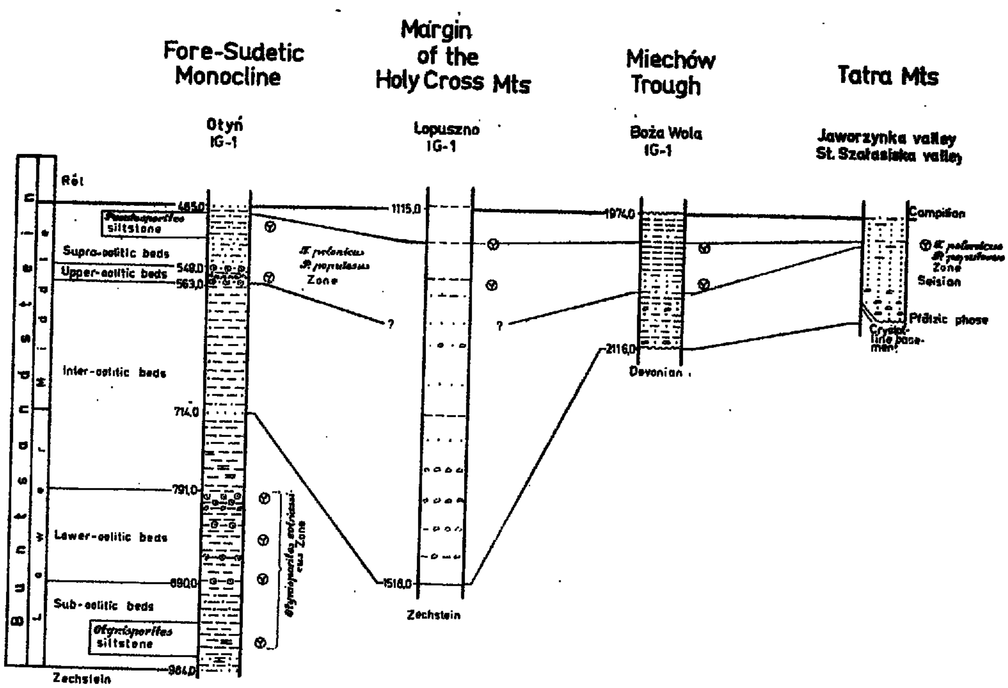

Fig. 3. Correlation of sediments of Middle Buntsandstein in some sections. Explanations as at Fig. 4

new, unexpectable information. A thickness of Buntsandstein in the Polish Lowland was found to be many times greater than in exposures and the sequences were much more complete. For such sequences a subdivision of Buntsandstein into lower, middle and upper parts are already unsatisfactory and frequently, due to another composition, impossible to be done. Among various proposals of Buntsandstein stratigraphy in the Polish Lowland the most consistent and the most detailed subdivision has been done for the Fore-Sudetic Monocline.

FORE — SUDETIC AREA

Good cores from that area were obtained in result of bitumen exploration and were analyzed by Tokarski (1962, 1965), then by Senkowiczowa (1965b) and Sokołowski (1967). Basing on a cyclic succession of evaporitic complexes Tokarski (1965) and Senkowiczowa (1965b) prepared independently a lithostratigraphical subdivision of Röt. The Senkowiczowa's subdivision, slightly modified was then applied by Fuglewicz (1977b, 1979a, Table 1).

Sokołowski (1967) presented a stratigraphic scheme for the whole Buntsandstein of the Fore-Sudetic Monocline. Basing on a physico-chemical changeability of the sediments and referring to the subdivision of Röt by Tokarski, he distinguished 21 lithologic-logging complexes within the Buntsandstein (Table 1). A great facial changeability of deposits of Buntsandstein made the Sokołowski's subdivision to be not of a universal significance what has been already noticed

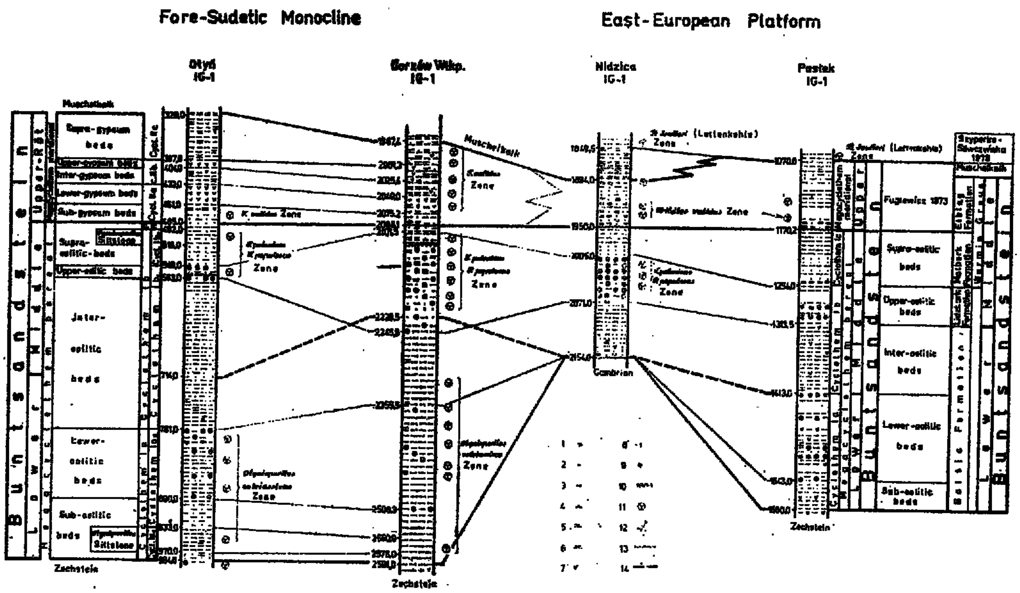

Fig. 4. Correlating section of some profiles of the Buntsandstein of the Fore-Sudetic Monocline and of the north-eastern Poland

1 — conglomerates, *2* — sandstones, *3* — claystones and siltstones, *4* — marls, *5* — limestones, *6* — dolomites, *7* — gypsum and anhydrite, *8* — salts, *9* — oolitic sediments, *10* — stromatolites, *11* — megaspores, *12* — tectonic contact, *13* — sedimentary discontinuities, *14* — lower border of the Middle Buntsandstein

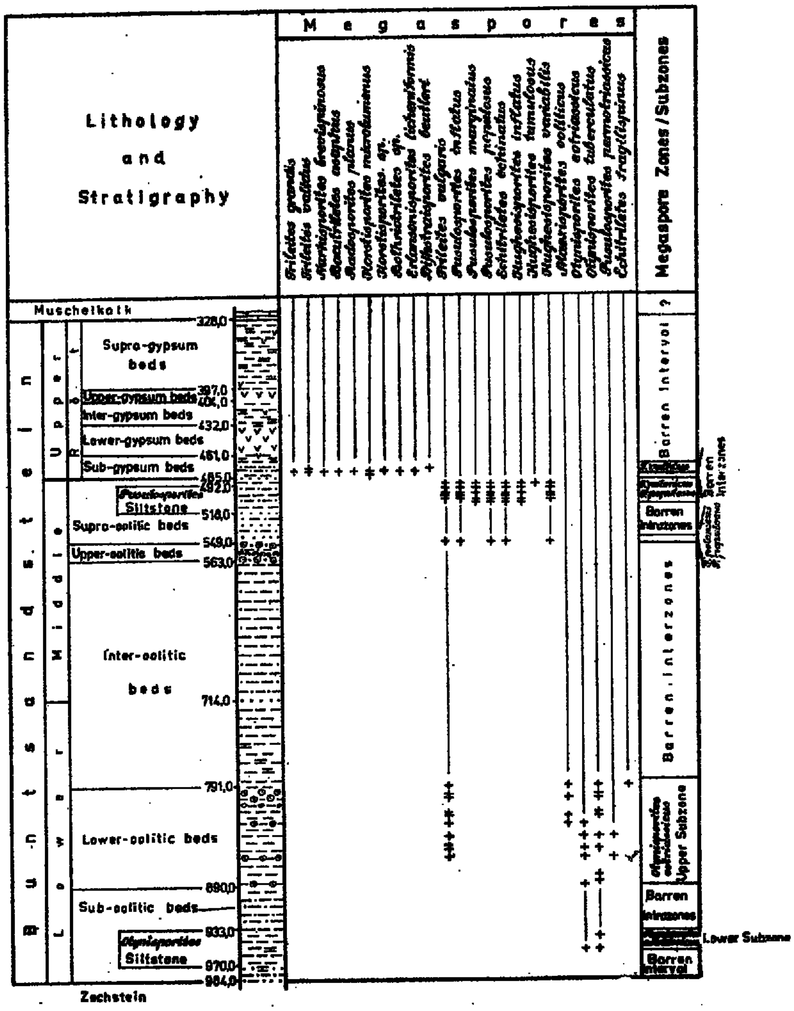

Fig. 5. Section and stratigraphy of the Buntsandstein in the borehole Otyń *IG-1*. Explanations as at Fig. 4

by many authors. For wider lithostratigraphic correlations only some of the distinguished complexes can be used as e.g. the complexes *18* and *15* (being more or less the equivalents of lower — oolitic beds and upper-oolitic beds according to Fuglewicz 1973).

Fuglewicz (1979) presented (on the basis of a sequence of the borehole Otyń *IG-1*) a stratigraphic subdivision of Buntsandstein grounded in megaspores and in a cyclic succession of lithologic complexes. The subdivision was based on alternate repeat of barren complexes of usual brick-red colour of a closed inland reservoir and of rocks with prevailing greenish-gray colours with abundant organic remains, the origin of which was connected with marine ingressions. The author correlated this subdivision with the one of himself (Fuglewicz 1973), prepared for Buntsandstein of the north-eastern Poland.

Table 1

Confrontation of stratigraphic schemes of the Buntsandstein applied in the Fore-Sudetic Monocline and their approximate correlation

Tokarski 1965, Sokołowski 1967						Numbers of complexes	Fuglewicz 1977, 1979	Senkowiczowa 1965		
Muschelkalk							Muschelkalk			
Buntsandstein	Upper-Röt	Middle and Upper Röt	Upper Part	Upper division	"upper carbonate" series	1	Supra-gypsum beds	Wilczkowice beds	Upper	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Upper Part	Upper division	"upper carbonate" series	2	Supra-gypsum beds	Wilczkowice beds	Upper	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Upper Part	Upper division	"upper carbonate" series	3	Supra-gypsum beds	Wilczkowice beds	Upper	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Upper Part	Lower division	upper evaporite maximum	4	Upper-gypsum beds	Gypsum beds II	Upper	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Upper Part	Lower division	"lower carbonate" series	5	Upper-gypsum beds	Gypsum beds II	Upper	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Upper Part	Lower division	"lower carbonate" series	6	Inter-gypsum beds	Intragypsum beds	Upper	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Upper Part	Lower division	"lower carbonate" series	7	Inter-gypsum beds	Intragypsum beds	Upper	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Lower Part		"white series"	8	Lower-gypsum beds	Gypsum beds I	Lower	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Lower Part		"white series"	9	Lower-gypsum beds	Gypsum beds I	Lower	Röt
Buntsandstein	Upper-Röt	Middle and Upper Röt	Lower Part		"white series"	10	Lower-gypsum beds	Gypsum beds I	Lower	Röt
Buntsandstein	Upper-Röt	Lower			variegated pelites	11	Sub-gypsum beds	Wschowa beds	Lower	Röt
Buntsandstein	Middle	mica series				12	Sub-gypsum beds	Wschowa beds	Lower	Röt
Buntsandstein	Middle	mudstone series				13	Supra-oolitic Pusulosporites Siltstone beds	Wschowa beds	Lower	Röt
Buntsandstein	Middle	mudstone-sand series				14	Supra-oolitic Pusulosporites Siltstone beds			
Buntsandstein	Middle	limestone-oolithic-dolomite ser.				15	Upper-oolitic beds			
Buntsandstein	Middle	sand-dolomite series				16	Inter-oolitic beds			
Buntsandstein	Middle	pink sand series				17	Inter-oolitic beds			
Buntsandstein	Lower	limestone-oolite series				18	Lower-oolitic beds			
Buntsandstein	Lower	red clay-sand series				19	Sub-oolitic Otynisporites Siltstone beds			
Buntsandstein	Lower	variegated clay-sand series				20	Sub-oolitic Otynisporites Siltstone beds			
Buntsandstein	Lower	variegated sand-clay series				21	Sub-oolitic Otynisporites Siltstone beds			
Zechstein							Zechstein			

NORTH-WESTERN POLAND AREA

The Buntsandstein of that area was studied by Szyperko-Śliwczyńska (1966, 1972, 1973a, 1979). She has analyzed several fragmentary cored boreholes and distinguished two series of Middle Buntsandstein the older, Pomeranian one divided into upper and lower parts and the younger — Połczyn one. That scheme was based on physico-chemical changes of the rocks making it possible to distinguish the sandstone complexes, possible to be investigated in a larger area according to the authoress. But the authoress has not mentioned any depth interval of the distinguished series in any of her papers so, this subdivision practically could not be used. Within the Röt Szyperko-Śliwczyńska distinguished several typical lithological complexes that were connected afterwards with the

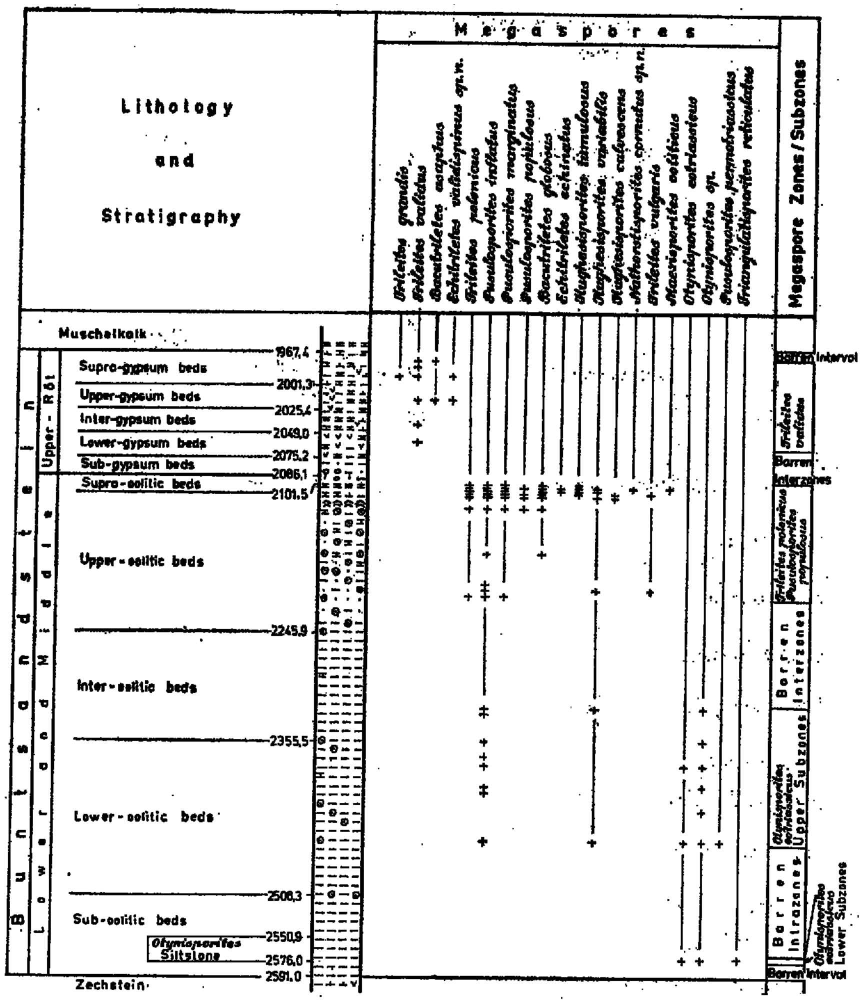

Fig. 6. Section and stratigraphy of the Buntsandstein in the borehole Gorzów Wielkopolski *IG-1*. Explanations as at Fig. 4.

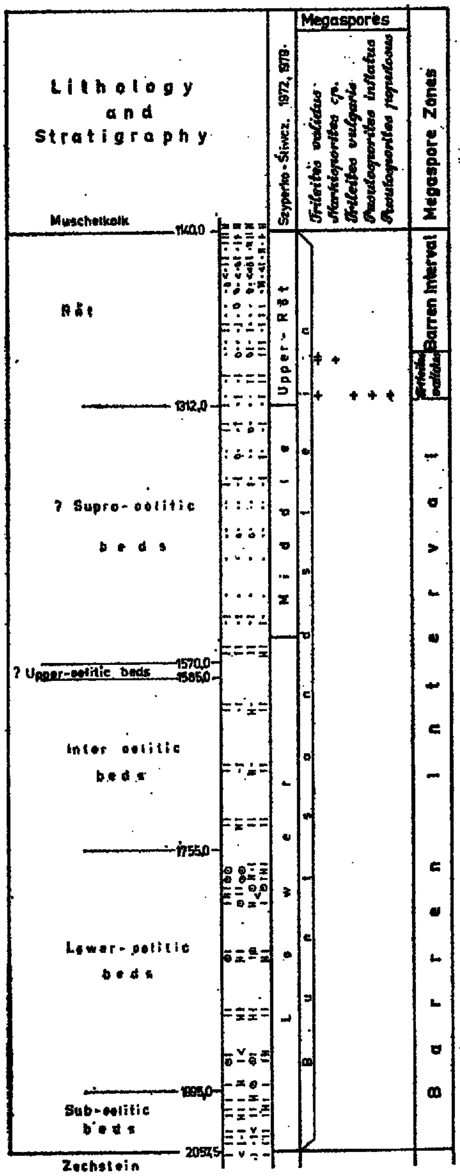

Fig. 7. Section and stratigraphy of the Buntsandstein in the borehole Kamień Pomorski *IG-1*. Explanations as at Fig. 4

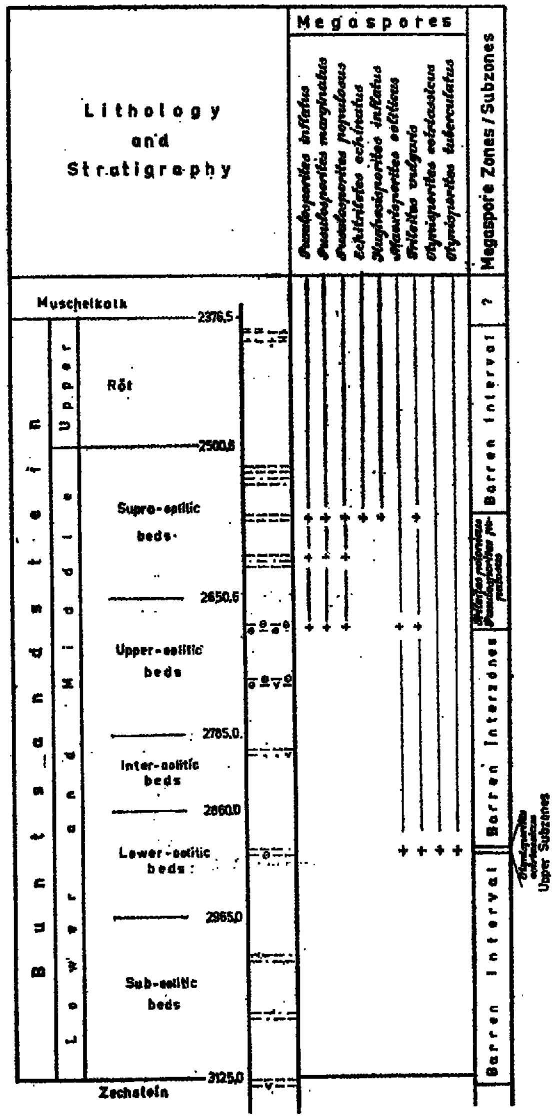

Fig. 8. Section and stratigraphy of the Buntsandstein in the borehole Września *IG-1*. Explanations as at Fig. 4

subdivision of Sokołowski (1967) of Buntsandstein in the Fore-Sudetic Monocline and with a subdivision of herself for the area of the north-eastern Poland (Szyperko-Śliwczyńska 1972, 1979).

