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Microfacial analysis of the Zechstein Limestone in the Eastern Part of the Peri-Baltic Syneclise (Preliminary report)

ABSTRACT: The paper presents a microfacial analysis of the Zechstein calcareous rocks (*Ca 1*) from the eastern part of the Peri-Baltic syneclise based on materials from 27 boreholes drilled by the Oil Research Survey. Twenty microfacies in 5 groups namely the recrystallized, algal, faunistic, laminated and nonlaminated are distinguished. Basing on microfacial analysis, sedimentation zones were established, *i.e.* basin, reef, back-reef and bank facies.

INTRODUCTION

Microfacial analysis of the Zechstein limestone of the *Ca 1* horizon comprised between the underlying copper-bearing shales and overlying Werra anhydrite from the area of the north-eastern Poland has been carried out in 1972—1973. The present paper is an enlarged elaboration of that work and it is confined to the area of the eastern part of the Peri--Baltic syneclise (Fig. 1).

The aim of this work is a first concise characteristics of the sedimentary environment and facial variability based on microfacial analysis and macroscopic observations of the rocks.

The analysed material consisted of columns from 27 boreholes. The cores were about 50 per cent as average but in some cases much less (Table 1). In exceptional cases only a part of the horizon was cored.

The localization of the boreholes and Zechstein stratigraphical scheme were obtained from the Oil Research Survey.

The authors wish to express their thanks to the Geological Research Bureau for Oil Industry “Geonafta” in Warszawa and to the Oil Research Surveys in Piła

Table 1

Borehole	Total thickness in m	Coring in m	Number of polished surfaces	Number of thin sections
Barciany 1	47.0	28.4	32	32
Barciany 2	8.9	1.2	3	3
Dębowiec Warmiński 2	15.0	10.7	13	12
Dobre Miasto 1	22.8	13.4	15	13
Dobre Miasto 2	17.6	9.4	12	12
Glądy 4	8.8	4.6	7	8
Gładysze 1	6.5	3.1	5	7
Gładysze 2	10.5	5.7	10	11
Głębock 1	8.7	5.7	13	6
Henrykowo 1	12.2	3.9	9	7
Klewno 1	45.1	35.6	43	37
Krynica Morska 2	10.1	5.2	7	7
Lesieniec 1	44.0	16.1	18	19
Lidzbark Warmiński 1	30.3	11.4	14	14
Liski 1	9.5	2.2	4	4
Łankiejmy 1	75.3	24.7	29	31
Młynary 1	11.0	8.5	9	9
Młynary 3	4.2	1.2	3	2
Paluzy 1	62.4	31.0	37	38
Pieszkowo 1	11.2	4.3	7	7
Sępopol 2	17.0	14.0	18	17
Zaręby 1	9.7	6.0	7	7
Zaręby 2	4.5	2.8	4	3
Zawada 1	57.2	30.2	36	35
Żelazna Góra 1	12.1	8.1	11	10
Żelazna Góra 3	13.5	11.8	13	13
Żelazna Góra 5	8.3	7.8	8	8
Total	583.4	307.0	387	372

and in Wołomin for help in collecting materials; thanks are due to Ing. E. Kłyś, M. Sc., Ing. A. Łaptaś, M. Sc., and to J. Balwierz for their help during the work. To Prof. S. Dżułyński, D. Sc., and S. Gąsiorowski, D. Sc., the authors are indebted for useful remarks and discussions.

MATERIAL AND METHODS USED

All the columns of the investigated drillings as well as 387 polished surfaces have been macroscopically described. Colours of the rocks were determined on polished surfaces using the GSA Rock Color Chart. The microfacial analysis was done on the basis of investigations of 372 thin sections. In all calculations for the particular microfacies and for the content of dolomite thicknesses represented by the particular samples were taken into account. The data thus obtained although still incomplete seemed to be representative. This rule was abandoned in the case of faunal groups where only the number of samples was given in which particular animal group was ascertained. Similar method was used in the case of stylolites.

DESCRIPTION OF MICROFACIES

Classification of microfacies

The rocks of the Zechstein limestone were subjected to recrystallization which, in some cases, has completely destroyed the primary texture and structure of the rock, in others — hardly touched it. Such processes as dolomitization, calcitization, anhydrytization and gypsification have changed the primary rocks as well. The character and degree to which the primary rocks were changed are essential for the classification of microfacies. The rocks which were subjected to such changes that their primary character cannot be deciphered are classified as recrystallized microfacies (symbol R).

The remaining microfacies may be subdivided into the organogenic (with abundant organogenic particles), and nonorganic ones (with rare nonorganic components).

Most organogenic rocks show prevalence of algal particles over the animal ones and such rocks were classified as the algal microfacies (symbol A). In few cases of domination of faunal remains over the algal ones, the rocks were classified as faunal microfacies (symbol F).