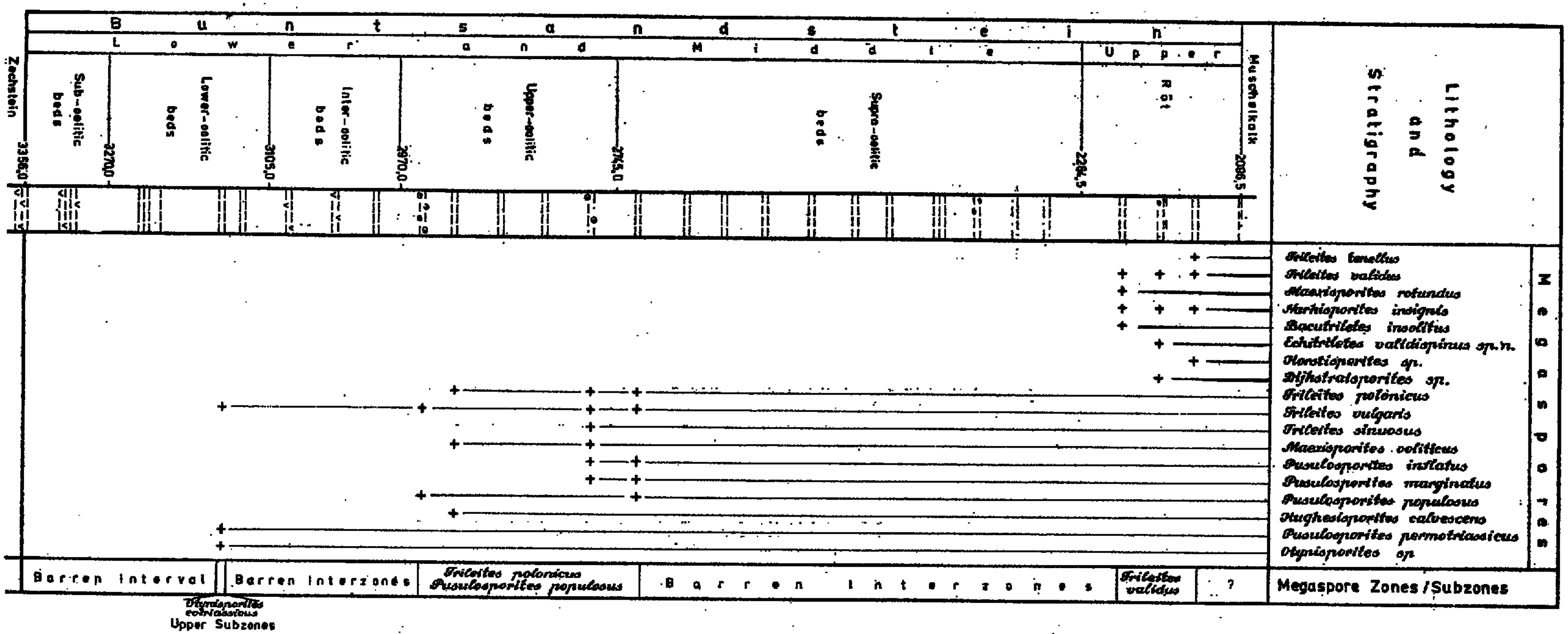

Fig. 9. Section and stratigraphy of the Buntsandstein in the borehole Konary *IG-1*. Explanations as at Fig. 4

KUJAWY AREA

Buntsandstein of the Kujawy area is known from only several uncompletely cored sections and it has not been yet a subject of more detailed stratigraphical studies. One of the first sections of this area comes from the Szubin borehole in which over 1000 m thick sediments of Buntsandstein have been drilled through. In the seventies several other drills were done. Some of them (Konary *IG-1*, Je-

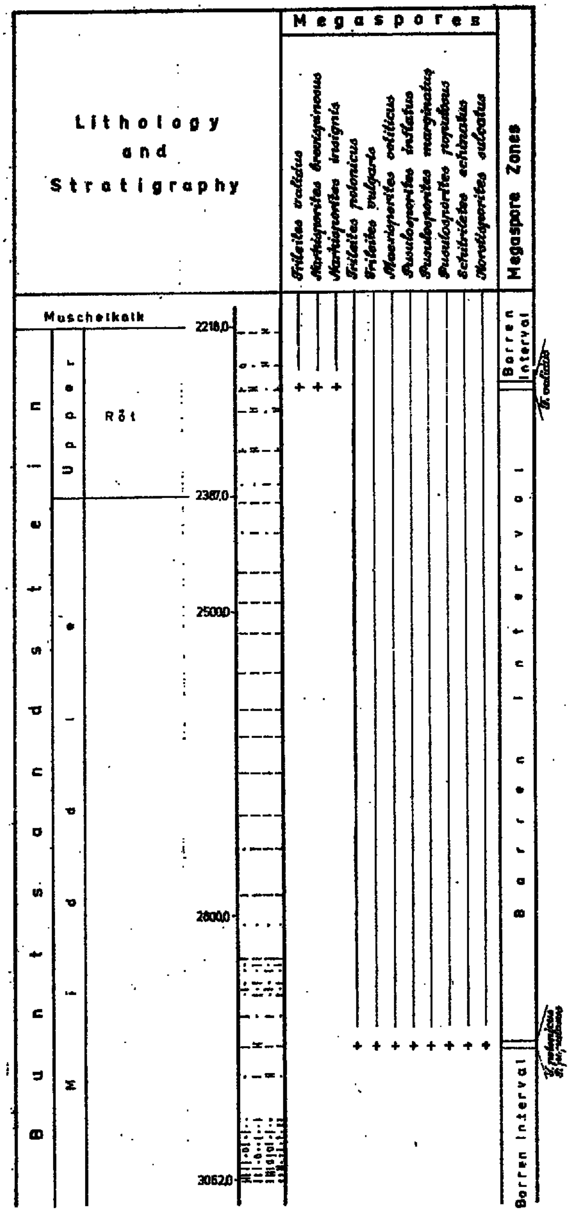

Fig. 10. Section and stratigraphy of the Buntsandstein in the borehole Jeżów *IG-1*. Explanations as at Fig. 4

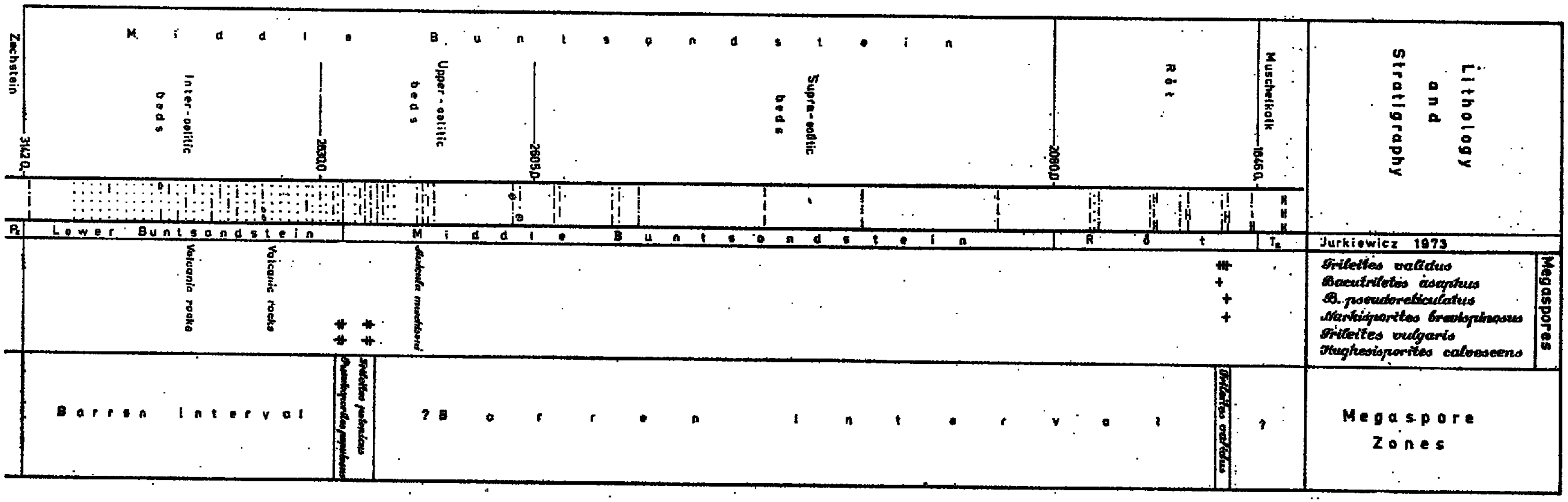

Fig. 11. Section and stratigraphy of the Buntsandstein in the borehole Studzianna *IG-2*. Explanations as at Fig. 4

żów *IG-1*, Studzianna *IG-2*) are more precisely stratigraphically analyzed in this paper.

NORTH-EASTERN POLAND AREA

The Triassic sediments in that area were mainly analyzed by Szyperko-Śliwczyńska (1959, 1960, 1961, 1962, 1964, 1967, 1973a, 1973b, 1974, 1979) who presented, in her last paper, a history of studies over the sediments of Buntsandstein in that region of Poland.

In her first studies Szyperko-Śliwczyńska based the stratigraphy of Buntsandstein mainly on results of works of Lithuanian geologists, using their names of some units. In the later papers the authoress introduced new units of their own but named differently in every time (Szyperko-Śliwczyńska 1979, Table 2).

Fuglewicz (1973) introduced a palaeontologic method based on megaspores to the stratigraphy of Buntsandstein. An analysis of sections from north-eastern

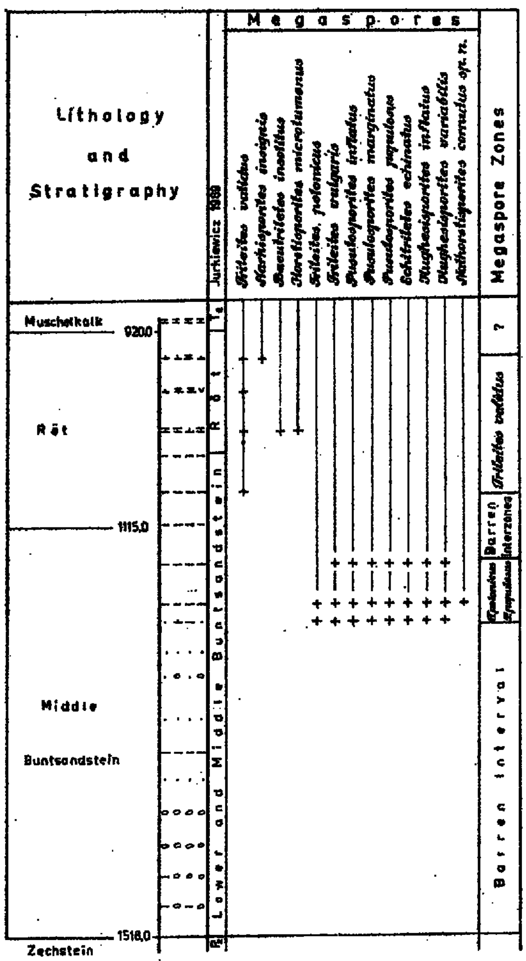

Fig. 12
Section and stratigraphy of the Buntsandstein in the borehole Łopuszno *IG-1*. Explanations as at Fig. 4

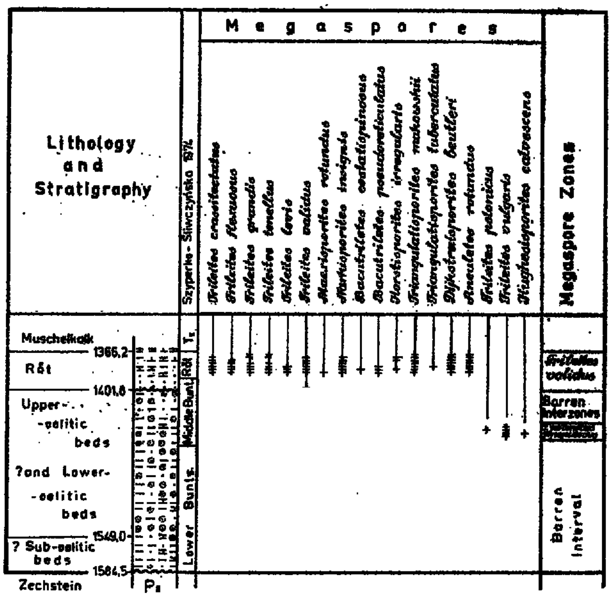

Fig. 13
Section and stratigraphy of the Buntsandstein in the borehole Tłuszcz *IG-1*. Explanations as at Fig. 4

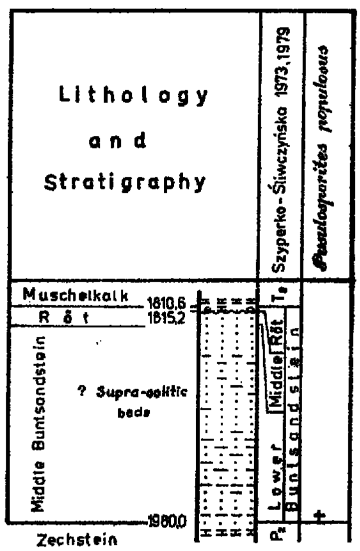

Fig. 14
Section and stratigraphy of the Buntsandstein in the borehole Magnuszew *IG-1*. Explanations as at Fig. 4

Poland and from central Poland brought the author to a conclusion that sedimentation of Lower and Middle Buntsandstein had been ruled by a regularity of alternate occurrence of barren inland complexes and of complexes with organic marine fossils (Fig. 4). On the ground of that a stratigraphic scheme and a subdivision into sedimentary cyclothems were prepared.

Szyperko-Śliwczyńska (1979) summed up her studies over the stratigraphy of Buntsandstein in north-eastern and northern Poland. The paper contained several serious mistakes; some of them are to be discussed in the present paper.

HOLY CROSS MTS

A subdivision of Dembowska (1957) based on a section of the borehole Radoszyce 3, was one of the first subdivisions of Buntsandstein in that area. Later on, the stratigraphic schemes prepared by Senkowiczowa and Ślączka (1962) and by Senkowiczowa (1970) were published, basing on information from exposures. These authors came to a conclusion that there were too great differences in a development of Buntsandstein so, they introduced two connected with each other schemes for the north-eastern Margin of the Holy Cross Mts. But these schemes reflect only a local lithologic composition and they are not based on fossils.

Szyperko-Śliwczyńska (1979) has also referred to the stratigraphy of the Buntsandstein in the Margin of the Holy Cross Mts.

TATRA MTS

History of studies over the sediments of Lower Scythian (Werfenian) in the Tatra Mts is included in the paper of Roniewicz (1966). Kotański (1956) transferred a subdivision of Werfenian, applied in the Alps, to the Tatra Mts, with a proposal of calling the Lower Werfenian — Seisian and the Upper — Campilian. The Tatra Seisian composes of a set of clastic sediments underlying a carbonate Campilian and starting the Mesozoic sedimentary cycle. Fuglewicz (1979b) has found lately in the sediments of High-tatric and of Sub-tatric units an abundant assemblage of megaspores typical for Middle Buntsandstein.

BIOSTRATIGRAPHIC STUDIES

An occurrence of not very much abundant animal and plant fossils within the sediments of Buntsandstein has been known for a long time. After a break in evolution of organic world caused by a gradual regression of the Zechstein sea, its progressive renewing can be noted in the Buntsandstein. Towards its younger horizons a number of fossils keeps increasing, at the same time the best paläontologic documentation is included in a marine facies of Upper Buntsandstein i.e. of Röt (Fig. 20). But still a literature describing the organic remains of Lower Triassic of the German facies is very poor and includes mainly the contributions. A stratigraphy of these sediments has been entirely based on lithology up to the recent times.

The first attempt in presenting a stratigraphy of Buntsandstein based on guide fossils was done by Visscher (1971). On the ground of progressive morphologic changes of some pollen grains of the gymnosperms he distinguished 7 microevolutional phases (palynodems) within Upper Permian and Lower Triassic. These phases were found to be the basis for a chronostratigraphic classification and correlation of profiles of Permian-Triassic for the European area. Visscher proved that the Permian system of Central Europe was highly reduced and represented only by its lowermost part (Autunian) and uppermost part (Thuringian = Saxonian + Zechstein + Lower Buntsandstein). On the ground of correlation (based on palynodems) of Permian-Triassic sections coming from the area of the Variscitic Europe he concluded that the borders of Saxonian, Zechstein and Buntsandstein were diachronic. Besides, he supported an idea formulated by Murchison 130 years before that in the area of the Variscitic Europe the border between Permian and Triassic systems was the same as the border between Lower and Middle Buntsandstein (Fig. 25). This opinion seemed to have been supported by an occurrence of remains (and megaspores) of a lycopodium *Pleuromeia* within the sediments of Middle Buntsandstein; they appeared just in the Lower Triassic. Besides, this border was accentuated by a diastrophic turn caused by tectonic movements of the Pfälzic phase (Figs 3, 24).

The Fuglewicz's (1973) work was the next attempt in preparing a biostratigraphy of Buntsandstein. On the basis of megaspores from the sections of north-eastern and central Poland a stratigraphic scale was presented. The author distinguished three guide megaspore assemblages (defined by the numbers: I, II and III), on the ground of which he carried through a correlation with Buntsandstein sediments of the Nida Trough. The assemblage I was found to be a guide one for Middle Buntsandstein, the assemblage II — for Röt and the assemblage III probably could be included, according to the author, already into Middle Triassic. Therefore, it could be proved that the sediments previously included in the north-eastern Poland into Middle Buntsandstein (Szyperko-Śliwczyńska 1962), corresponded with Röt and probably, with Lower Muschelkalk. That conclusion was then supported in the next papers of the author (Fuglewicz 1977b, 1979a). Such interpretation was also confirmed by Mowszowicz's (1977) correlation of sediments of Lower and Middle Triassic of Central European Basin with Caspian area on the basis of ostracods and other microfossils.

Marcinkiewicz (1976) presented a distribution of megaspore assemblages in the sediments of Middle Buntsandstein in Poland. On the ground of occasional samples from various sections the authoress concluded that two typical (for Middle Buntsandstein megaspore assemblages (*Trileites polonicus* and *Talchirella daciae* = *Pusulosporites populosus* Fuglewicz 1977a, 1979a) „cannot be correlated with each other as they form a sequence and are characteristic for various lithologic-stratigraphic units". A correlation of Middle Buntsandstein sediments presented in this paper on the basis of megaspores coming from several sections from almost the whole country (Figs 4, 6, 9—10, 12) proved that the mentioned interpretation was not true.

The sediments of Middle and Upper Buntsandstein of the western Poland were the subject of a spore-pollen analysis of Orłowska-Zwolińska (1977). She distinguished within the Middle Buntsandstein three spore-pollen guide assemblages and an assemblage typical for Röt.

Neither palaeontologic nor stratigraphic works have been done up to recent times for Lower Buntsandstein but some short notes, informing about found phyllopods and prints of jellyfish (Aleksandrowicz & Słupczyński 1971), Wagenbreth 1968, Müller 1969). Styk (1972, 1975) described two species of ostracods and one foraminifer species from Lower Buntsandstein of N and NE Poland.

A first stratigraphic scheme of Lower Buntsandstein based on megaspores and on lithology was done by Fuglewicz (1977b) for three sections from a south-western margin of the Fore-Sudetic Monocline. The author distinguished a megaspore assemblage typical for Lower Buntsandstein and called it the assemblage *Otynisporites eotriassicus*. In the next paper, dealing also with the Fore-Sudetic Monocline, the author presented a stratigraphy of the whole Buntsandstein in a section of the borehole Otyń *IG-1* that he found, due to its complete development, very good megaspore documentation and full core recovery to be the stratotypic one for that area (Fuglewicz 1979a).

STRATIGRAPHY AND CORRELATION

LITHOSTRATIGRAPHY

In a considerable part of Poland there are two oolitic complexes within the Buntsandstein. For such sections a lithostratigraphic subdivision was applied, based on alternate occurrence in the section of barren brick-red rocks of a drainageless inland reservoir and of marine oolitic complexes, usually greenish-gray and with abundant fossils (Fuglewicz 1973). On the ground of that a subdivision into sedimentary cycles was formed (Figs 4, 25).

An occurrence of oolitic complexes within the sediments of the Lower Triassic is typical not only for the territory of Poland. This facies has been best investigated in the Polish-German part of the Central European Basin (Rogenstein Facies); it is to be also found in the Prypeć Trough (Kisnierius & Sajdakovskij 1972) and in the Moscow Basin, to the shores of the White Sea (Strok & Gorbatkina 1976). Therefore, a subdivision of the Buntsandstein into oolitic beds and non-oolitic beds, although informal, reflects best the principles that rule a sedimentation evolution of Lower Triassic sediments. Besides, this subdivision enables an easy separation of usuall thick series of Buntsandstein and makes it possible to correlate the sections in the vast area where the facies is present. Applying an informal subdivision of Buntsandstein the author was governed by a recommendation of the International Stratigraphic Guide (Hedberg 1976) that: „in some stratigraphic situations it is much better to be governed by a common sense as such approach will more effectively favour a clarity, understanding and progress".

BOREAL MEGACYCLOTHEM

Fuglewicz (1973) distinguished two megacyclothems within Lower and Middle Triassic: a boreal one including the Lower and Middle Buntsandstein and a meridional one composing of Röt and Muschelkalk. Studies of Buntsandstein in the remaining part of Poland have drawn the author to a conclusion that Lower and Middle Buntsandstein form only a part of the complex, a sedimentation of which was started after the movements of the Saalic Phase and was connected with a communication of Central European Basin and the boreal sea. A sedimentation of this complex was ended by the Hardegsen Phase that resulted in a change of an existing tectonic regime. The boreal cyclothem understood in that way includes then the sediments of Saxonian, Zechstein as well as of Lower and Middle Buntsandstein. The megacyclothem is divided by the Pfälzic Phase into two parts. The lower part of the boreal cyclothem, including Saxonian, Zechstein and Lower Buntsandstein (Sub-oolitic beds and lower-oolitic beds) corresponds exactly with Thuringian within the meaning of Visscher (1971). The upper part, deposited after the movements of the Pflälzic Phase, composes of inter-oolitic beds, upper-oolitic beds and supra-oolitic beds (Fig. 25).

CYCLOTHEM *IA* (REGRESSIVE ONE)

(Sub-oolitic Beds and Lower-oolitic Beds)

This cyclothem deposited in a similar palaeogeographic plan as the Zechstein one, continues the Zechstein sedimentation. An extent of this cyclothem is generally the same as the extent of the uppermost Zechstein.

Sub-oolitic beds compose of the oldest sediments of Buntsandstein and continue, almost everywhere, a sedimentation of uppermost Zechstein. They are not uniform. In the north-eastern and nothern Poland they form an uniform clayey-siltstone complex with rare concentrations of anhydrite and are brick-red and brown. But sporadic pollens these sediments do not contain any fossils. The Sub-oolitic beds seem to be similar in the Kujavian-Pomeranian Swell but no fully cored sections make their more detailed analysis impossible.

In the Fore-Sudetic Monocline (borehole Otyń *IG-1* and Gorzów Wielkopolski *IG-1*) there is, within brick-red rocks corresponding with the Sub-oolitic beds, a complex of gray claystones and siltstones containing abundant and different fossils as hystrichospheres, miospores and megaspores (Figs 4—6). This complex is distinguished as the *Otynisporites* Siltstone (Fuglewicz 1979a) and its origin is distinctly connected with an open sea (occurrence of hystrichospheres).

An identical lithologic changeability was noted previously by Sokołowski (1967) within the lowermost Buntsandstein of the Fore-Sudetic Monocline. According to him the oldest complex (complex *21*) started with red and cherry-red claystones and sandstones. It is overlain by several metres thick gray or dark-gray claystones and siltstones with limestone lamine and marine features according to this author.

A similar complex of gray and greenish-gray rocks can be found also within Lower Buntsandstein of Germany. Schulze (1969) distinguished them as Graubankbereich, being the upper part of the series Sandstein-Schieferton-Zone.

So, within the Lower Buntsandstein of the Fore-Sudetic Monocline two marine complexes occur. They allow to distinguish within the Cyclothem *Ia* two smaller cyclothems defined as Ia_1 and Ia_2 (Fuglewicz 1979a and Figs 2, 4). The Cyclothem Ia_1 corresponds approximately with complexes *21* and *20* of Sokołowski (Table 1). The Cyclothem Ia_2 begins with a red claystone-sandstone series (complex *19* of Sokołowski) and ends with the lower-oolitic beds (= complex *18* of Sokołowski) that have the features of marine sediments again (Usdowski 1963).

A subdivision of Lower Buntsandstein into two series (Untere Folge and Obere Folge) has been also accepted by German geologists (Boigk 1959).

An analysis of a typical profile of the borehole Otyń *IG-1* in the Fore-Sudetic Monocline leads to a conclusion that including by the author, the greenish-gray rocks with megaspores occurring in the lower part of Buntsandstein in the profiles of the boreholes Czerńczyce *IG-1*, Stęszów *IG-1* and Przesieczna *1*, into the lower-oolitic beds was not correct (Fuglewicz 1977b). These rocks as it results from a correlation based on megaspores of these profiles with the boreholes Otyń *IG-1* and Gorzów Wlkp. *IG-1* (Fig. 2), should be defined as the *Otynisporites* Siltstone although they contain rare oolitic inserts. This opinion is supported by an occurrence of a megaspore *Hughesisporites simplex* Fugl. in the borehole Stęszów *IG-1*; this megaspore has not been found in the sediments of the lower-oolitic beds.

A stratigraphic interpretation of such profiles as Czerńczyce, Stęszów and Przesieczna with a strongly reduced series of the lower-oolitic beds or its absence, is differently comprised in a geologic literature. Sokołowski (1967) considers that absence of the complex *18* (= lower-oolitic beds) in the eastern part of the Fore-Sudetic Monocline is probably caused by facial changes. Seidel (1965) and Trusheim (1961) found it to be a sedimentary break, defined as pra-Volpriehausen Diskordanz (= Pfälzic Phase in the present paper).

The sub-oolitic beds are from 37 m (in the borehole Pasłęk *IG-1*) up to 94 m (in the borehole Otyń *IG-1)* thick.

Lower-oolitic beds compose of the first oolitic complex of Buntsandstein and are a continuation of the sub-oolitic beds, forming with the latter a sedimentary cyclothem defined as *Ia* (Fuglewicz 1973). The sediments of the lower--oolitic beds are easy to be separated from brick-red underlying rocks due to their specific lithology and predominance of greenish-gray colour. In the Pomeranian Trough the regular inserts of oolitic limestones were found in a sequence of Buntsandstein by Szyperko-Śliwczyńska (1974). These sediments are almost entirely facially uniform and compose usually of alternate claystones and siltstones (locally sandstones) with oolitic limestones and dolomites containing rare (local) gypsum and anhydrite inserts. The oolitic inserts are in places up to 1 m thick. The sediments of the lower-oolitic beds are different in particular sections for a varying content of clayey-siltstone and sandstone rocks. Gray and greenish colour predominate (Fuglewicz 1973, Szyperko-Śliwczyńska 1979). These rocks contain fish scales and teeth, phyllopods and ostracods. In the Fore-Sudetic Monocline and in the Kujavian Swell there are the megaspores of the *Otynisporites eotriassicus* Zone (Figs 4, 9). Besides, remains of megaspores were also found in the Baltic Syneclise (borehole Pasłęk *IG-1*, Fuglewicz 1973).

A petrographic analysis of the oolitic sediments (Usdowski 1963) and paralic features of the whole complex of lower-oolitic beds (Fuglewicz 1973) prove the periodical connections with the open sea at that time.

The lower-oolitic beds are from about 100 m (borehole Otyń *IG-1*), to 240 m (borehole Kamień Pomorski *IG-1*) thick (Figs 4, 7, 15—16).

CYCLOTHEM *IB* (TRANSGRESSIVE ONE)

(Inter-oolitic beds, Upper-oolitic beds and lower part of Supra-oolitic beds of south-western Poland)

This cyclothem forms a separate phase in a deposition of Buntsandstein, taking its lithology and floristic composition into account. Its sedimentation has been mainly influenced by movements of the Pfälzic Phase (Figs 4, 24—25).

Inter-oolitic beds form the middle part of Buntsandstein of a similar composition in many sections. Movements of the Pfälzic Phase resulted in an isolation of the Central European Basin from the open sea so, radical changes in sedimentation of Buntsandstein occurred. In a closed inland reservoir mainly a thick complex was deposited of almost entirely red and brown sandstones, claystones and siltstones with inserts of gypsum and anhydrite and in the lower part with interbeds of conglomerates (Figs 3—4). These rocks do not contain usually any fossils.

Movements of the Pfälzic Phase caused a rapid increase of sedimentation rate. A great amount of terrigene material has been brought into the reservoir from the elevated alimentary areas in the south and south-west. In the places where the thickness is the greatest there are the greatest quantities of coarse clastic sediment. In the central part a fine material prevails, represented by clayey-siltstone rocks. A great amount of quartz pebbles and debris (quartz is the most popular component of the inter-oolitic beds) as well as an occurrence of pebbles of volcanic rocks (Fig. 11) prove that massifs of acid crystalline rocks and of acid volcanic rocks were exposed (Fuglewicz 1967).

The equivalents of these beds in the Tatra Mts. are similar (lower part of Seisian (Fig. 3); for them a northern direction of transport of the terrigene material is accepted (Roniewicz 1966).

A thickness distribution of the inter-oolitic beds in various zones of its occurrence is also typical. The greatest thickness is in the marginal part of the basin — in the south-western part of the Fore-Sudetic Monocline and in the Margin of the Holy Cross Mts. At the same time the central part of the basin was much more slowly subsided (Figs 16, 32).

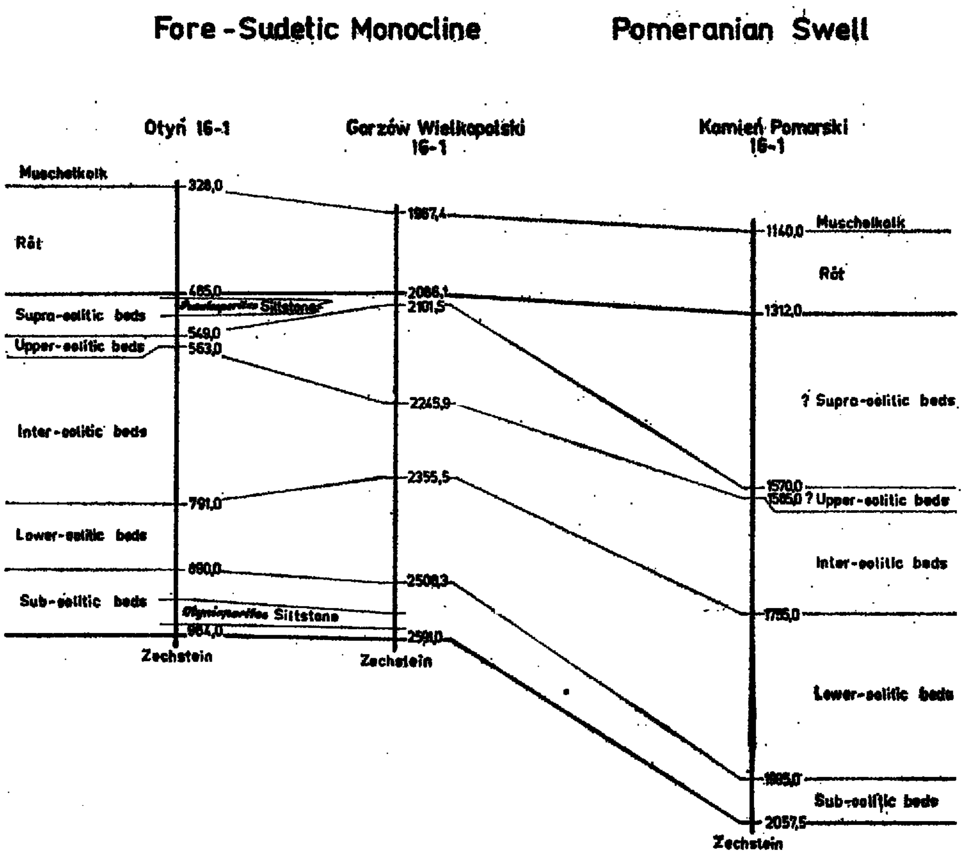

Fig. 15. Stratigraphic correlation of the Buntsandstein of Otyń and Kamień Pomorski

Upper-oolitic beds contain the second oolitic complex of Buntsandstein and due to an occurrence of abundant fossils, stromatolitic and Spirorbis rocks it is the most typical part of the sequence. The block movements of the Pfälzic Phase that started in the inter-oolitic beds continued as well during the upper-oolitic beds (although in a small way). In the south-western part of the basin (Bohemian

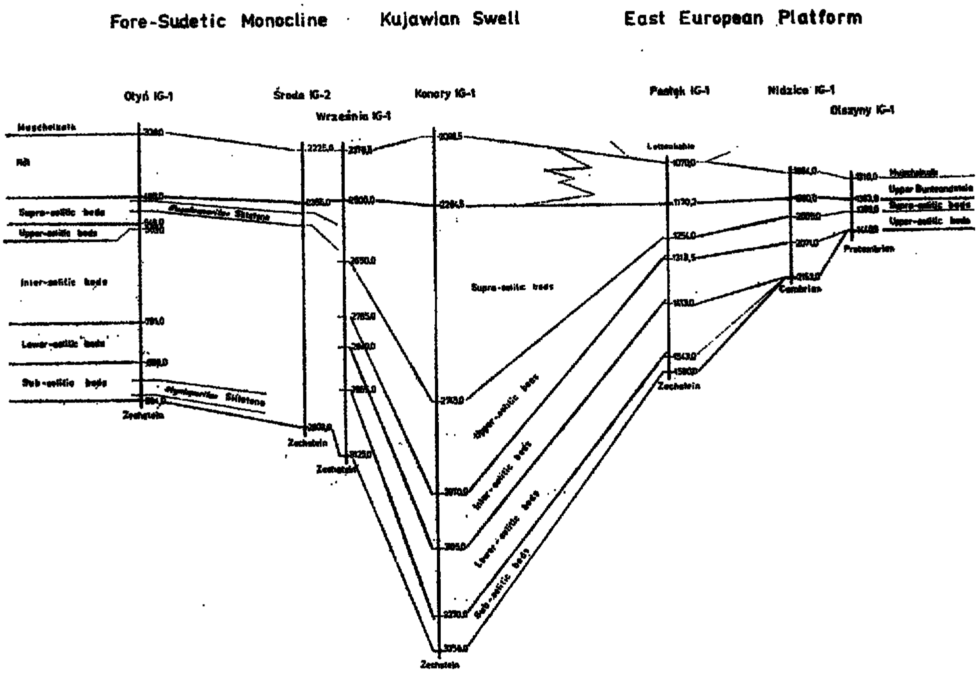

Fig. 16. Stratigraphic correlation of the Buntsandstein of some sections between Otyń and Olszyny

Massif?) a trend to uplifting has still prevailed so, the upper-oolitic beds are strongly reduced there (borehole Otyń *IG-1*) and contain a considerable admixture of terrigene material. Sokołowski (1967) found in these sediments of the Fore--Sudetic Monocline (complex 15) the radioactive anomalies and their origin connected with a destruction of Caledonian or older crystalline rocks. In contrast with that, in the north-eastern part of the basin (Mazury-Augustów Elevation) a subsidence prevailed so the upper-oolitic beds are transgressive there — they overly the older bedrock (borehole Olszyny *IG-1*) and are more complete.

In the whole area with the upper-oolitic beds it has quite a uniform composition. It starts usually with sandstones and passes quickly into an overlying complex of claystones and siltstones with inserts of oolitic limestones and dolomites (Rogenstein Facies) as well as into stromatolitic ones. Locally there are inserts of spirorbid limestones and dolomites composing almost entirely of spirorbid (or serpulid) tubes (Pl. 10, Fig. 5), with a typical pale-pink colour. Within the sediments of the upper-oolitic beds there is the most abundant fossil assemblage of the boreal Buntsandstein: vertebrate remains, pelecypods *Avicula murchisoni* Gein., foraminifers, hystrichospheres, ostracods and phyllopods, also many megaspores of the Trileites polonicus — Pusulosporites populosus Zone. A sedimentary type of these sediments proves well a connection of the Central European Basin with the open sea.

In spite of quite a uniform lithologic composition a subsidence rate was not the same. The maximum of a subsidence during the upper oolitic epoch occurred in the axial part of the basin i.e. in the Kujawy area and in the north-eastern part of the Fore-Sudetic Monocline (borehole Konary *IG-1*, Gorzów Wielkopolski

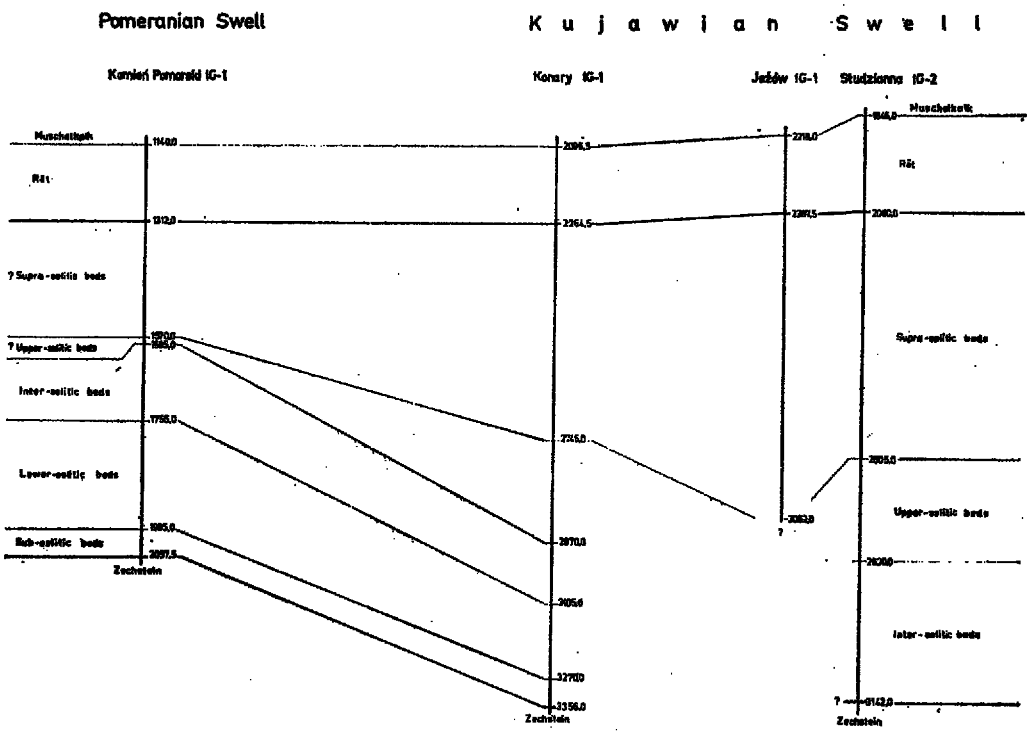

Fig. 17. Stratigraphic correlation of the Buntsandstein within the Kujavian-Pomeranian Swell

IG-1; Figs 4, 16). In the platform part of the north-eastern Poland a thickness of the upper-oolitic beds is generally the same. A considerable reduction of the upper-oolitic beds in south-western and southern parts of the Fore-Sudetic Monocline, in the Margin of the Holy Cross Mts. and in the northern Poland, and an extensive development of these beds in the sections of the boreholes Gorzów Wielkopolski *IG-1*, in the Kujawy area, in the Mazury-Augustów Elevation and in the Podlasie Trough lead to a presumption that the axis of maximum subsidence of the upper-oolitic beds was oriented as a parallel of latitude.

A thickness of the upper-oolitic beds is varying (Fig. 22) from 14 m (borehole Otyń *IG-1*) to 225 m in Kujawy (boreholes Konary *IG-1*, Studzianna *IG-2*).

Supra-oolitic beds form the youngest part of a boreal megacyclothem a sedimentation of which was influenced by the phenomena at the Teisseyre-Tornquist zone (Znosko 1979). At both sides of this zone the supra-oolitic beds have different thickness and lithology (Fig. 4).

In the north-eastern Poland the supra-oolitic beds are quite homogenous composing of clayey-siltstone and sandstone rocks, locally of conglomerate ones, usually of a brick-red colour. The rocks almost do not contain any fossils. In result of a pre-Röt erosion caused by movements of the Hardegsen Phase, the supra-oolitic beds were removed in some sections (borehole Tłuszcz *IG-1*) and the Röt sediments overlie directly the upper-oolitic beds (Fig. 13).

The supra-oolitic beds are quite different in the south-western and Central Poland where their thickness is locally great (Figs 4—5, 8—9), Almost in the whole area there is within the brick-red rocks a complex of gray and greenish

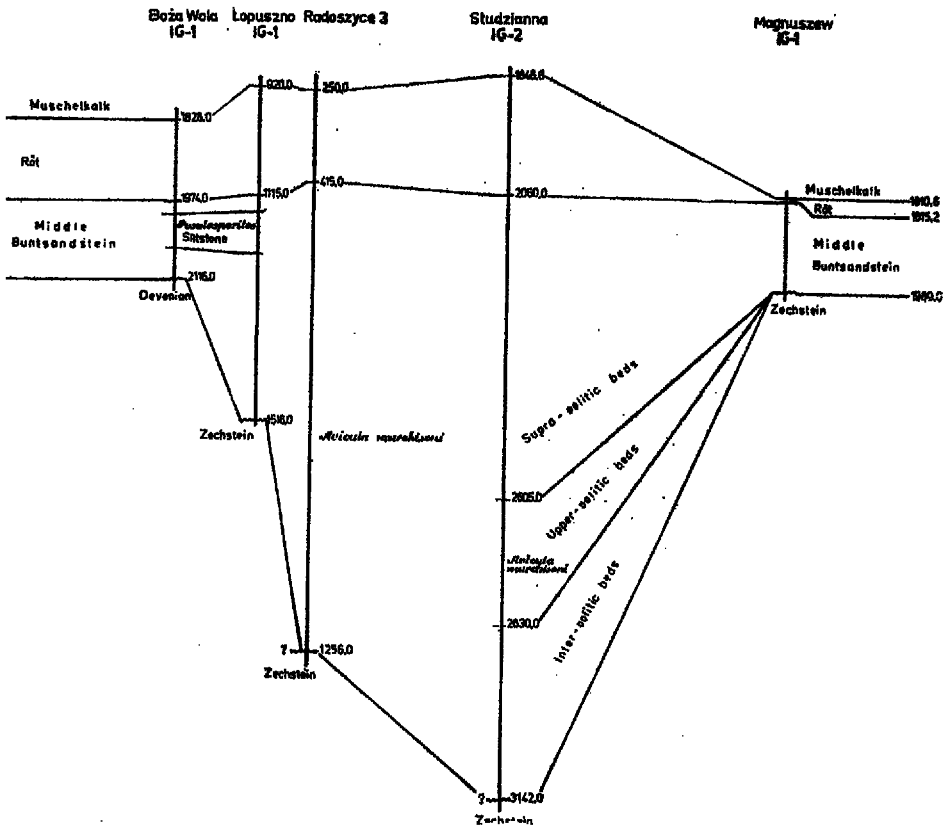

Fig. 18. Stratigraphic correlation of the Buntsandstein of Boża Wola and Magnuszew

siltstone with interbeds of sandstones rich in flora detritus. Locally there are inserts with fossil marine fauna (Boigk 1959, Sokołowski 1967). These siltstones in which numerous megaspores *Pusulosporites* have been found, were distinguished as the *Pusulosporites* Siltstone (Fuglewicz 1979a). A megaspore analysis basing on a very rich material proved that the *Pusulosporites* Siltstone corresponded with the upper part of the upper-oolitic beds of the north-eastern Poland (Fig. 19, Table 2). But marine fauna typical of the upper-oolitic beds (*Avicula murchisoni*) there were many common megaspore species (Table 2). On the ground of that the *Pusulosporites* Siltstone was included into the Cyclothem Ib as a cyclothem of the second order Ib_2 (Fig. 4).

The *Pusulosporites* Siltstone is widespred not only in the territory of Poland; similar sediments have been found long ago in Germany (Hardegsen-Folge, Boigk 1961). Lately, an identical megaspore assemblage has been noted in Rumania (Antonescu & Taugourdeau-Lantz 1973).

Abundance of megaspores within the *Pusulosporites* Siltstone proved that the complex had been deposited in conditions of a wet climate, probably connected with an occurrence of the upper-oolitic beds sea in the East European Platform.

At the end of the supra-oolitic beds the conditions of sedimentation have changed in the whole basin in result of a successive break in a connection of the basin with the open sea. The *Pusulosporites* Siltstone in the south-western Poland

and the upper-oolitic beds of the north-eastern Poland are overlain by a complex of palaeontologicaly barren rocks of brick-red colour (Cyclothem *Ic*, Fig. 4).

The supra-oolitic beds are of quite a varying thickness a distribution of which suggests that the greatest subsidence occurred within the Middle Polish Trough (Figs 16, 22). Farther from that area a thicknes of the supra-oolitic beds keeps decreasing (Gorzów Wielkopolski *IG-1*) and they are absent in the south--western part of the Fore-Sudetic Monocline at one side (Fuglewicz 1977b) and in the Podlasie Trough at the other side (borehole Tłuszcz *IG-1*, Fig. 13).

MERIDIONAL MEGACYCLOTHEM

UPPER BUNTSANDSTEIN

In result of the movements of the Hardegsen Phase a hitherto existing tectonic regime has changed in the Polish-German Basin at the beginning of Upper Buntsandstein (Figs 21, 23). The Sudetic Foreland was submerged and together with the Middle Polish Trough it was occuppied by the Röt sea that entered from the Tethys. Being emerged, the area of the north-eastern Poland occurred within the extent of inland sedimentation. Therefore, the Upper Buntsandstein in Poland is developed in a lagoonal-marine (Röt) as well as in inland facies (north-eastern Poland).

RÖT

Röt sediments are best known in the Fore-Sudetic Monocline and their subdivision is based on occurrence of two evaporitic complexes (Fig. 4, Table 1). This subdivision can be also applied for the Röt sediments of the western Margin of the Holy Cross Mts and of the southern Poland (Nida Trough, Carpathian Foreland; Senkowiczowa 1965a). The megaspore analyses proved (Fuglewicz 1973, 1979a) that the lower part of the Beds from Wschowa according to Senkowiczowa (1965b), contains the megaspores of the T. polonicus — P. populosus Zone (*Pusulosporites* Siltstone) and so, it should be included into the Middle Buntsandstein (Table 1). After precising in this way the lower Röt boundary and slight nomenclature changes, the subdivision of Senkowiczowa was also accepted in the present paper.

The lowermost part of Röt is formed by the sub-gypsum beds (Fig. 4, Table 1) that are mainly represented by siltstones and sandstones of marine origin what is proved by an occurrence of *Myophoria costata* Zenk. (Gajewska 1964a). In these beds numerous megaspores of the Trileites validus Zone were found, typical for Upper Buntsandstein (Fig. 5). In the places where the movements of the Pfälzic Phase occurred there is at the Röt bottom a distinct sedimentary discontinuity accentuated by a thick (locally) conglomerate complex (Figs 6, 19). In some places no uppermost sediments of Middle Buntsandstein occur. Such situation was found, among others in a section of the borehole Tłuszcz *IG-1* where the supra-oolitic beds were absent and the Röt sediments were overlying the upper-oolitic beds (Fig. 13) and in the borehole Gorzów Wielkopolski *IG-1* where the supra-oolitic beds seemed to be strongly reduced (Figs 4, 6). According to Senkowiczowa (1965b) in the borehole Gorzów Wielkopolski *IG-1* the lowermost Röt does not occur; Szyperko-Śliwczyńska (1973a) considers it to be present there. This problem cannot be solved univocally as no fossils are present. But a correlation of a section of the borehole Gorzów Wielkopolski *IG-1* with the neighbouring boreholes (Otyń *IG-1*, Środa *IG-2*) brings to a conclusion that the rock complex included between the upper-oolitic beds and the bottom of Röt anhydrite represents a higly reduced series of the supra-oolitic beds (Cyclothem *Ic*) of Middle Buntsandstein and the sub-gypsum beds of Röt (Figs 4, 6).

The upper part of the Röt composes in the Fore-Sudetic Monocline of limestones and dolomites and also, of clayey-marly rocks with two evaporite inserts, mainly gypsum and anhydrite ones (Figs 4—5). Locally (in the western part of the monocline), there is a rock salt but the anhydrites (Gajewska 1964b). These upper parts of the Röt contain locally an abundant fossil fauna (mainly pelecypods) that occurs usually within the carbonate inserts. The clayey fragments contain frequently many megaspores of the Trileites validus Zone that is a typical for Röt. An analysis of megaspores found in the Röt sediments enables a more precise subdivision of this sequence. A more detailed subdivision of the Röt of the south-western and southern Poland is possible on the ground of more distinct lithologic changes. An occurrence of two lagoonal complexes in the Fore-Sudetic Monocline makes it possible to distinguish two full cyclothems within the Röt i.e. *IIa* and *IIb* (Fig. 4). Each cyclothem begins with sediments of more or less open sea and ends with lagoonal ones. The Cyclothem *IIc* comprises the uppermost Röt (supra-gypsum beds) and the Lower Muschelkalk and ends with lagoonal deposits of Middle Muschelkalk.

Röt sediments have been also noted in several boreholes in the area of the Middle Polish Trough where probably (no fully cored sections are known from this area) they have the greatest thickness. The Röt in this area includes a considerable content of sands coming probably from the northern and north-eastern alimentary areas. No complete sections makes it impossible to prepare a more precise stratigraphy now.

The sediments of Upper Buntsandstein of the north-eastern Poland are distinctly influenced by the movements of the Hardegsen Phase. In all the analyzed sections from this area the Upper Buntsandstein begins with conglomerates and sandstones that start a new sedimentary cycle (Fuglewicz 1973 and Fig. 4).

In this area the paralic sediments of Röt occur only in the boreholes Tłuszcz *IG-1* and Magnuszew *IG-1*. Marine inserts with *Myophoria costata* Zenk. are there interbedded with limnic sediments that contain but macroscopic plant remains, the numerous megaspores of the Trilites validus Zone (Fig. 13). In the remaining part of the north-eastern Poland there are mostly inland sediments (freshwater or brackish) of Upper Buntsandstein with an abundant plant detritus. Only in the Mazury-Augustów Elevation these rocks are covered by a thin cap of the Muschelkalk. In the Baltic Trough (borehole Pasłęk *IG-1*) that was not occuppied by Röt and Muschelkalk sea, the whole Triassic system composes of inland sediments of Buntsandstein and Keuper megafacies. Therefore, the inland sediments of Upper Buntsandstein do not correspond with Röt only but also with Muschelkalk (Fig. 4).

The described terrigene rocks of the north-eastern Poland have been included for a long time into the Middle Buntsandstein (Szyperko-Śliwczyńska 1961, 1962, 1964). In her latest paper (Szyperko-Śliwczyńska 1979) the authoress changed slightly her previous opinion by including the lower part of this terrigene complex (Elbląg Formation) into the Middle Buntsandstein and the upper one, just beneath the Muschelkalk sediments in the borehole Nidzica *IG-1*, into the Röt (Fig. 4). The megaspore analysis of these terrigene rocks done by the present author and their correlation with the Röt sediments of the south-western Poland (Fuglewicz 1973, 1977b, 1979a) proved that the lower part of the complex contained very numerous megaspores of the Trileites validus Zone and so, it corresponded with Röt. The megaspores occurring in the upper part of this terrigene complex represented probably a separate zone as there were among them the species (*Tenellisporites marcinkiewiczae* Reinh. and Fricke and *Echitriletes multispinosus* Fugl.) unknown for Röt but appearing for the first time in Muschelkalk. So, these sediments have been already earlier included by the author (Fuglewicz 1973) into Middle Triassic. This conclusion was confirmed by works of Mowszowicz (1977) who carried through a correlation of Triassic sediments of the Central European Basin and of the Caspian area on the basis of ostracods (occurring among others in the described beds). A vertical spread of most ostracod species, found by Styk (1974) in sediments of Buntsandstein containing the IIIrd megaspore assemblage (Fuglewicz 1973), was proved to comprise Olenekian and whole Anisian.

CYCLIC TYPE OF SEDIMENTATION OF BUNTSANDSTEIN DEPOSITS

A cyclic type of sedimentation of the Buntsandstein has been already observed a long time ago, first of all by German geologists. Boigk (1957, 1959), inspired by Richter-Bernburg's (1955) subdivision of Zechstein into cycles, was the first who prepared a stratigraphic scheme of Buntsandstein in Germany based on a cyclic type of sedimentation of its series. He distinguished several cyclothems calling them after the names of villages; each cyclothem started with coarse-grained sediments and ended with clayey-siltstone rocks (Sohlbankazyklen). The Boigk's scheme was generally accepted by German geologists after slight modifications, especially as regards the Middle Buntsandstein. But it was of limited extent and presented many difficulties in correlation with sediments of Buntsandstein of a marginal zone of the basin (Backhaus 1971, Richter-Bernburg 1974). A correctness of these correlations will not be estimated before a biostratigraphic correlation what has not been done yet in Germany.

Another approach to a cyclicity of sedimentation of the Buntsandstein was presented by Wohlburg (1968); in his subdivision every cyclothem started with claystones and ended with sandstones (Dachbankazyklen). Each of distinguished cyclothems represented a transition from more or less marine conditions (clayey member) to brackish and limnic ones (sandstone member).

The observations of the present author suggest that a cyclic sedimentation of the Buntsandstein was governed not only by epeirogenic movements but also by climatic phenomena connected with them. The Buntsandstein is one of the series a structure of which composes of alternate barren (palaeontologicaly) clayey-siltstone and sandstone complexes, usually of brick-red colour that probably have been deposited in semi-desert areas and of similar lithologicaly rocks with numerous megaspores and other fossils, usually of gray or greenish-gray colour that have been deposited in a wet climate, probably under the influence of marine ingressions. On the ground of it the author distinguished three cyclothems within the sediments of Lower and Middle Buntsandstein in the north-eastern Poland (Fuglewicz 1973, and Fig. 4). In the Fore-Sudetic Monocline (that is more mobile) there are four complexes geneticaly connected with sea ingressions; they make it possible to distinguish two cyclothems of a lower order within the cyclothems mentioned above (Fig. 4, Fuglewicz 1979a).

The described cyclicity of sedimentation results from typical for Buntsandstein tectonic and palaeogeographic conditions. Similarly as in Zechstein the Central European Basin was subjected also in Buntsandstein to epeirogenic movements, leading to a periodical connection with an open sea. Such changes occurred after all in other palaeogeographic conditions than the ones of Zechstein. A sedimentation of the Lower and Middle Buntsandstein occurred in a considerably shallower reservoir fed with great quantities of freshwater and in a much wetter climate. For that reason no evaporites on a larger scale can be found in the Lower and Middle Buntsandstein. But these differences there are also distinct similarities in a cyclic structure of both formations. In Zechstein as well as in Buntsandstein there are marine inserts; occurrence in some Buntsandstein beds of hystrichospheres, jellyfish prints (Müller 1969), foraminifers, oolitic deposits typical for a marine environment (Usdowski 1963) and glauconite prove univocally an existence of periodical connections of the Central European Basin and of the open sea. Marine inserts are different than the other complexes of Buntsandstein due to a predominance of greenish-gray and dark-gray colours; the fossils occur within these beds almost exclusively.

Barren brick-red sediments of Buntsandstein are the equivalent of Zechstein evaporite complexes; they were deposited in the Central European Basin isolated from the open sea. These sediments start each cyclothem and pass upwards into the rocks of a marine origin. Such cyclicity is noted in every section of the Buntsandstein and, independently on local facial features, enable a correlation of even far-off profiles (Fig. 4).

DEFINING OF SECTION BOUNDARY WITHIN BUNTSANDSTEIN

LOWER BOUNDARY OF BUNTSANDSTEIN

In the lowered parts of the Central European Basin a sedimentary pass of Zechstein into Buntsandstein is continuous. At the beginning of Buntsandstein only a type of sedimentation has changed. Already at the end of Zechstein a participation of clayey-siltstone rocks has gradually increased in the salt series. A replacement of salt deposits by terrigene rocks at the beginning of Buntsandstein was caused by a wetter climate what resulted in an increased erosion of peripheric zones of the basin.

A stratigraphy of Upper Zechstein and of Lower Buntsandstein is still unsufficiently known so a problem of the boundary between these two formations is unsolved. The first biostratigraphic analyses of Lower Buntsandstein have not been published until recent times (Fuglewicz 1977b, 1979a; Szyperko-Śliwczyńska 1979). In some inserts within the lowermost Buntsandstein numerous fossils have been found as hystrichospheres, miospores and megaspores (Figs 2, 20), all of great stratigraphic importance. In Germany a more detailed analysis of Upper Zechstein has not been done until recent times; it resulted in finding the 5th cyclothem (Reichenbach 1970).

The boundary between Zechstein and Buntsandstein is defined in a different way, depending on a zone of the basin. In its central part the boundary is set at the top of evaporites of the 5th cyclothem (Ohre). But this cyclothem does not compose of typical sediments everywhere. Outside its extent the boundary is appointed conventionally at the top of the Aller evaporites. In the peripheral zone the evaporites Z_3 (Leine) are overlain by clastic rocks distinguished as the top terrigene series (Wagner 1978) that probably correspond with a regressive Zechstein series. In some areas there are at the bottom of this series 1—2 anhydritic inserts (up to 1 m thick). The top of the terrigene series is accepted to be the equivalent of the upper part of Z_4 (Aller) or of the whole Z_4 (Wagner 1978).

In Poland the sediments of Buntsandstein overlie the rocks of different age (from Zechstein to Precambrian). As results from a megaspore analysis a sedimentation of the Buntsandstein has begun in every part of the Triassic basin at different time so the lower boundary of Buntsandstein is distinctly diachronous. The beginning of sedimentation of this series was signalled by an inflow of a clastic sediment; a coarser one was deposited at the side zones of the basin and a finer one in its central part. In the peripheries the beginning of sedimentation is noted after the movements of the Pfälzic Phase, not until the inter-oolitic beds (that usually overly the older rocks) and locally, even later (Fig. 24). A problem of the boundary of Buntsandstein and Zechstein is then reduced to the profiles with a complete Zechstein series in which there is also a continuation of sedimentation up to Buntsandstein (central zones of the basin).

Taking into account an occurrence of red, palaeontologicaly barren complexes at the border of Zechstein and Buntsandstein, a detailed noting of this border is not possible on the basis of a fossil fauna. So, it must be based on lithology. But a presence of gray and green interbeds with fossils at the boundary may allow for a precising of the boundary and for a reduction of a correlating error. Fig. 2 presents an example of defining the Zechstein-Buntsandstein boundary in several sections of the Fore-Sudetic Monocline. The author proposes to consider the bottom of the sub-oolitic beds (=bottom of the Cyclothem *Ia*) for the lower limit of Buntsandstein. Finding a bottom of these beds is not difficult as in every complete sequence the bottom of the Buntsandstein composes of barren red sandstones or siltstones (proving an increase of energy of sedimentation) passing upwards into greenish-gray clayey-siltstone rocks (*Otynisporites* Siltstone) with numerous megaspores of the Otynisporites eotriassicus Zone (Fore-Sudetic Monocline) or into the lower-oolitic beds (other parts of the country). These rocks occur usually consequently and regularly in the Buntsandstein sections of various areas. The boundary defined in this way seems to be easy to find as it is based on lithologic as well as on palaeontologic criteria. The megaspores of the uppermost Zechstein in the borehole Otyń *IG-1* represent a different megaspore assemblage (Pl. 1, and Fig. 2).

LOWER BOUNDARY OF MIDDLE BUNTSANDSTEIN

Definition of this boundary has been based for a long time on a rapid change of a sedimentation type resulting in a presence of coarse-clastic terrigene sediment in a section. These changes were undoubtedly connected with movements of the Pfälzic Phase that occurred mainly in south-western and southern margins of the basin. Therefore, in this zone the boundary of the Lower and Middle Buntsandstein is well defined (Fig. 3). Conglomerates and coarse-grained sandstones of the lower part of the Middle Buntsandstein are frequently separated there by a sedimentary break from fine — grained clayey-siltstone and carbonate rocks of Lower Buntsandstein and in many other sections — from older rocks. Such distinct change of palaeogeographic and sedimentary conditions must have occurred in a vaster area as the Middle Buntsandstein begins in many sections with coarse-clastic terrigene sediments. But it is not an evidence for a synchronous lower boundary of this sequence. A correlation of the sections in various parts of the basin made it possible to conclude that this boundary was of distinct diachronous type (Fig. 4).

The sedimentation changes at the border of Lower and Middle Buntsandstein have also occurred in north-eastern and northern Poland although their intensity was much smaller there. Only in a peripheral part of the reservoir (in relation to the Middle Polish Trough) the bottom of the Middle Buntsandstein is recorded by an admixture of a coarser matter (borehole Nidzica *IG-1*, and Fig. 4). In other sections from this area the movements of the Pfälzic Phase resulted only in an entire disappearance of the Rogenstein Facies and in a colour change from a greenish-dray into an almost completely brick-red, typical for the inter-oolitic beds. For that reason the bottom of the Middle Buntsandstein seems to correspond in these sections with the boundary of the lower-oolitic beds and of the inter-oolitic beds (Fig. 4) i.e. it occurs within the Baltic Formation but it does not at its top as it is suggested by Szyperko-Śliwczyńska (1979). But it is worth notice that in some sections (Pasłęk *IG-1* and Fig. 4) an influx of coarser terrigene sediment at the beginning of Middle Buntsandstein was very insignificant or did not occur at all; in such cases it is more difficult to define the lower boundary of these sediments.

UPPER BOUNDARY OF BUNTSANDSTEIN

The movements of the Hardegsen Phase were the next tectonic event in the Buntsandstein epoch that resulted in a distinct change of a type of sedimentation. But these movements had a different intensity in various parts of the basin. A denudation removed a considerable part of the Middle Buntsandstein in the uplifted areas (Figs 7, 13). Starting a new sedimentary cycle the bottom sediments of Upper Buntsandstein overlie discordantly in these sections the older rocks and compose of coarse-clastic facies. So, in many parts of the Central European Basin the described border is of a decided diastrophic type (Fig. 4).

In the sections in which there is a continuous transition from the Middle to the Upper Buntsandstein (Figs 4—5, borehole Otyń *IG-1*) the boundary is sometimes distinguished on the ground of occurrence (already at the bottom) of guide marine fossil fauna of Röt and of megaspores of the Trileites validus Zone.

LOWER BOUNDARY OF UPPER BUNTSANDSTEIN

In a considerable part of the Central European Basin this border occurs within a continuous series of a meridional megacyclothem, including Röt and Muschelkalk (Fig. 4). The upper border of the Buntsandstein is then conventionally beneath the Myophoria Beds, included for a long time by Polish workers into Muschelkalk (Senkowiczowa 1965b, Tokarski 1965) and lately, also by German geologists (Kozur 1975) what is practically in agreement with an upper extent of a typical for Röt *Myophoria costata* Zenk.

This border is completely different in the sections in which the Upper Buntsandstein sediments compose of inland facies. In the Polish part of the Central European Basin the area of north-eastern and northern Poland is of that type. As proved by a megaspore analysis the Upper Buntsandstein sediments, including freshwater and brackish facies, correspond in age with Röt and locally (borehole Pasłęk *IG-1*), with the whole Muschelkalk (Fig. 4). Including by Szyperko-Śliwczyńska (1979) the top part of the Buntsandstein (above the Elbląg Formation) in a borehole Pasłęk *IG-1* into Muschelkalk is problematical as these are the terrigene sediments without any fossils. In some sections the sediments of Upper Buntsandstein are overlain by the youngest probably, sediments of Muschelkalk (borehole Nidzica *IG-1*) the bottom of which defines at the same time the upper boundary of Buntsandstein. In the areas not occuppied by Röt and Muschelkalk sea (borehole Pasłęk *IG-1*) a megafacies of Buntsandstein is in contact with a megafacies of Keuper, the bottom of which is defined by megaspores of the Dijkstraisporites beutleri Zone, typical for the lowermost Keuper (Fig. 4).

BIOSTRATIGRAPHY

DESCRIPTION OF MEGASPORES OF BUNTSANDSTEIN IN POLAND

Among the mesophytic megaspores the megaspores of Buntsandstein form the earliest and the best known in Poland assemblage nowadays. It results from a good familiarity with these fossils in many sections in the Polish Lowlands as well as their recent find in the Tatra Mts (Fuglewicz 1979b). The megaspores of Buntsandstein are typical for their short stratigraphic range, occurring in quite great quantities and also, they generally repeat in many sections; so, they play a part of good guide fossils.

A taxonomic analysis of the Lower Triassic megaspores proved that they were of decided mesophytic type. Among 14 described genera a single one only (*Triangulatisporites*) is known from the Palaeophytic era.

An occurrence of Buntsandstein megaspores is closely connected with the environmental conditions (Fuglewicz 1973, 1977b). Among the marine facies of Middle and Upper Buntsandstein the smooth specimens definitely predominate; for inland facies the ornamented specimens are typical (Fig. 21).

Microflora and macroflora of Lower Triassic are specific for their close connection with a vegetation of Gondwanaland. It is especially characteristic for Middle Buntsandstein. Among 7 megaspore species described from Tasmania (Dettmann 1961), four of them occur in the sediments of Middle and Upper Buntsandstein of Poland (Fuglewicz 1973). The megaspores of Buntsandstein of the genus *Pusulosporites* are similar to the ones of Gondwanaland. A great similarity in an ornamentation of exina as well as a similar structure of mesosporium effected in including these megaspores by some authors into the genus *Talchirella* of Gondwanaland (Antonescu & Taugourdeau-Lantz 1973).

Among the macroscopic plant remains in sediments of Middle Buntsandstein of the Margin of the Holy Cross Mts, in boreholes Radoszyce 3 and Ruda Strawczyńska *1*, an occurrence of leaves of the Gondwana fern of a Glossopteris type (*Glossopteridium czarnockii* Boch.) was proved (Bocheński 1957; Pawłowska 1978); it was known only from the Gondwanaland and from the Siberian floristic province.

MEGASPORE STRATIGRAPHY

The sections of Buntsandstein compose usually of intervals with megaspores (and other fossils) and of barren complexes.

An analysis of vertical extents of megaspores made it possible to distinguish three guide assemblage zones corresponding with three phases of vegetation evolution in the Buntsandstein epoch: the assemblage zone Otynisporites eotriassicus typical of Lower Buntsandstein, the assemblage zone Trileites polonicus — Pusulosporites populosus typical of Middle Buntsandstein, and the assemblage zone Trileites validus typical of Upper Buntsandstein. The zones are named after the most abundant and most typical species. On the ground of differences in a quantitative and qualitative composition the Otynisporites eotriassicus Zone was divided into two subzones: Otynisporites eotriassicus lower Subzone and Otynisporites eotriassicus upper Subzone.

Every assemblage zone has a different species composition; the zones occur in different sections in the same succession thus, enabling the age determination and the stratigraphic correlation.

The barren complexes were distinguished as barren intervals, intrazones and interzones (Fig. 20). Figures 5—14 illustrate the stratigraphic extents of the species in the zones of the analyzed sections. Fig. 20 is

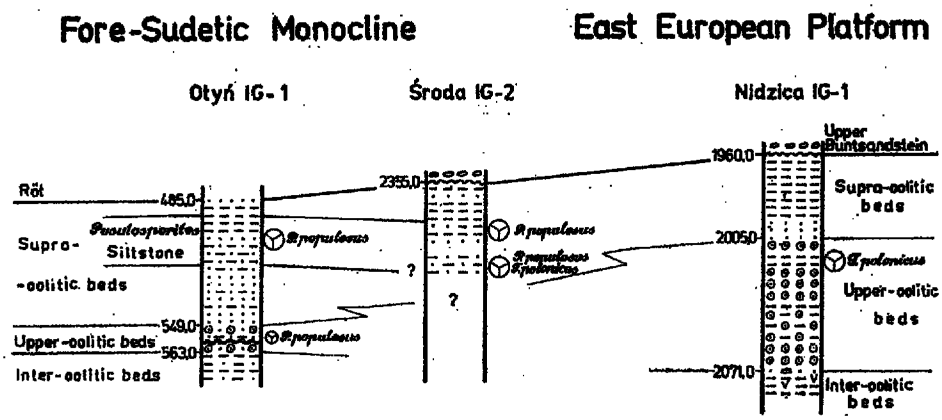

Fig. 19. Correlation of megaspore assemblages of Middle Buntsandstein in some sections

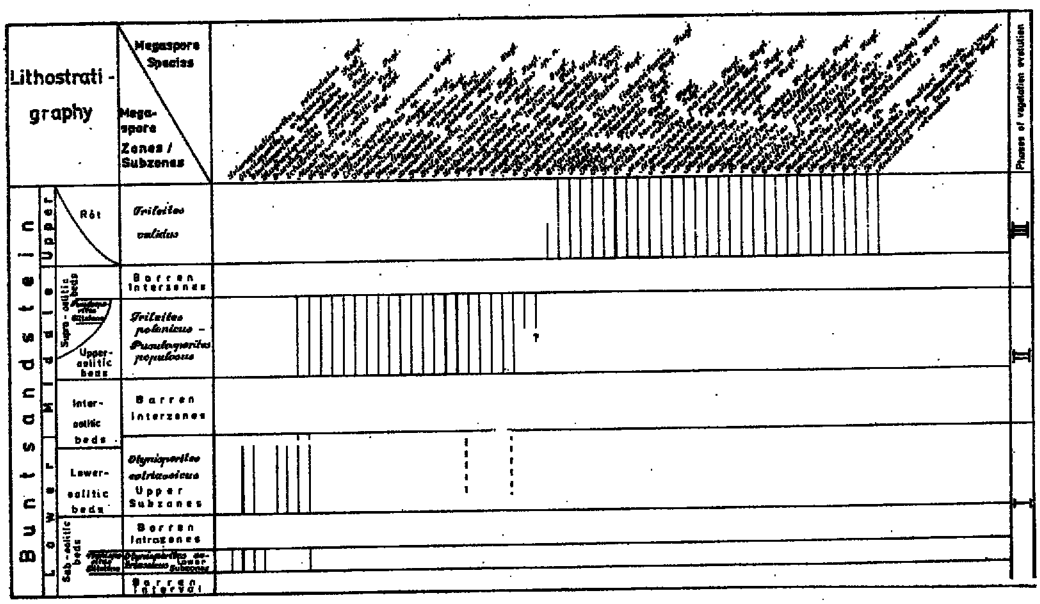

Fig. 20. Stratigraphic occurrence of megaspores in sediments of Buntsandstein of Poland

a compilation of all the studied sections and presents a generalized stratigraphic extent of all found megaspore species.

ASSEMBLAGE ZONES

In sediments of Lower Buntsandstein the megaspores were found in the Fore-Sudetic Monocline and in Kujawy so, a biostratigraphic scheme proposed for that period concerned these areas only. From the other parts of Poland the sections of the boreholes Kamień Pomorski *IG-1* and Pasłęk *IG-1* were analyzed but practically, no megaspores were found.

Barren Interval that underlies the Otynisporites eotriassicus Zone includes the earliest part of Buntsandstein and is overlain by the first, earliest megaspore Otynisporites eotriassicus Zone. Beneath that zone no megaspores were found.

The interval composes of red clayey-siltstone and sandstone rocks and occurs almost in every section in which the Zechstein forms a continuous sequence with the Buntsandstein.

OTYNISPORITES EOTRIASSICUS ZONE

The zone is best represented in the section of the borehole Otyń *IG-1*, at an interval of 793.0—956.0 m. The bottom of the zone was defined at the depth where the megaspores appeared for the first time.

For the Otynisporites eotriassicus Zone numerous *Trileites vulgaris* Fugl., *Otynisporites eotriassicus* Fugl. and *Otynisporites tuberculatus* Fugl. are typical. *Maexisporites ooliticus* Fugl. is a relatively popular species. *Pusulosporites permotriassicus* Fugl., *Pusulosporites inflatus* Fugl., *Hughesisporites variabilis* Fugl. and *Hughesisporites simplex* Fugl. are rare and there are sporadic *Echitriletes fragilispinus* Fugl., *Triangulatisporites reticulatus* Fugl.

Among other fossils ostracods, phyllopods and hystrichospheres were found.

In the section from the Fore-Sudetic Monocline (Otyń *IG-1*, Gorzów Wielkopolski *IG-1*) the described zone can be divided into two subzones: O. eotriassicus lower Subzone and O. eotriassicus upper Subzone separated by Barren Intrazone (Figs 5—6, 20). The lower subzone is defined by occurrence of megaspores after the Barren Interval. For this subzone *Triangulatisporites reticulatus* Fugl. and *Hughesisporites simplex* Fugl. are typical; these species were not found in the following sequences. The upper subzone is defined by an occurrence of *Echitriletes fragilispinus* Fugl. and *Maexisporites ooliticus* Fugl.

The O. eotriassicus Zone is connected entirely with sediments of Lower Buntsandstein and enables a detailed biostratigraphic correlation of the Fore-Sudetic Monocline and of the Kujawy area. No data from the north-eastern Poland and poor cores from other sections (Kamień Pomorski *IG-1*, Konary *IG-1*, Września *IG-1*, etc.) make wider correlations impossible nowadays.

BARREN INTERZONE O. EOTRIASSICUS — T. POLONICUS — P. POPULOSUS

In all the sections in which a full sequence of the Buntsandstein between the O. eotriassicus Zone and T. polonicus — P. populosus Zone was drilled through, there is a series of red clayey siltstone and sandstone rocks without megaspores. In most sections this barren horizon agrees well with the borders of the inter-oolitic beds; only in the borehole Gorzów Wielkopolski *IG-1* the megaspores of the O. eotriassicus Zone overpass the upper boundary of the lower-oolitic beds (Figs 6, 20). No megaspores in the discussed Barren Interzone is probably a result of a drier climate due to separation of the Central European Basin from the open sea. It is a very typical episode during evolution of the Buntsandstein, probably occurring in the whole basin.

TRILEITES POLONICUS — PUSULOSPORITES POPULOSUS ZONE

The renewed wet conditions in the epoch of the upper-oolitic beds caused an intensive development of the club mosses. The megaspores, on the ground of which the *T. polonicus* — *P. populosus* Zone was distinguished, are known from almost the whole territory of Poland with the Tatra Mts inclusive.

The lower boundary of the zone was defined at a depth with first megaspores after the inter-oolitic beds unfavourable for development of plants. Almost in all the analysed section of the Polish Lowland this boundary corresponds with the lower boundary of the upper-oolitic beds. Only in the borehole Studzianna *IG-2* the megaspores of this zone occur beneath the found inserts of oolitic limestones but an incomplete core recovery should be taken into account.

The upper boundary of the *T. polonicus* — *P. populosus* Zone corresponds with the upper boundary of the upper-oolitic beds of the north-eastern Poland and in the borehole Gorzów Wielkopolski *IG-1* and with the upper boundary of

Table 2

Occurrence of megaspores in some sections of Buntsandstein in Poland

	Upper-oolitic beds		Pusulosporites Siltstone		Tatra Mts	
	South—western Poland (borehole Gorzów Wielkopolski *IG-1*)	north—eastern Poland (borehole Nidzica *IG-1*)	south—western Poland (borehole Otyń *IG-1*)	Middle Polish Trough (borehole Konary *IG-1*, Jeżów *IG-1*)	Jawo-rzynka valley	Stare Szałasiska valley
Trileites polonicus Fugl.	+	+	—	+	+	—
Pusulosporites inflatus Fugl.	+	+	+	+	+	—
P. marginatus Fugl.	+	+	+	+	—	—
P. populosus Fugl.	+	—	+	+	+	+
Echitriletes echinatus Fugl.	+	—	+	+	—	+
Hughesisporites variabilis Dett.	+	—	+	—	+	+
H. tumulosus Marc.	+	+	+	—	—	—
H. inflatus Fugl.	—	—	+	—	+	—
Nathorstisporites cornutus sp.n.	+	+	—	—	+	—
Trileites vulgaris Fugl.	+	+	+	+	—	—
T. sinuosus (Dett.) Fugl.	—	+	—	+	—	—
Hughesisporites calvescens Fugl.	+	—	—	+	—	—
Maexisporites oolíticus Fugl.	+	—	+	+	—	—
Bacutriletes globosus Fugl.	+	+	—	—	—	—
Pusulosporites crassus Fugl.	—	+	—	—	—	—
Horstisporites spinosus Fugl.	—	+	—	—	—	—
H. heteroreticulatus Fugl.	—	+	—	—	—	—
H. sulcatus Fugl.	—	+	—	+	—	—
H. elegans Fugl.	—	+	—	—	—	—
Erlansonisporites sp.	—	+	—	—	—	—
Triletes sp.	—	+	—	—	—	—
Henrisporites sp.	—	—	—	—	—	+

the *Pusulosporites* Siltstone in the Fore-Sudetic Monocline as well as in the margin of the Holy Cross Mts (Fig. 20).

Varying environmental conditions reflected in a facial changeability caused a development of differentiated megaspore assemblages. For a paralic facies of oolitic limestones the assemblage *Trileites polonicus* is typical; it occurs in the north-eastern Poland. A. detailed description of this assemblage is included in the paper of Fuglewicz (1973). Among the species known until nowadays from the oolitic facies only there are: *Pusulosporites crassus* Fugl., *Bacutriletes globosus* Fugl., *Horstisporites heteroreticulatus* Fugl., *Horstisporites spinosus* Fugl., *H. elegans* Fugl., *Erlansonisporites* sp., *Horstisporites sulcatus* Fugl. and *Triletes* sp. But in the area of the north-eastern Poland some species of this assemblage were found in the Fore-Sudetic Monocline in the borehole Gorzów Wielkopolski *IG-1*, within the same oolitic facies as in the north-eastern Poland (Fig. 6, and Table 2).

For the limnic facies of Middle Buntsandstein the assemblage *Pusulosporites populosus* is typical; it is best represented in the *Pusulosporites* Siltstone in the borehole Otyń *IG-1* at the Fore-Sudetic Monocline (Fig. 5). The assemblage composes of the following species in its typical formation: *Trileites vulgaris* Fugl., *Pusulosporites inflatus* Fugl., *P. marginatus* Fugl., *P. populosus* Fugl. *Echitriletes echinatus* Fugl., *Hughesisporites inflatus* Fugl., *H. tumulosus* Marc., *H. variabilis* Dett. Particularly the index species of both assemblages avoid one another: *Trileites polonicus* Fugl. and *Pusulosporites populosus* Fugl. For example in the *Pusulosporites* Siltstone in the borehole Otyń *IG-1 Pusulosporites populosus* Fugl. is abundant but no *Trileites polonicus* Fugl. occurs at all. It is quite opposite in the north-eastern Poland where *Trileites polonicus* Fugl. is abundant but there is a complete lack of *Pusulosporites populosus* Fugl. There are the following species common for both assemblages: *Trileites polonicus* Fugl., *T. sinuosus* (Dett.) Fugl., *T. vulgaris* Fugl., *Pusulosporites inflatus* Fugl., *P. marginatus* Fugl., *P. populosus* Fugl., *Maexisporites ooliticus* Fugl., *Echitriletes echinatus* Fugl., *Horstisporites sulcatus* Fugl., *Hughesisporites calvescens* sp.n., *H. tumulosus* Marc., *H. variabilis* Dett. (Table 2). Between the Fore-Sudetic area and the area to the north-eastern Poland there is quite a vast zone with the Middle Polish Trough; in this zone the assemblage of *Trileites polonicus* and *Pusulosporites populosus* coexist (Table 2) and a predominance of a particular species depends on a facies type.

The megaspores of the T. polonicus — P. populosus Zone are accompanied by an abundant fossil assemblage found mainly in the sediments of the upper oolite and described in the chapter "Stratigraphy".

BARREN INTERZONE T. POLONICUS — P. POPULOSUS — TRILEITES VALIDUS

In all the studied sections there is between the T. polonicus — P. populosus Zone and T. validus Zone a complex of red clayey siltstone and sandstone rocks without any megaspores. These rocks were deposited in the palaeogeographic conditions, the same as in the inter-oolitic beds and resultted in an extinction of flora of the T. polonicus — P. populosus Zone.

TRILEITES VALIDUS ZONE

At the beginning of Upper Buntersandstein there was again a connection of the Central European Basin with the open sea what resulted in a change into a watter climate. These phenomena caused a development of the successive, third

Lower Triassic vegetation. The megaspores of that time constitute the T. validus Zone that can be distinguished almost in the whole area of Poland. It composes of 30 megaspore species (Fig. 20).

The T. validus Zone is best represented in a section of the borehole Tłuszcz *IG-1* where an inland facies, overfilled with plant remains, interfinger with a marine facies. The bottom of the zone is defined by the first megaspores after the *Barren Interzone*. In many sections the bottom of the zone corresponds with a lower boundary of Röt. But mostly the lower boundary of the zone occurs slightly higrer up as the lowermost part of Röt, distinguished as the sub-gypsum beds, is composed of red rocks that usually do not contain any megaspores.

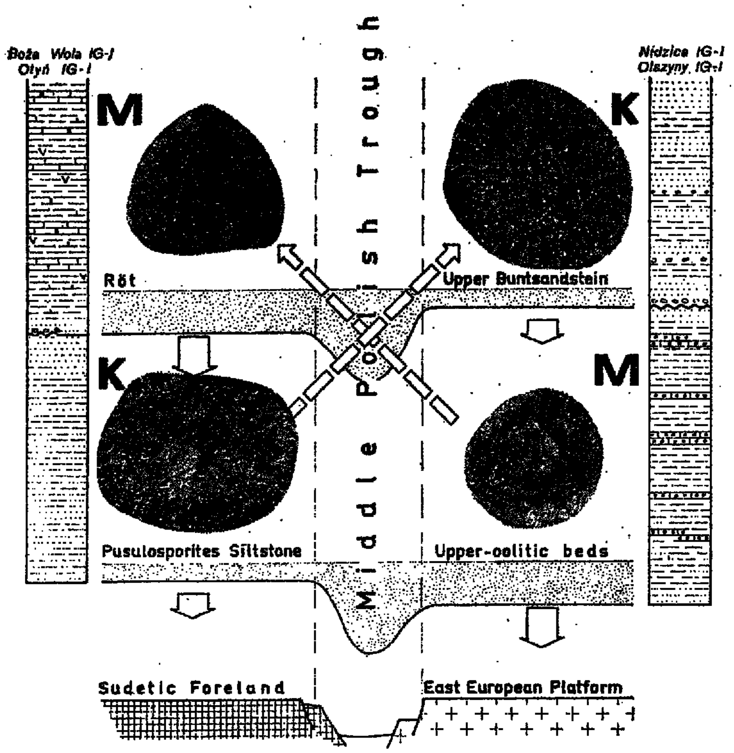

Fig. 21. Differentiation of the subsidence rate of the Middle and Upper Buntsandstein sediments and connection of megaspore assemblages with marine (*M*) and inland (*L*) facies. Dashed arrows show possible evolutional trends

Similarly as in the case of the T.polonicus — P.populosus Zone there is also in this zone a connection of a megaspore content with environmental conditions. In claystones and siltstones occurring within these marine sediments a decided predominance is gained by the smooth specimens (Fig. 21). *Trileites validus* Fugl. is the most typical species of the Röt facies and is usually numerous. *Trileites tenellus* Fugl. is more rare but occurs sometimes in large quantities (Boża Wola *IG-1*, Tłuszcz *IG-1*).

In the inland facies (north-eastern Poland) the mentioned smooth specimens occur sporadicly or do not occur at all and the ornamented megaspores predominate (Fuglewicz 1973). For inland facies the following megaspores are typical:

Bacutriletes insolitus Fugl., *Maexisporites parvus* Fugl., *M.pyramidalis* Fugl., *M.rotundus* Fugl. and *Verrutriletes fragilis* Fugl.

Among the more rare species but present in various facies there are: *Narkisporites brevispinosus* Fugl., *N. insignis* Fugl., *Bacutriletes asaphus* Fugl., *Echitriletes pectinatus* Fugl., *E.validispinus* sp.n., *Horstisporites microlumenus* Dett., *Dijkstraisporites beutleri* Reinh., *Aneuletes rotundus* Fugl.

A particular attention should be paid to the species *Erlansonisporites licheniformis* Fugl., known up to nowadays from the lowermost Upper Buntsandstein — from marine (Stęszów *IG-1*, Otyń *IG-1*) as well as from inland (Nidzica *IG-1* at a depth of 1948.0 m) facies.

The megaspores of the T.validus Zone are accompanied by an abundant fossil assemblage, connected mainly with the Röt sediments.

PALAEONTOLOGIC DESCRIPTION OF NEW MEGASPORE SPECIES

Genus *Echitriletes* (van der Hammen, 1954) Potonie, 1956
Echitriletes validispinus sp. n.
(Pl. 7, Fig. 5)

1973. *Echitriletes? sp. 1*; Fuglewicz, p. 434, Pl. 27, Fig. 1.
1973. *Echitriletes? sp. 2*; Fuglewicz, p. 434—435, Pl. 28, Fig. 4.
Holotype: specimen No. *IGP/95* (Pl. 7, Fig. 5).
Type locality: Boża Wola *IG-1*, depth 1841.0 m.
Type horizon: Röt.
Derivation of the name: latin *validispinus* — with strong prickles.
Diagnosis: Trilete rays distinct. Curvaturae lacking. The spore surface covered with strong, usually acute spines.
Material: 7 specimens
Dimensions (in μm):
Diameter of megaspores (without spines) — 400—900
Length of Y-rays — 0.85R—R
Height of Y-rays — 13—35
Width of Y-rays — 20—25
Length of spines — up to 100
Thickness of spines (at the base) — 15—45

Description. — Megaspores subtriangular (small specimens) to round (large specimens). Trilete rays developed as straight ridge or bands. No curvaturae. A whole surface of the spore is covered with strong, usually acute single spines.

Remarks. — Megaspores are mostly similar to *Echitriletes multispinosus* Fugl., but they have wider arms of the trilete rays and more solid acute spines.

Occurrence. — Upper Buntsandstein (Olenekian-Anisian) of the Polish Lowland.

Genus *NATHORSTISPORITES* Jung, 1958
Nathorstisporites cornutus sp. n.
(Pl. 3, Figs 2—3; Pl. 4, Fig. 6)

1979b. ?*Echitriletes* sp.; Fuglewicz, p. 273, Pl. 2, Fig. 2.
Holotype: specimen No. *IGP/96* (Pl. 3, Fig. 3).
Type horizon: upper-oolitic beds of Middle Buntsandstein.
Derivation of the name: latin *cornutus* — horned; a spore surface is covered with horn-like appendages.
Diagnosis: Trilete rays form a branched bend. Curvaturae usually lacking. The spore surface covered with branched horn-like appendages.

Dimensions (in μm):
Diameter of megaspores 330—600
Length of Y-rays — 0.8R
Height of Y-rays — 16—23
Width of Y-rays — 8—12
Length of appendages — 25—45 (close to the Y-rays) and up to 70 (at a megaspore edge)
Thickness of appendages — 4 (close to the Y-rays) to 14 (at an equator)
Thickness of appendage bases — 10—35

Description. — Megaspores rounded in shape. Trilete rays form a widely branched band. Curvaturae usually lacking. A whole surface of the spore is covered with usually horn-like appendages. Close to the arms of trilete rays the appendages are more numerous and also, they are more thick-set and branch earlier. In the outer part of the spore the appendages are less numerous and they start to branch higher up. At the base the appendages form rooty branches which is especially visible close to the equator of a spore where the appendages are less numerous. Badly preserved specimens (broken appendages) possess only the appendage bases of a truncated cone shape. Spore exina is spongy.

Remarks. — Megaspores are mostly similar to *Nathorstisporites flagellulatus* Dett. but they have a smaller diameter, lower trilete rays and much shorter branched horn-like appendages.

Occurrence. — Middle Buntsandstein of Poland.

TECTONIC MOVEMENTS OF THE BUNTSANDSTEIN EPOCH

Although a greater part of the post-Variscan cover of the Central European Basin developed during Triassic a process of sedimentation was not continuous at that time. During Buntsandstein a thickness of which forms almost a half of the whole Triassic, two phases of tectonic movements can be distinguished that played a decided role on sedimentation and on formation of stratigraphic breaks: the Pfälzic Phase that occurred at the border of Lower and Middle Buntsandstein (Fig. 24) and the Hardegsen Phase that occurred at the turn of Middle and Upper Buntsandstein. Reactions of various parts of Poland on the tectonic movements of Buntsandstein were different. The Fore-Sudetic

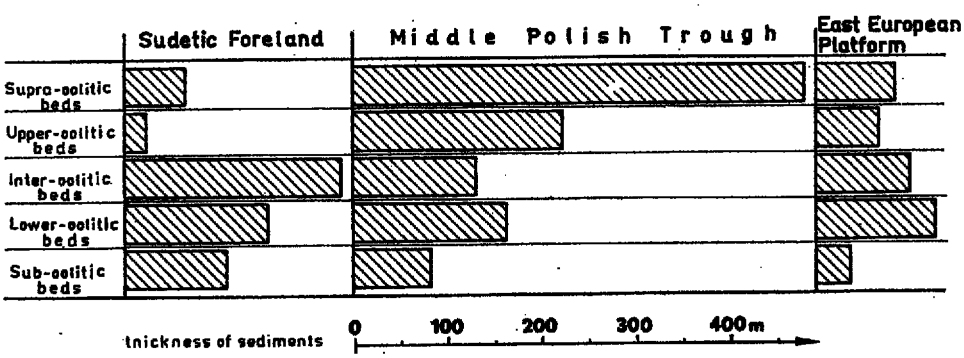

Fig. 22. Scheme of subsidence of the Lower and Middle Buntsandstein of Poland at every phase of its evolution

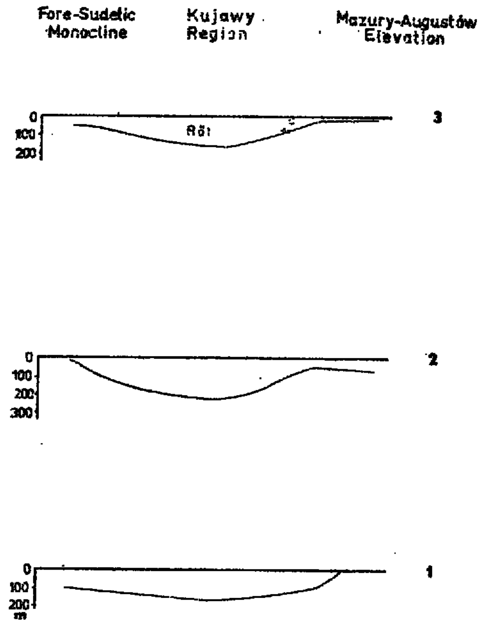

Fig. 23. Scheme of subsidence of the Buntsandstein at some phases of its evolution. *1* — Lower Buntsandstein (Lower oolite Epoch), *2* — Middle Buntsandstein (Upper oolite Epoch), *3* — Upper Buntsandstein

area and the north-eastern Poland were subjected to vertical tectonic movements of opposite directions.

In the Fore-Sudetic area the Pfälzic Phase resulted mainly in uplifting whereas the nort-eastern Poland subsided at the same time (Figs 21, 23). Quite a different situation is typical for a period of the Hardegsen Phase movements. After the differentiated block movements the Fore-Sudetic area was subsided at that time whereas the area of the north-eastern Poland was uplifted. These varying tectonic move-

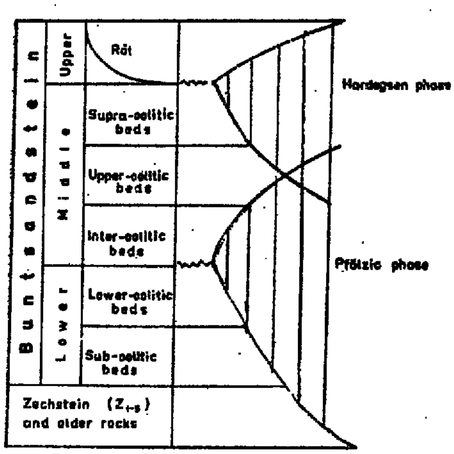

Fig. 24. Phases of tectonic movements and their time extent during the Buntsandstein Epoch

ments in the Fore-Sudetic area and in the north-eastern Poland resulted in greatest thickness of the Buntsandstein in the Central Poland zone (Figs 16, 21—23).

As the lower part of the post-Variscan cover (corresponding with Cimmerian structural stage) begins in the Central European Basin after the movements of the Saalic Phase with the sediments of Saxonian, the Pfälzic and Hardegsen phases should be treated as two earliest phases of the Cimmerian cycle (Schwab & al. 1973, Beutler & Schüler 1978).

PFÄLZIC PHASE

The Pfälzic Phase was distinguished by Stille (1924) as the tectonic movements occurring at the border of Permian and Triassic in the Palatinate area. Stille treated the Pfälzic Phase as a weak record of the Variscan Orogeny and with a varying intensity in various places. After Falk (1974) these movements played a decided role in tectonics of Palatinate. The Buntsandstein overlies there discordantly the oldest rocks but its age has not been precisely defined yet. As Zechstein overlies there concordantly the sediments of Upper Rotliegendes, the Pfälzic Phase must have occurred there after Zechstein.

Polish geological bibliography contains only some data referring to the Pfälzic Phase. No papers dealing with biostratigraphy of Lower Buntsandstein have been written until quite lately so, an assumption could be accepted of a continuous sedimentation between Zechstein and Buntsandstein not only in the central part of the basin but also in its marginal zones where Zechstein as well as Buntsandstein sediments are strongly reduced and compose of similar facies.

Detailed studies over the biostratigraphy of Buntsandstein undertaken in Poland lately enable a more precise localization of the Pfälzic Phase and prove its great influence on a type of sedimentation. These studies suggest that the Lower Buntsandstein occurs almost only in these sections in which there is a full sequence of Zechstein. In places where no Upper Zechstein sediments were found the sediments of Lower Buntsandstein are also absent. As results from the data of a megaspore analysis and from a correlation based on lithology, the movements of the Pfälzic Phase occurred in the territory of Poland mainly at the turn of Lower and Upper Buntsandstein, in the inter-oolitic beds. The Pfälzic Phase resulted among others in a distinct cyclic sedimentation of the Middle Buntsandstein (in opposite to Lower Buntersandstein), expressed by alternate coarse-grained and fine-grained rocks. During the phase the block movements of dictyogenic features occurred, best recorded in the south-eastern part of the Fore-Sudetic Monocline (Deczkowski & Gajewska 1974), in the margin of the Holy Cross Mts and in the elevations of the East European Platform (Mazury—Augustów Elevation) and also, in the Tatra Mts (Fig. 3).

In the German part of the Triassic sedimentary basin there is a discontinuity at the bottom of Volpriehausen-Folge, distinguished by Trusheim (1961) as V-Diskordanz and corresponding with the movements of the Pfälzic Phase. Absence of biostratigraphic analyses dealing with Buntsandstein in the German bibliography and great difference of opinions in the stratigraphy based on lithology make it impossible to assume an attitude towards the German territory.

Fore-Sudetic area is of essential significance for a knowledge of a type of the Pfälzic Phase movements due to an occurrence of complete and well studied sections of Zechstein and Buntsandstein that enable a precise localisation of diastrophic changes.

In this area the Lower Buntsandstein (sub-oolitic beds and lower-oolitic beds) although it has a different lithology from the Zechstein, was deposited in the palaeogeographic conditions similar to the ones of Zechstein. It always continues the Zechstein sequence creating with it a single sedimentary cyclothem. A radical change of the sedimentation type at the turn of Lower and Middle Buntsandstein (after the lower-oolitic beds) was caused by the movements of the Pfälzic Phase. In result of these movements the southern margin of the basin (the Variscan one) must have been elevated as that area started to supply with a great quantity of a coarse-clastic terrigene material in the inter-oolitic beds. A distinct increase of the sedimentation rate caused by the movements of the Pfälzic Phase have been accepted for a long time to define the border of Lower and Middle Buntsandstein; this border is well pronounced in the Fore-Sudetic area.

South-eastern part of the Fore-Sudetic area. In the sections of the boreholes between Kluczbork and Częstochowa Deczkowski & Gajewska (1974) proved the movements of the Pfälzic Phase at the turn of Zechstein and Buntsandstein. In result of these movements there occurred an uplifting of the zone Więcki-Wołczyn and of the north-eastern margin of the Upper Silesian Coal Basin. The Lubliniec ridge was most elevated and was emerging during Lower Buntsandstein and locally, during Middle Buntsandstein. The authors based their interpretation on a lithologic and geophysical correlations but absence of palaeontologic data made it impossible to precise the age of deformations connected with the Pfälzic Phase.

Coarse-clastic sediments of Buntsandstein connected with the movements of the Pfälzic Phase can be considered for an equivalent of the Saxonian molasse occurring in this area and deposited after the Saalic Phase. In result of the movements of the Pfälzic Phase the same alimentary areas were probably elevated as the ones that supplied with terrigene material for the Saxonian series.

Margin of the Holy Cross Mts. Buntsandstein in that area is known from many exposures and boreholes. Similarly as in the south-eastern part of the Fore-Sudetic Monocline the terrigene, usually coarse-clastic rocks predominate in it.

A megaspore analysis of samples coming from many sections proves that the Lower Buntsandstein does not occur there and various older rocks are overlain by the sediments of Middle Buntsandstein (Fig. 3). A lower part of these sediments is barren and similar to the inter-oolitic beds and probably, it is of the same age.

Many workers that studied the Mesozoic Margin of the Holy Cross Mts assumed, basing mainly on indirect premises, a sedimentary continuity between Zechstein and Buntsandstein. Such suggestion could be a result of observations of the sections in which there is a contact of Zechstein and Buntsandstein sediments of the same lithological composition (regressive conglomerates of Zechstein and transgressive conglomerates of Middle Buntsandstein). A continuity of Zechstein and Buntsandstein sediments was accepted among others in the section of the borehole Radoszyce 3 (Pawłowska 1957) although the rocks included into the Lower Buntsandstein had not been found anywhere but in the Holy Cross Mts. Decided marine features of these sediments (presence of dolomite, calcite and glauconite as well as of foraminifers in the cement) and gradual decrease of the content of carbonates suggest that they probably are still of Zechstein age.

It should be reminded that Samsonowicz (1929) set the boundary of Zechstein and Buntsandstein at the bottom of the complex with an exotic material transported by rivers.

An analysis of Zechstein and Buntsandstein in a section of the borehole Ruda Strawczyńska made Pawłowska (1978) admit an existence of a distinct sedimentary discontinuity. Although in the section the boundary Zechstein-Buntsandstein occurred within the coarse-clastic conglomerate rocks the authoress concluded that: „At the border of Buntsandstein and Zechstein there occurred a change of alimentary areas and of transport directions during a sedimentation of conglomerates of two different systems. So, no sedimentary continuity can be accepted between these conglomerate series".

Therefore, it is still unknown what is the time gap of the stratigraphic break that separates these two complexes. Some premises are a result of palynologic analyses done by Dybova-Jachowicz & Laszko (1978) and of megaspore analyses of the present author. According to these authoresses there is a distinct floristic break at the border of Zechstein and Buntsandstein. A pollen spectrum of Upper Zechstein of the Holy Cross Mts corresponds well with the 3rd Zechstein cyclothem (Leine) of Germany and in the overlying Buntsandstein sediments the author found only the megaspores typical for Middle Buntsandstein (T.polonicus — — P.populosus Zone) and also, the guide pelecypods *Avicula murchisoni* Gein. (Figs 3, 18).

The mentioned evidence suggest that at the turn of Zechstein and Buntsandstein the area of the Holy Cross Mts was uplifted (Pfälzic Phase) and then, denuded. A sedimentation began after a break of Upper Zechstein (Z_4? — Z_5) and Lower Buntsandstein so, in Middle Buntsandstein. In this respect the Holy Cross Mts are much similar to the Tatra Mts where the sedimentation began in the same period.

The movements of the Pfälzic Phase seem to have been represented by block movements described by Głazek & Romanek (1976, 1978) from Jaworznia area in result of which according to the authors, the Devonian limestones were destructed and mudflows, clastic veins as well as small tectonic grabens and horsts were formed. Folded and eroded Devonian sediments are overlain by a complex of siltstone-sandstone rocks and conglomerates. These conglomerates contain the pebbles of acid effusive rocks and of their tuffs, unknown in the Holy Cross Mts (Fuglewicz 1967). The conglomerates of the same composition (after Dr. A.Barczuk, *personal information)* have been found by the author in other sections from the Holy Cross Mts (boreholes Łopuszno *IG-1*, Studzianna *IG-1*, Figs 11—12). They occur also in Seisian sediments (i.e. of Middle Buntsandstein) in the Tatra Mts (Roniewicz 1966). Pebbles of volcanic rocks have been also found in a conglomerate of Buntsandstein in the south-eastern part of the Fore-Sudetic Monocline: they overlie there an eroded (due to the Pfälzic movements) Zechstein of older bedrock (Deczkowski & Gajewska 1974). In the Margin of the Holy Cross Mts and in the Tatra Mts these conglomerates pass towards the top into clayey-siltstone rocks with many megaspores typical for Middle Buntsandstein (T.polonicus — P.populosus Zone).

Conglomerates and sandstones occurring in the Margin of the Holy Cross Mts and in the Tatra Mts, overlain by sediments with fossil fauna and flora of Middle Buntsandstein, have been most probably deposited during a lower part of Middle Buntsandstein. No fossils, predominant brick-red colour and well expressed inland origin of these sediments incline to a conclusion that they correspond with the inter-oolitic beds of a full section of Buntsandstein (Fig. 3). Similar sandstones from Tumlin and Ciosowa Góra are probably of the same age; their detailed sedimentologic analysis was done by Gradziński, Gągol & Ślączka (1979).

North-eastern Poland. The Buntsandstein cover overlies in the north-eastern Poland various older rocks (up to Precambrian ones inclusive, Fig. 16; Fuglewicz 1973). A continuity at the boundary of Zechstein and Buntsandstein is known only from the bedrock depressions (borehole Pasłęk *IG-1*). In the areas with uplifting trends (connected with the Pfälzic Phase) a new, Triassic sedimentary cycle stars with sediments of Middle Buntsandstein (with the inter-oolitic beds in a borehole Nidzica *IG-1* or with the upper-oolitic beds in a borehole Olszyny *IG-1*, Fig. 4, 16; Fuglewicz 1973).

Tatra Mts. Passendorfer (1957) was one of the first who proved the movements of the Pfälzic Phase in the Tatra Mts. The Pfälzic Phase is also suggested by Kotański (1961). But the earliest Triassic sediments in the Tatra Mts have been supposed to be barren until nowadays and defined as Seisian on the ground of analogy with the Alps only, the age of the movements there could not be determined precisely.

A megaspore analysis last-made (Fuglewicz 1979b) proved that in the High-tatric Succession (Stare Szałasiska valley and Żółta Turnia) as well as in the Lower — Křižne Sub-tatric Succession (Jaworzynka valley) the earliest series of the tatric sedimentary cover are of Middle Buntsandstein age (Fig. 3). Thus, the deposition of the sedimentary cover in the Tatra Mts began after the movements of the Pfälzic Phase.

HARDEGSEN PHASE

The tectonic movements that caused a sedimentary discontinuity and a conspicuous stratigraphic break between Middle and Upper Buntsandstein, were distinguished by Trusheim (1961) as the Hardegsen Phase. These movements, defined as H-Diskordanz are common in the western part of the Central European Basin. In Poland they were distinguished for the first time by Fuglewicz (1977b).

According to Beutler and Schüler (1978) the Hardegsen movements could result in some Buntsandstein sections of East Germany in a stratigraphic break reaching the lower-oolitic beds (Bernburg-Folge). But it should be taken into account that the German geologists still use only a lithostratigraphic scheme of Buntsandstein.

In the Polish part of the Triassic sedimentary basin where a palaeontologic method was applied for the first time for Buntsandstein sediments (Fuglewicz 1973), an interval of the Hardegsen Phase could be defined more precisely. In this country the Hardegsen break seems to be a smaller one. An erosion caused by the Hardegsen movements was the more intensive in the marginal parts of the basin. At the south-western part of the Fore-Sudetic Monocline the Röt sediments are underlain by the inter-oolitic beds (Fuglewicz 1977b). Effects of the Hardegsen movements were very significant in the north-eastern Poland as they radically changed a previous type of sedimentation and started a new sedimentary cycle (Fig. 4). In the Podlasie Trough a pre-Röt erosion reached the upper-oolitic beds (Fig. 13). A great pre-Röt break is described by Szyperko-Śliwczyńska (1976) from the sections of the Pomeranian Trough. In the central part of the basin the Hardegsen movements were less intensive. They resulted in a local considerable reduction of the supra-oolitic beds (borehole Gorzów Wielkopolski *IG-1*) and in a deposition of conglomerates, locally up to several metres thick, at the Röt bottom (borehole Środa *IG-2*).

Dictyogenic movements within the Central European Basin were followed by epeirogenic subsidence of the south-western part of the basin what resulted in an ingression of the Röt sea and then, of the Muschelkalk sea. In contrary, north-eastern and northern areas were elevated and during the whole Röt, Lower (Nidzica *IG-1*) or the whole Muschelkalk (Pasłęk *IG-1*) occurred within a zone of inland sedimentation (Fig. 4). This change of previous tectonic regime caused by the Hardegsen movements, was of great significance for a sedimentation type of the Buntsandstein in the whole territory of Poland.

PALAEOGEOGRAPHY

The sediments of Buntsandstein were deposited in a vast basin created at the edge of the Palaeozoides and of the Precambrian (East

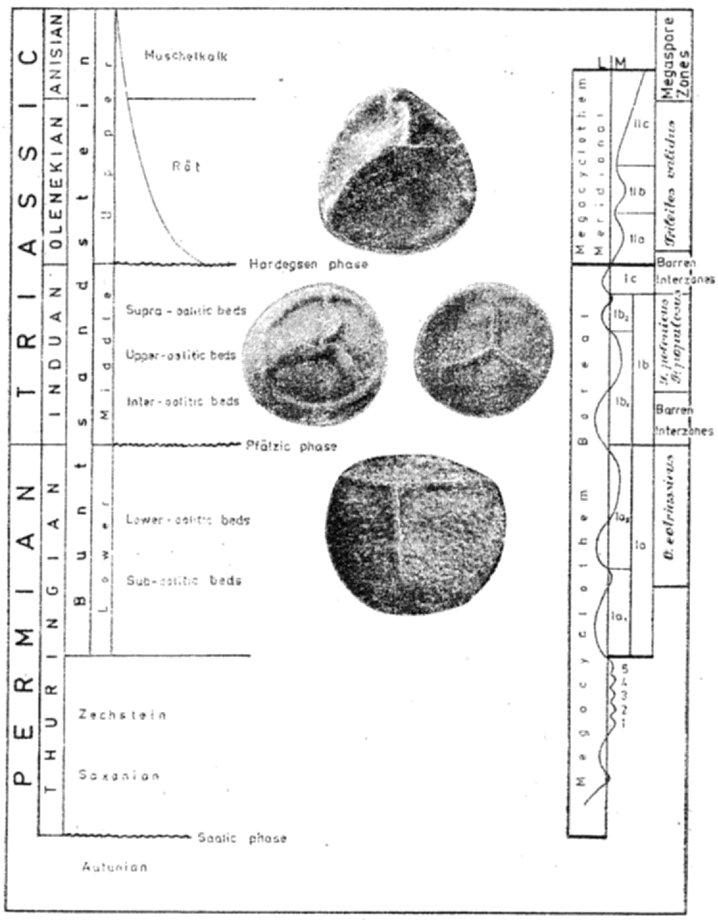

Fig. 25. Diastrophism and stratigraphy of sediments at the border of Permian and Triassic in the Polish part of the Central European Basin

L — predominance of inland conditions, *M* — predominance of marine conditiins, *1—5* — Zechstein cyclothems, Ia_1 — cyclothems of Lower Buntsandstein in the Fore-Sudetic Monocline, *Ia* — in the north-eastern Poland, *IIa* — Röt cyclothems

European) Platform after the movements of the Saalic Phase (Fig. 25). The border zone of these two great regions passes across the central part of Poland and from a geotectonic point of view the Polish territory is the only one to investigate the effects of their interrelations. It is supported by a very good documentation of the sedimentary cover based on exposures, numerous boreholes and on geophysical investigations.

In Triassic and also in younger geological periods these two regions were subjected to epeirogenic movements of contrary directions (Figs 21, 23). In result the greatest Mesozoic subsidence occurred at the border of the Palaeozoides and of the Precambrian Platform (Middle--Polish Trough). In the trough the thicknest series of the Permian-Mesozoic cover were deposited in the post-Variscan period.

A direction of the epeirogenic movements in both regions was of primary importance for a connection of the Central European Basin with the southern open sea (Tethys) or with a boreal sea.

Absence of the Rogenstein in the northern part of the North Sea proved by the boreholes not a long time ago (Brennand 1975), seems to suggest that the Central European Basin was connected with a boreal sea along the south-eastern margin of the Baltic Shield, through Lithuanian and Moscow basins. The facies of the Lower Triassic occurring within these basins are much similar to the typical Buntsandstein sediments of the German Basin. This connection was also active during Late Mesozoic (Jurassic, Cretaceous) and enabled a migration of boreal fauna south-westwards.

Uplifting of the Hardegsen Phase to which the Precambrian Platform was subjected at the end of Middle Buntsandstein, resulted in a long--time break in a connection with a boreal sea and in a renewed connection with the Tethys ocean at the beginning of Röt.

At the end of Zechstein the Central European Basin has become gradually smaller and smaller. It has lost its marine features and changed at the beginning of Butsandstein into a closed inland reservoir. The sediments of the lowermost Buntsandstein almost always continue a sedimentation of Upper Zechstein so, the basin of Lower Buntsandstein occuppied a similar area as the one of Zechstein. The banks of the basin were probably emerged and eroded at the beginning of Buntsandstein sedimentation recorded by terrigene matter due to increased fluvial erosion.

During the Buntsandstein there were cyclic climatic changes recorded in the sections by alternate occurrence of barren sediments of a common brick-red colour and of greenish-gray sediments with megaspores (Fig. 20). The periods with a wet climate must have been more and more intensified as it is proved by more and more rich megaspore assemblages found in the Buntsandstein sections (Fig. 20).

In a semi-desert environment at the beginning of Buntsandstein quite similar barren and brick-red siltstone-sandy sediments of the sub-oolitic beds were deposited in the whole basin.

During the lower-oolitic beds the basin was connected with the open sea but its shape was still the same. Only a type of sedimentation has changed. The first oolitic complex was deposited with a predominance of gray and greenish colours, with numerous animal and plant fossils as: phyllopods, ostracods, foraminifers and fragments of vertebrates.

In the Fore-Sudetic Monocline these changes occurred in two phases. After the sedimentation of red rocks of the lower part of the sub--oolitic beds a sequence of clayey-siltstone gray and dark-gray rocks was deposited, containing red interbeds at the top only and with various fossils (*Otynisporites* Siltstone). Marine features of these rocks are proved by hystrichospheres. Then, there was a short-period regression of the sea in the Fore-Sudetic Monocline in result of which a red clayey-sandstone series was deposited (complex *19* of Sokołowski). The area was again connected with the open sea during the epoch of the lower-oolitic beds.

After a deposition of the lower-oolitic beds the tectonic conditions have changed due to Pfälzic movements and the inter-oolitic beds were formed. The movements caused a successive separation of the Central European Basin from the open sea and so, a renewed drying of the climate. In the whole vast reservoir brick-red rocks of the inter--oolitic beds were mainly deposited; they were almost completely devoid of fossils. These phenomena had a principal influence on the changes of a vegetation cover. They started a new phase in evolution of vegetation. The Pfälzic Phase resulted in radical changes of a sedimentation type and started a new sedimentary cycle (Cyclothem *Ib*). Large rivers of strong currents eroded and transported a coarse material. So, in many places thick conglomerate and gravel-sandy complexes were deposited (Margin of the Holy Cross Mts, southern margin of the Fore-Sudetic Monocline, Tatra Mts). In many places the rocks of the previous sedimentary cycle were deposited. The Holy Cross Mts that had been denuded before, were subsided and covered by exotic deposits. Only at the bottom of the Middle Buntsandstein there is also a local material (pieces of Devonian limestones) but common exotic rocks; the latter contain in the sections (close to Jaworznia by Kielce; boreholes Łopuszno *IG-1*, Studzianna *IG-1*) the pebbles of volcanic rocks but quartz.

Similar conditions of sedimentation were also in the Tatra Mts. An occurrence in this area of pebbles of volcanic rocks similar to the ones in the Margin of the Holy Cross Mts and a predominating content of vein quartz in the conglomerates suggest that the sediment must have come from the same alimentary area.

The processes of denudation must have result at last in peneplanation of the area formed by the Pfälzic movements what enabled the boreal sea to enter the Central European Basin during the epoch of the upper-oolitic beds. For a certain period of time the conditions of sedimentation were stabilized and similar to the ones of the lower--oolitic beds. Almost in the whole territory of Poland there was at that time a sedimentation of oolitic limestones and dolomites (Rogenstein Facies), as well as of stromatolitic and spirorbids ones in a shallow reservoir. No evaporites and also, numerous marine fossils prove a normal or nearly normal marine environment.

The tectonic changes and first of all, a connection with the open sea resulted in a certain increase of a climatic humidity what favoured an evolution of heterosporous vegetation. The latter is proved by numerous megaspores occurring in sediments of that age.

Soon, at the Fore-Sudetic Monocline an uplifting occurred (final signs of the Pfälzic Phase?) that caused a sea regression and an inland sedimentation again. These movements were compensated by a further subsidence of the Precambrian Platform (Figs 21, 23). In such environment a sedimentation of upper part of the upper-oolitic beds in the north-eastern Poland occurred at the same time as a deposition of a terrigene complex in the Fore-Sudetic Monocline (except the section of the borehole Gorzów Wielkopolski *IG-1)*; the sediments of this complex are red at the bottom and pass upwards into an insert, several metres thick, of gray and greenish — gray siltstones with interbeds of sandstones containing an abundant detritus of plants (*Pusulosporites* Siltstone). There are sporadic marine inserts. The same type of sedimentation is known from the territory of Germany (Hardegsen — — Folge).

At the end of the boreal Buntsandstein (Cyclothem *Ic)* there was the next separation of the basin from the open sea. In a closed inland reservoir occuppying the whole territory of Poland, the barren brick--red terrigene rocks were deposited (Fig. 4).

The beginning of the Upper Buntsandstein is proved by the changes caused by the movements of the Hardegsen Phase; the effects of this phase were opposite to the changes caused by the movements of the Pfälzic Phase (Figs 21, 23). After the differentiated dictyogenic movements there occurred the epeirogenic movements within the basin; they resulted in a change of previous tectonic regime. The Fore-Sudetic area was subjected to a subsidence and then, covered by the Röt sea.

The area of the north-eastern Poland was uplifted. So, a successive radical change of sedimentation conditions occurred.

In the north-eastern Poland strong-current rivers carried a thick material, coming mainly from the north and north-east. In many places thick inserts of conglomerates and of gravel-sandstone rocks were deposited (Figs 4, 7). Fine-grained rocks contain abundant macroflora remains and megaspores that prove a change into a more wet climate, caused probably by the Röt sea in the neighbourhood.

A considerable content of sands coming from the northern alimentary area (Baltic Shield) is noted not only in the Röt-corresponding terrigene series of north-eastern and northern Poland but also in the sediments of Röt occurring within the Middle-Polish Trough (Figs 10—11).

In the Fore-Sudetic area the ingressions of the Tethys sea occurred in phases. In the Röt section there are two ingressive — regressive full cycles (Fig. 4).

The Röt thickness is the greatest in the Middle Polish zone (Figs 21—23) but a subsidence rate was much smaller there in comparison with the Middle Buntsandstein. In the Fore-Sudetic area as well as in the Middle Polish zone the sediments of Röt pass gradually into the sediments of Muschelkalk.

A sedimentation of the Upper Buntsandstein was quite different in north-eastern and northern Poland. Inland sediments (corresponding with Röt) at the Mazury—Augustów Elevation are overlain by thin deposits of the Upper Muschelkalk (Fig. 4). The other parts of the East European Platform have been influenced neither by the Röt sea nor by the Muschelkalk sea. The whole Triassic system composes there of inland sediments of Buntsandstein and Keuper megafacies (Fig. 4).

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RYSZARD FUGLEWICZ

STRATYGRAFIA I PALEOGEOGRAFIA DOLNEGO TRIASU W POLSCE NA PODSTAWIE MEGASPOR

(Streszczenie)

Przedstawiono wyniki badań nad litostratygrafią, biostratygrafią i paleogeografią triasu dolnego Polski Niżowej oraz obszaru tatrzańskiego. Materiału do badań dostarczyły rdzenie 18 otworów wiertniczych, w tym 11 otworów było pełnordzeniowych. Z obszaru tatrzańskiego materiał do badań pobrano z odsłonięć triasu wierchowego w rejonie Żółtej Turni i w dolinie Starych Szałasisk oraz z triasu reglowego, z doliny Jaworzynki.

Analiza badanych profili doprowadziła autora do wniosku, że cechą charakterystyczną pstrego piaskowca na całym prawie obszarze Niżu Polskiego jest występowanie dwóch horyzontów oolitowych, których geneza związana jest z ingresjami morskimi. Pozwoliło to zastosować opracowany wcześniej dla obszaru Polski NE schemat litostratygraficzny (Fuglewicz 1973). Na podstawie uzyskanych danych została wykonana mapka zasięgów ogniw pstrego piaskowca związanych z ingresjami morskimi warstw oolitowych donych, warstw oolitowych górnych i retu, (fig. 1).

Prowadzone przez autora na przestrzeni przeszło 10-ciu lat systematyczne poszukiwania megaspor w utworach pstrego piaskowca różnych regionów Polski pozwoliły na zgromadzenie bogatej ich kolekcji. Analizie megasporowej poddano około 900 prób, które autor macerował udoskonaloną przez siebie metodą (Fuglewicz 1977).

W wyniku badań megasporowych opracowano paleontologicznie 46 nowych gatunków megaspor (Fuglewicz 1973, 1977, 1979), z których dwa: *Echitriletes validispinus* sp.n., i *Nathorstisporites cornutus* sp.n., zawiera obecna praca. Ponadto 6 gatunków megaspor opisano w kategorii *species* ze względu na małą ilość okazów.

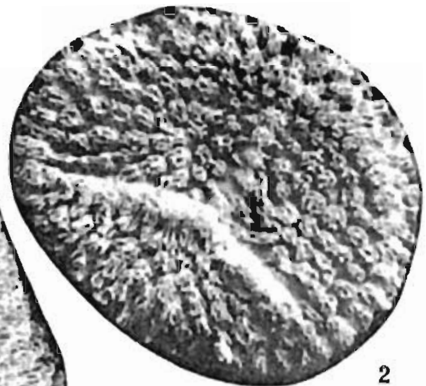
Zebrany materiał megasporowy, pochodzący z całego pstrego piaskowca Polski pozwolił na wyróżnienie 3 zon megasporowych: zony Otynisporites eotriassicus, przewodniej dla pstrego piaskowca dolnego; zony Trileites polonicus — Pusulosporites populosus, przewodniej dla pstrego piaskowca środkowego oraz zony Trileites validus, przewodniej dla pstrego piaskowca górnego. W obrębie zony O. eostriassicus wydzielono 2 podzony: O. eotriassicus dolną i O. eotriassicus górną. Kompleksy nieme zostały wyróżnione jako interwały, śródzony i międzyzony jałowe (fig. 21).

Graficznie przedstawiono litologię i inwentarz megasporowy 10-ciu ważniejszych profili wiertniczych (fig. 6—15). W otworach pełnordzeniowych można było dokładnie wyznaczyć granice lito- i biostratygraficzne, zaś w otworach rdzeniowanych tylko kontrolnie granice te mają charakter przybliżony.

Zastosowanie skali biostratygraficznej do korelacji profili pstrego piaskowca pozwoliło na skorygowanie błędów popełnionych w korelacjach opartych wyłącznie na metodzie litologicznej. Dotyczy to zwłaszcza korelacji utworów pstrego

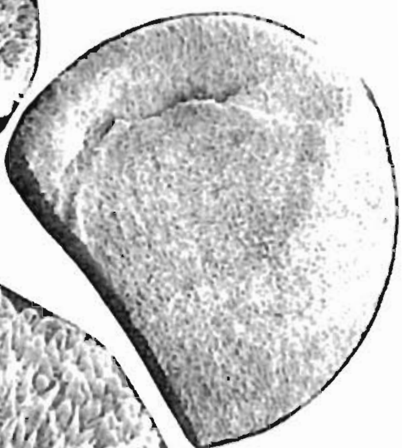
piaskowca Polski SW z obszarem Polski NE (fig. 4). Badania megasporowe oddały również duże usługi w interpretacji warunków środowiskowych i paleogeograficznych.

Zestawienie danych lito- i biostratygraficznych umożliwiło wykrycie luk sedymentacyjnych, spowodowanych działaniem dwóch faz tektonicznych, palatyńskiej i hardegseńskiej, które miały decydujący wpływ na przebieg sedymentacji utworów pstrego piaskowca. Wykazano, że subsydencją, sedymentacją oraz paleogeografią pstrego piaskowca w Polsce, a prawdopodobnie i w całym basenie środkowoeuropejskim, rządziły ruchy kontrastowe płyt paleozoicznej i prekambryjskiej (fig. 22, 24).

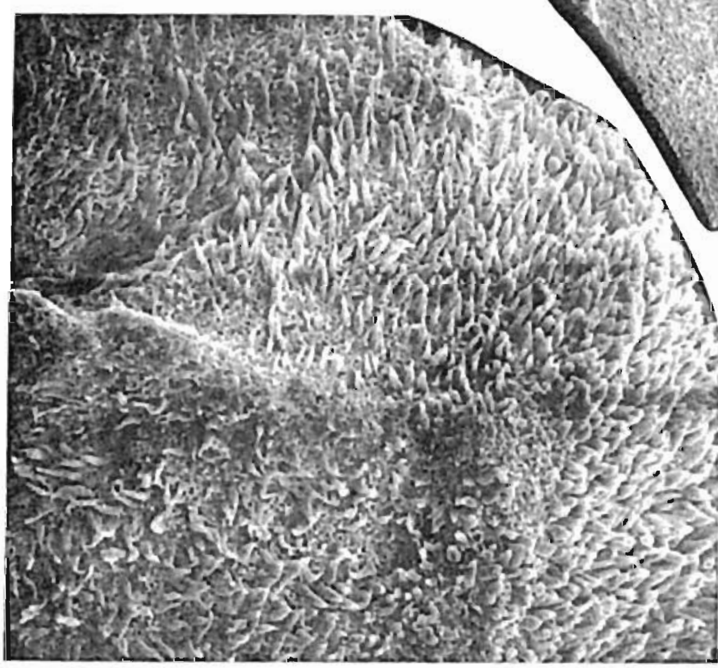


2

1



3a

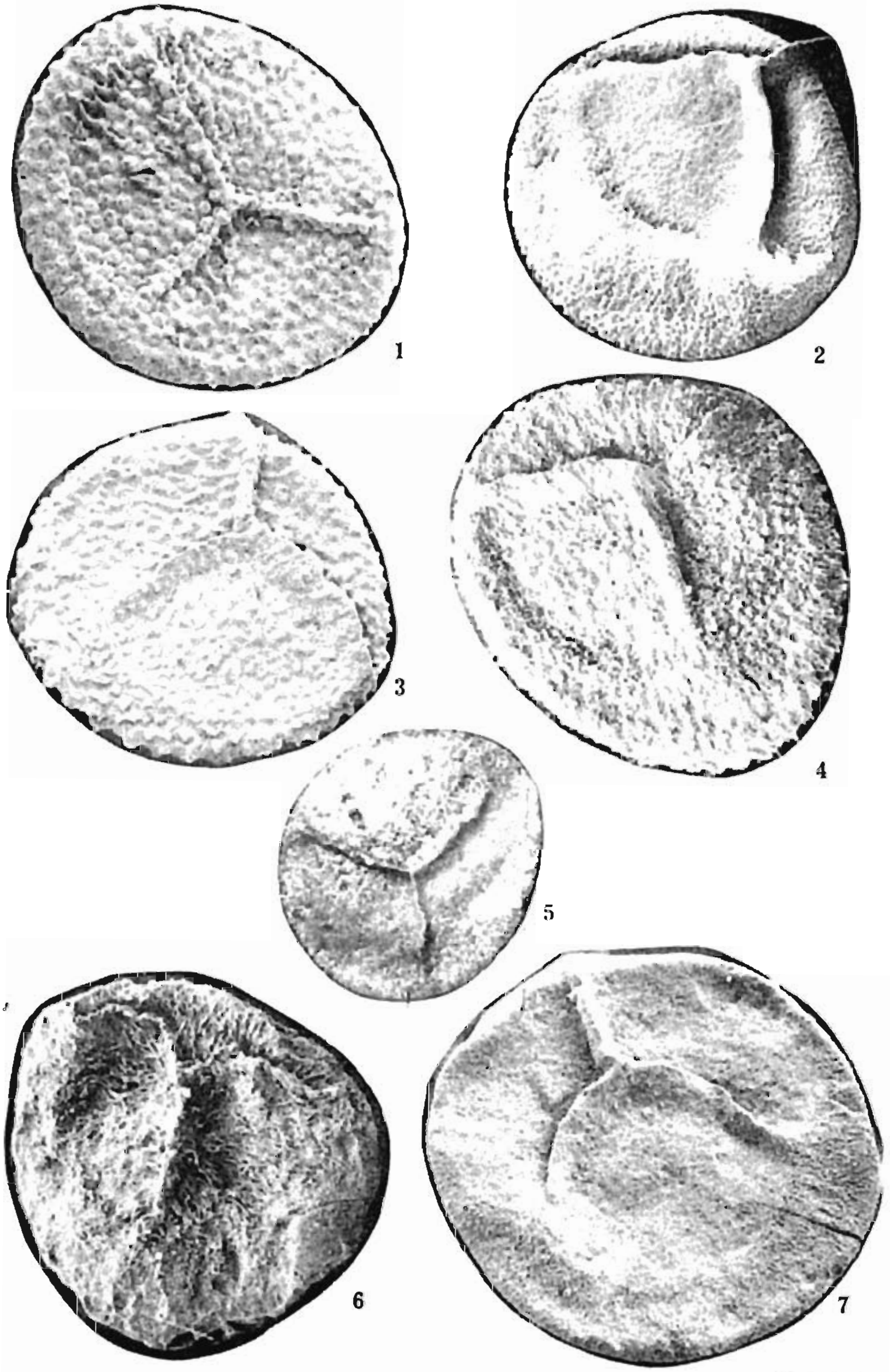


3b

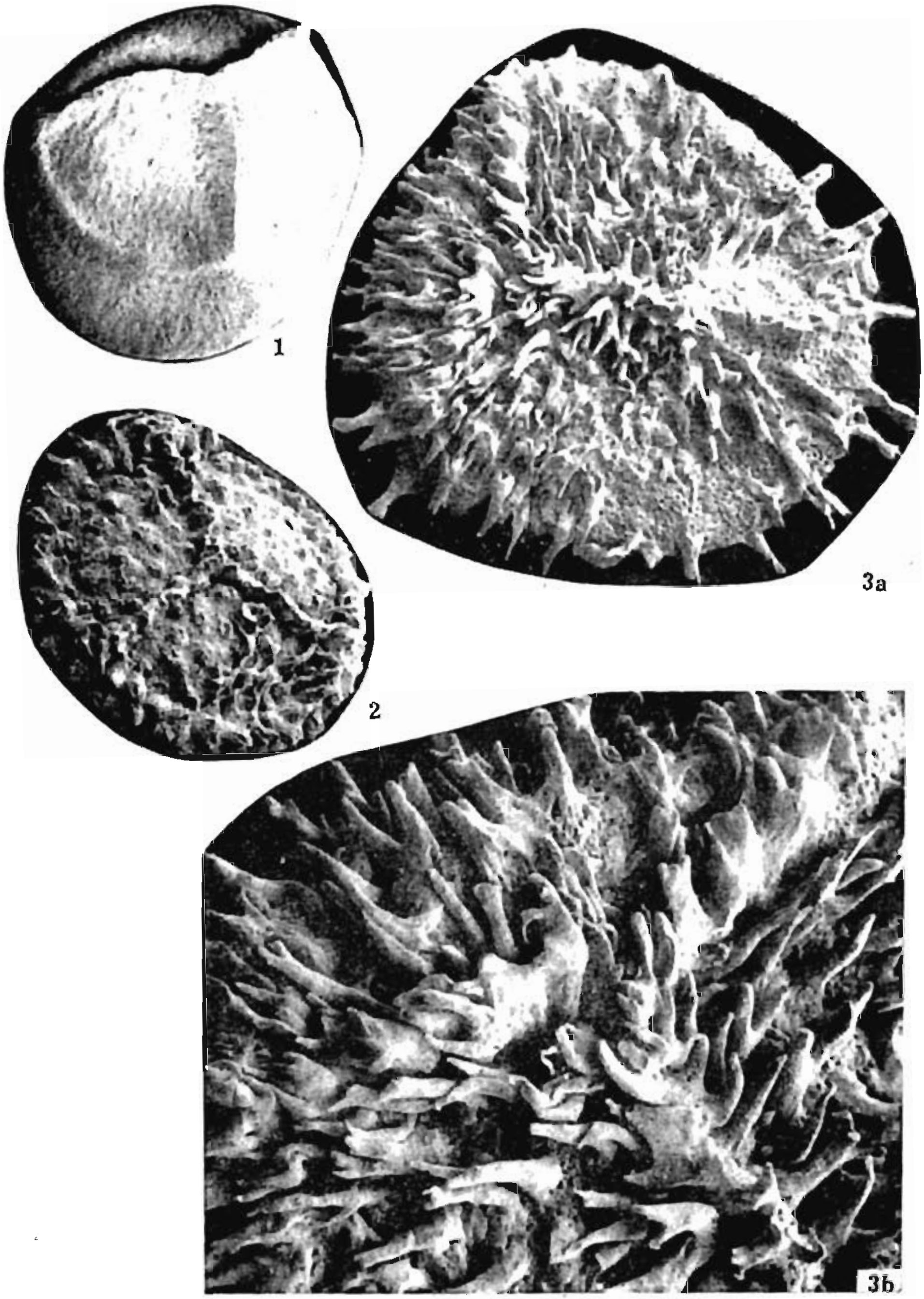
1 — *Otynisporites* sp.; borehole Otyń *IG-1*, depth 1010.0 m; Zechstein; megaspore in lateral view; SEM, ×250.
2 — *Otynisporites* sp.; Otyń *IG-1*, depth 1010.0 m; Zechstein; proximal surface; SEM, ×200.
3 — *Echitriletes* sp.; Otyń *IG-1*, 992.0 m; Zechstein; *a* — megaspore in lateral view; SEM, ×200; *b* — fragment of megaspore; ×750.

PL. 2

1 — *Echitriletes fragilispinus* Fugl.; Otyń *IG-1*, 793,0 m; lower-oolitic beds; proximal surface; SEM, × 150.
2 — *Pusulosporites permotriassicus* Fugl.; Otyń *IG-1*, 863,5 m; lower-oolitic beds; megaspore in lateral view; SEM, × 200.
3 — *Otynisporites tuberculatus* Fugl.; Otyń *IG-1*, 805.0 m; lower-oolitic beds; proximal surface; SEM, × 150.
4 — *Otynisporites eotriassicus* Fugl.; Otyń *IG-1*, 854.5 m; lower-oolitic beds; proximal surface; SEM, × 250.



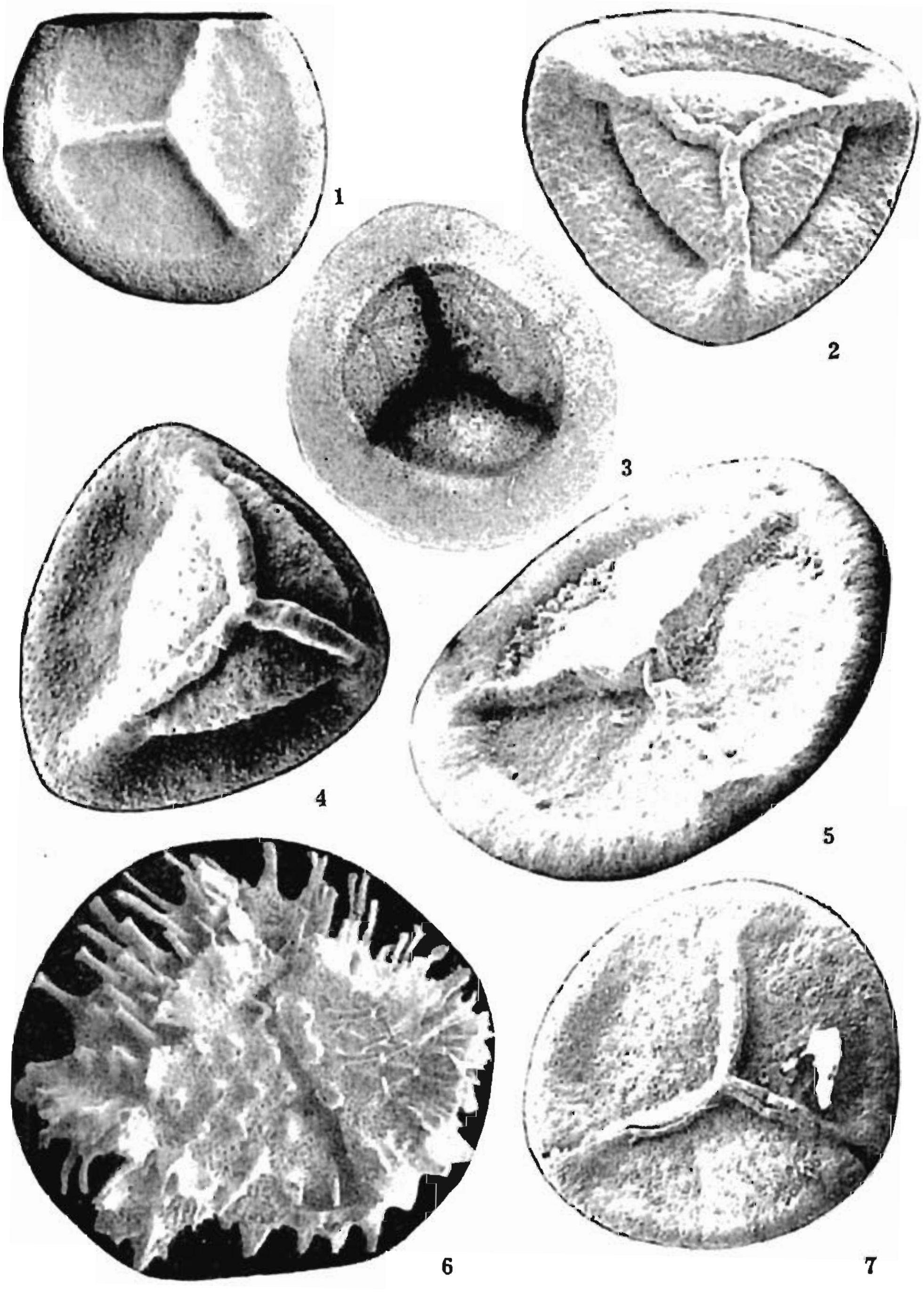
5 — *Trileites vulgaris* Fugl.; Gorzów Wielkopolski *IG-1*, 2102.5 m; upper-oolitic beds; proximal surface in reflected light; × 100.
6 — *Hughesisporites calvescens* Fugl.; holotype; Studzianna *IG-2*, 2807.8 m; upper-oolitic beds; proximal surface; SEM, × 200.
7 — *Maexisporites ooliticus* Fugl.; Września *IG-1*, 2680.5 m; upper-oolitic beds; proximal surface; SEM, × 200.



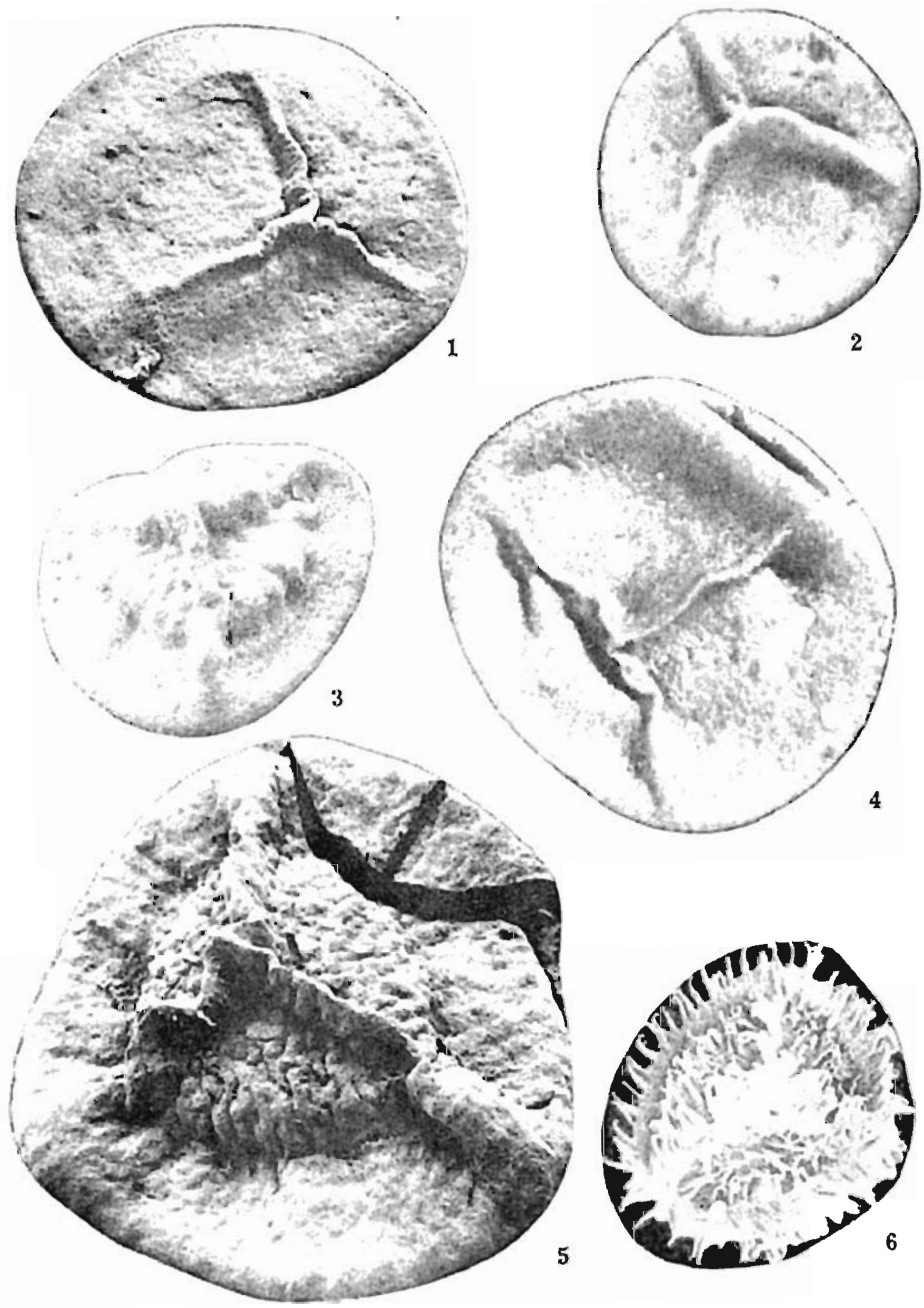
1 — *Trileites polonicus* Fugl.; Środa *IG-2*, 2409.0 m; supra-oolitic beds; proximal surface; SEM, ×140.

2 — *Nathorstisporites cornutus* sp. n.; Jaworzynka valley (Tatra Mts); Middle Buntsandstein; proximal surface; SEM, ×120.

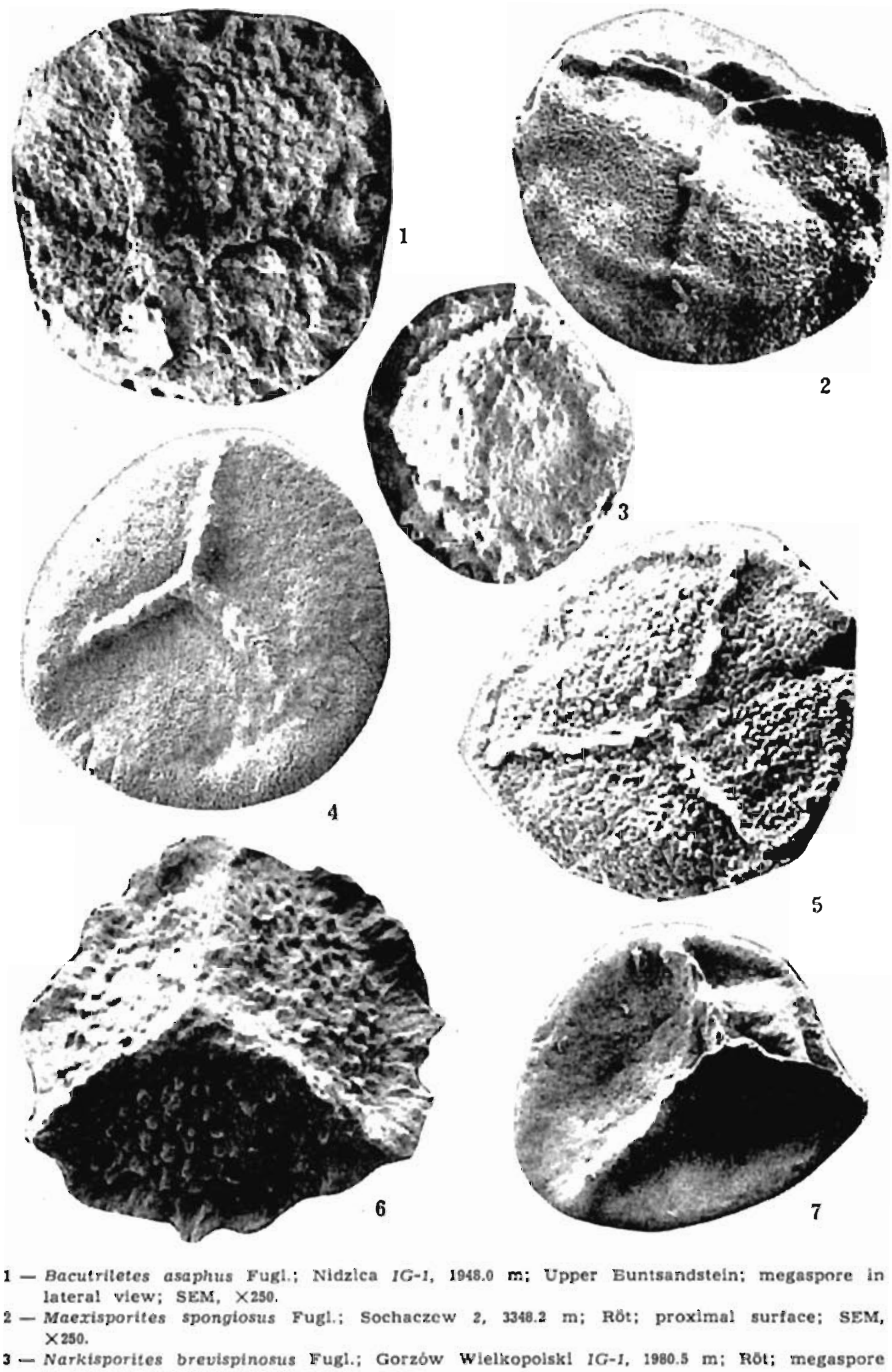
3 — *Nathorstisporites cornutus* sp. n.; holotype; Gorzów Wielkopolski *IG-1*, 2101.5 m; upper-oolitic beds; SEM; *a* — proximal surface, ×220; *b* — fragment of megaspore; ×480.



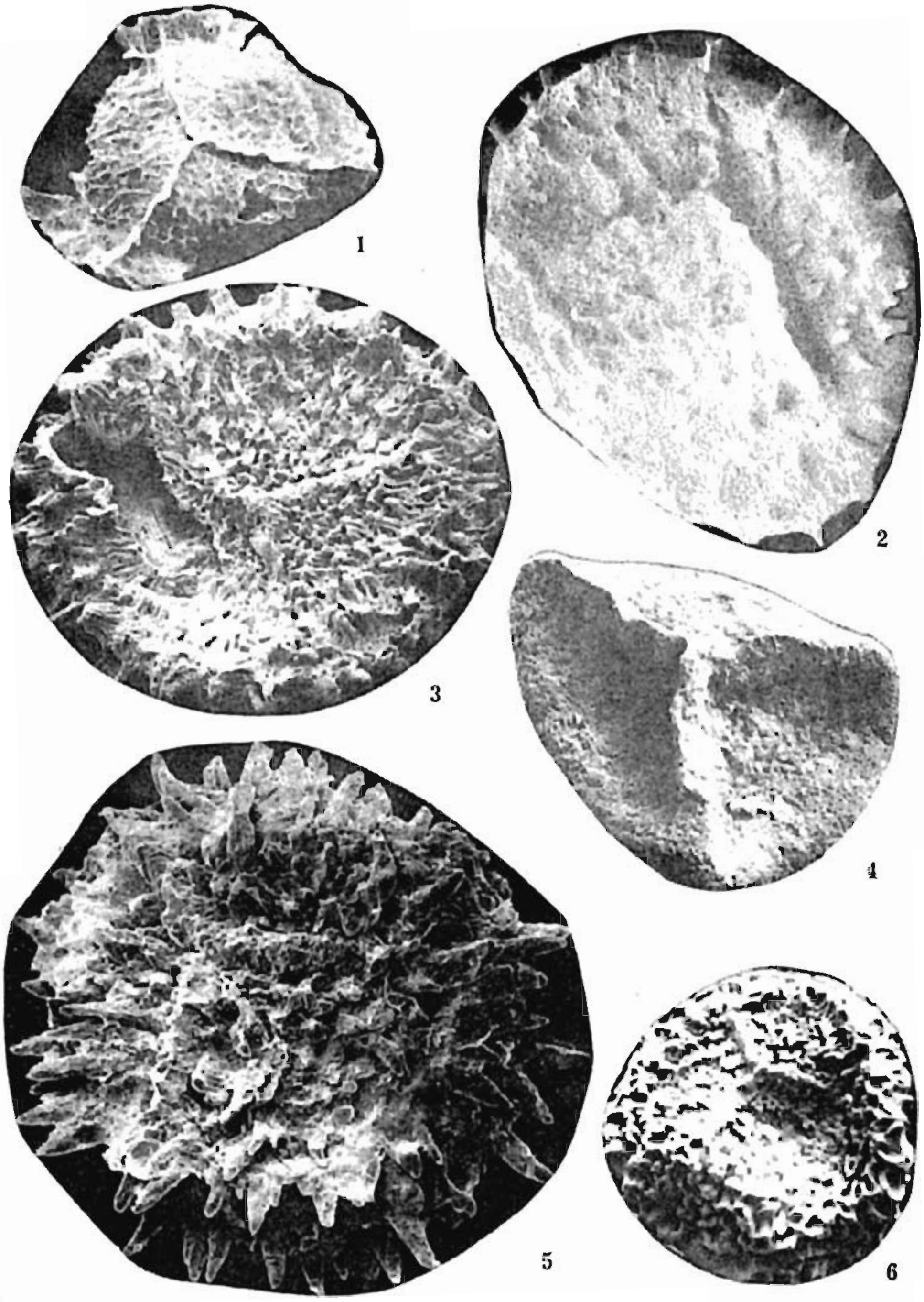
1 — *Pusulosporites marginatus* Fugl.; Września *IG-1*, 2574.5 m; supra-oolitic beds; proximal surface; SEM, × 60.
2-4 — *Pusulosporites inflatus* Fugl.; proximal surface; 2 — Września *IG-1*, 2574.5 m; supra-oolitic beds; SEM, × 150; 3 — Nidzica *IG-1*, 2012.0 m; upper-oolitic beds; transmitted light; × 100; 4 — Otyń *IG-1*, 492.5 m; supra-oolitic beds; SEM, × 150.
5 — *Pusulosporites marginatus* Fugl.; holotype; Nidzica *IG-1*, 2012.0 m; upper-oolitic beds; proximal surface; SEM, × 230.
6 — *Nathorstisporites cornutus* sp.n.; Nidzica *IG-1*, 2012.0 m; upper-oolitic beds; megaspore in lateral view; SEM, × 150.
7 — *Pusulosporites populosus* Fugl.; Września *IG-1*, 2574.5 m; supra-oolitic beds; proximal surface; SEM, × 150.



1 — *Trileites tenellus* Fugl.; Konary *IG-1*, 2153,0 m; Röt; proximal surface; SEM, ×200.
2 — *Trileites crassitectatus* Fugl.; Tłuszcz *IG-1*, 1371.0 m; Röt; proximal surface in reflected light; ×100.
3 — *Hughesisporites tumulosus* Marc.; Nidzica *IG-1*, 2012.0 m; upper-oolitic beds; proximal surface; SEM, ×150.
4 — *Trileites grandis* Fugl.; Kliczków *1*, 1670.0 m; Röt; proximal surface in reflected light; ×100.
5 — *Hughesisporites inflatus* Fugl.; holotype; Boża Wola *IG-1*, 2002.0 m; Middle Buntsandstein; proximal surface; SEM, ×250.
6 — *Echitriletes echinatus* Fugl.; Otyń *IG-1*, 510.0 m; supra-oolitic beds; proximal surface; SEM, ×100.



1 — *Bacutriletes asaphus* Fugl.; Nidzica *IG-1*, 1948.0 m; Upper Buntsandstein; megaspore in lateral view; SEM, ×250.
2 — *Maexisporites spongiosus* Fugl.; Sochaczew 2, 3348.2 m; Röt; proximal surface; SEM, ×250.
3 — *Narkisporites brevispinosus* Fugl.; Gorzów Wielkopolski *IG-1*, 1980.5 m; Röt; megaspore in lateral view; SEM, ×90.
4 — *Maexisporites rotundus* Fugl.; holotype; Nidzica *IG-1*, 1948.0 m; Upper Buntsandstein; proximal surface; SEM, ×200.
5 — *Maexisporites parvus* Fugl.; holotype; Nidzica *IG-1*, 1948.0 m; Upper Buntsandstein; proximal surface; SEM, ×250.
6 — *Narkisporites insignis* Fugl.; Tłuszcz *IG-1*, 1379.0 m; Röt; proximal surface; SEM, ×200.
7 — *Trileites validus* Fugl.; Buków 1, 3235.8 m; Röt; proximal surface; SEM, ×200.



1 — *Triangulatisporites makowskii* (Fugl.) Karcz.; Tluszcz *IG-1*, 1378.0 m; Röt; proximal surface; SEM, ×100.

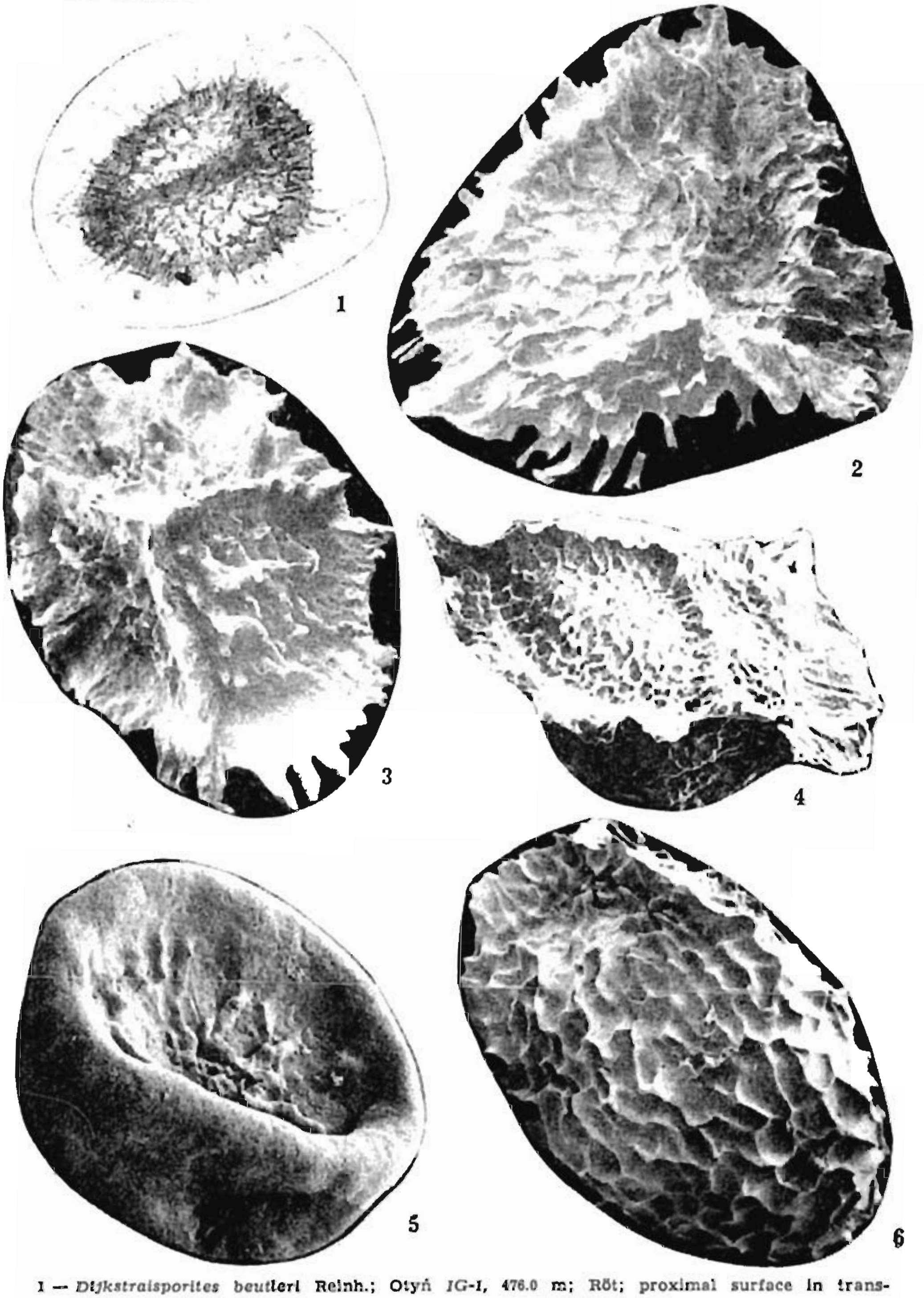
2 — *Bacutriletes insolitus* Fugl.; Kamień Pomorski *IG-1*, 1288.0 m; Röt; proximal surface; SEM, ×200.

3 — *Bacutriletes costatispinosus* Fugl.; Tluszcz *IG-1*, 1386.0 m; Röt; proximal surface; SEM, ×250.

4 — *Maexisporites pyramidalis* Fugl.; Nidzica *IG-1*, 1948.0 m; Upper Buntsandstein; proximal surface; SEM, ×300.

5 — *Echitriletes validispinus* sp. n.; holotype; Boża Wola *IG-1*, 1841.0 m; Röt; proximal surface; SEM, ×200.

6 — *Bacutriletes pseudoreticulatus* Fugl.; Tluszcz *IG-1*, 1384.0 m; Röt; proximal surface; SEM, ×200.



1 — *Dijkstraisporites beutleri* Reinh.; Otyń *IG-1*, 476.0 m; Röt; proximal surface in transmitted light; ×100.

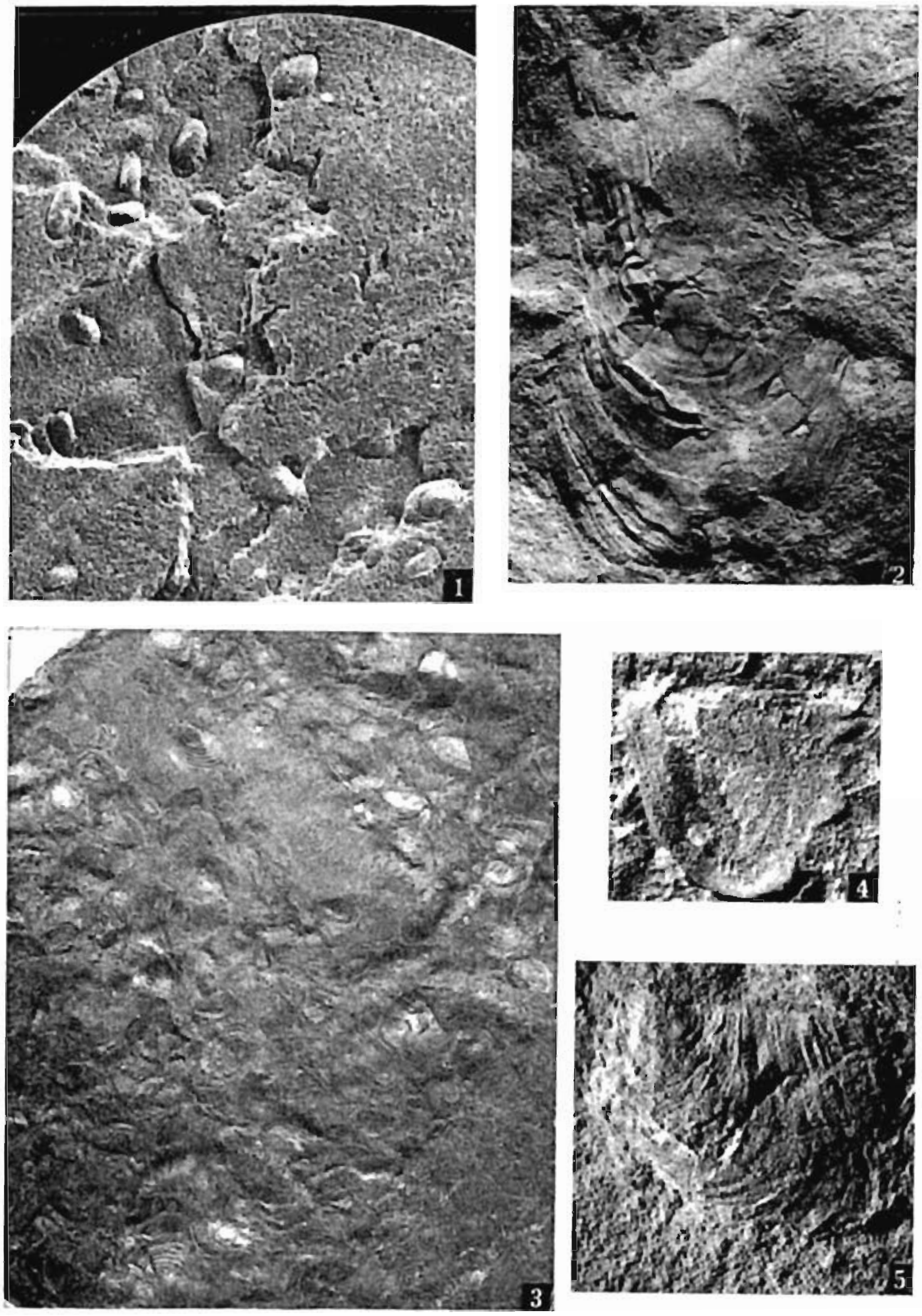
2 — *Dijkstraisporites beutleri* Reinh.; Boża Wola *IG-1*, 1842.0 m; Röt; proximal surface; SEM, ×150.

3 — *Echitriletes pectinatus* Fugl.; Boża Wola *IG-1*, 1482.0 m; Röt; proximal surface; SEM, ×150.

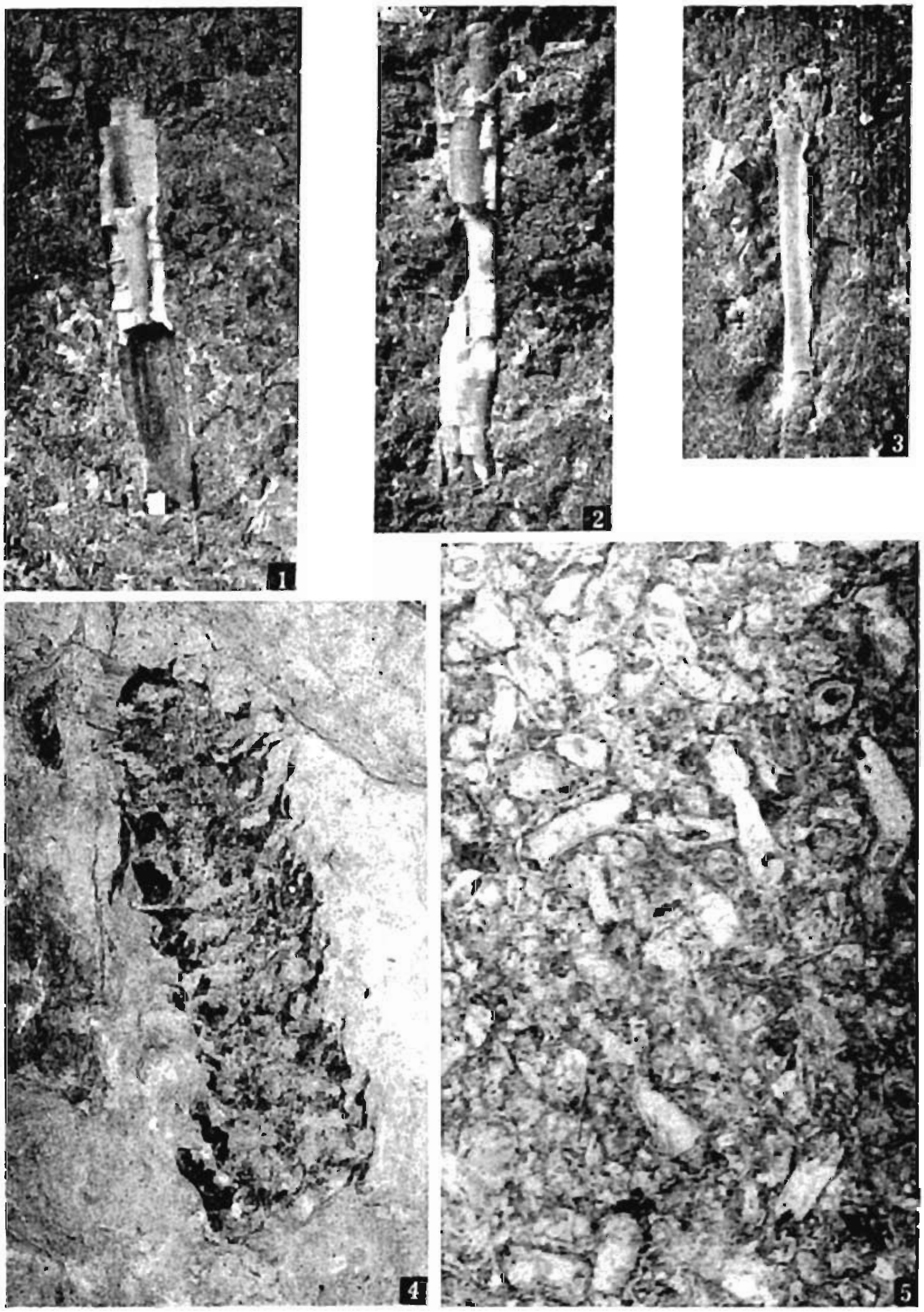
4 — *Triangulatisporites makowskii* (Fugl.) Karcz.; Tłuszcz *IG-1*, 1834.0 m; Röt; megaspore in lateral view; SEM, ×150.

5 — *Aneuletes rotundus* Fugl.; Kliczków *1*, 1670.0 m; Röt; proximal surface; SEM, ×250.

6 — *Horstisporites irregularis* Fugl.; Tłuszcz *IG-1*, 1384.0 m; Röt; megaspore in lateral view; SEM, ×120.



1 — Fragment of core with interior cast of the pelecypods (?*Avicula murchisoni* Gein.); Studzianna *IG-2*, 2716.0 m; upper-oolitic beds; ×1.
2 — *Liebea* sp.; Jeżów *IG-1*, 3045.0 m; Middle Buntsandstein; ×2.
3 — Fragment of core with phyllopods; Jeżów *IG-1*, 2928,0 m; Middle Buntsandstein; ×2.
4—5 *Avicula murchisoni* Gein.; Jeżów *IG-1*; Middle Buntsandstein; ×3; 4 — 3058.0 m; 5 — 3045.0 m.



1—3 — Problematical organic fossils; Września *IG-1*; 2682.5 m; upper-oolitic beds; ×5.
4 — Strobile of lycopodium (?*Pleuromeia*) with megaspores *Pusulosporites*; Otyń *IG-1*, 504,0 m; *Pusulosporites* Siltstone (supra-oolitic beds); ×1.
5 — Dolomite with spirorbids; Oltyń *IG-1*, 550,8 m; upper-oolitic beds; ×6.5.