The inorganic rocks were subdivided into two groups: laminated — the rocks with directional textures (symbol L) and nonlaminated — the nonoriented ones (symbol N). Breccias and intraformational conglomerates form a separate group (symbol B). Combination of breccias with conglomerates into one group resulted from frequent passages between these two types of rocks.

The distinguished microfacies within these groups (R, A, F, L, N, B) are marked with numbers, *e.g.* A_1, A_2, etc.

Size of particles and presence (or lack) of detrital quartz were taken as criteria for the distinction of microfacies. Among the recrystallized rocks the degree of recrystallization was the main criterium. Subdivision of the algal rocks was most difficult. The accepted subdivision based on the morphology of algal bodies is an attempt to systematize them, which may be somewhat altered in future works.

Mixed microfacies were introduced in the classification *e.g.* A_1/L_1 and L_2/R the dominating or primary microfacies mentioned on the first place and R always later on.

Recrystallized microfacies (R)

Here are classified the rocks most components of which are recrystallized thus the primary microfacial character of the rocks cannot be established.

Microfacies R_1

Fine- and medium recrystallized rocks with still discernible organic structures.

Here belong dolomitic limestones and dolomites usually fine-, less frequently mediumgrained of nonoriented texture, or of weakly marked directional texture, frequently clayey, with quartz pelite in some cases and with small pyrite crystals. Clayey or clayey-ferruginous substance occurs in nodules, stripes or lenses directionally oriented. Porosity is due to recrystalization. Anhydrite impregnations were frequently noted which sometimes form the rock cement. Undeterminable fragments of shells, algal fragments, and foraminifers, serpulae, brachiopods, ostracods and bryozoans are frequent. These remnants are preserved in coarse crystalline calcite. Large calcite crystals with relic dolomite crystals point to calcitization processes.

Microfacies R_2

Fine- to medium recrystallized rocks without discernible organic textures.

These are most frequently dolomites, less common are limestones usually fine crystalline, clayey as a rule with quartz pelite, porous (Pls 16, 17; 22, Fig. 1). Anhydrite impregnation are common, those with gypsum less frequent. Pyrite crystals and coal fragments occur sporadically. Flakes of clay are preferentially oriented.

Undeterminable organic remnants are common. Recrystallized lumps coated with micrite possibly of algal derivation were noted. Small lumps (nodules) with quartz pelite in the middle may represent mudeater coprolites. Some organic fragments are preserved in dolomite and anhydrite and resemble foraminifer outlines. Large calcite crystals with dolomite inclusions point to calcitization.

Microfacies R_3

Coarse recrystallized rocks without discernible organic textures.

These are coarse-crystalline dolomites with small concentrations and stripes of clayey or clayey-ferruginous substances, and with anhydrite impregnations. Sometimes porous.

Algal microfacies (A)

Here are classified rocks whose main and most characteristic component are particles of algal origin. Microfacies should correspond to particular sedimentary environment. This is fulfilled by four microfacies (A_1, A_2, A_3, A_6), and not by two other ones (A_4, A_5). The latter occur in more strongly altered rocks.

Microfacies A_1

Rocks with stromatolites and onkolites in basal cement with admixture of clastic quartz.

These are rocks in which occur stromatolites *sensu* Longan & *al.* (1964) *i.e.* laminated structures developed in result of sticking of sediment to algal film — either on firm bottom (Logan's & *al.* types *LLH* and *SH*), or on objects moved by water (onkolites — Longan's & *al.* type *SS*). In the A_1 microfacies concentric micritic laminae which overgrow organic chips (Pls 2; 22, Fig. 4) or crystals of carbonates (Pl. 19, Figs 1—2) maybe either symmetrical and regular or incomplete, disrupted and indented. Size of stromatolites and onkolites ranges 0.3 mm — up to some millimetres and may attain a dozen mm in diameter. These structures occur in basal cement consisting of fine carbonate grains with admixture of organic and terrigenic chips. The particles are nonoriented as a rule, in some cases strips and concentrations of onkoids and bands of clayey substance occur. Sulphates are sporadic.

The following varieties have been distinguished within the A_1 microfacies:

a) with large stromatolites (Pl. 3);
b) with large, usually badly sorted onkoids, in regard of size, in abundant cement (Pl. 1);
c) with fine-more uniform in size onkoids, rather densely packed sometimes with fine voids.

Besides there are some passages to recrystallized microfacies (A_1/R). In the first stage recrystallization embraces the cement, then onkoids which leave concentrations of larger and lighter crystals or a rim consisting of light crystals.

Microfacies A_2

Rocks with spherical, concentric algal structures, without clastic quartz.

Spherical algal structures show from one up to seven concentric shells consisting of carbonate grains (less than 0.01 mm in diameter). The dimensions of these forms vary from 0.1 mm up to a dozen mm (Pls 4; 19, Fig. 4). The smallest ones show but one shell only. In some cases larger common shell envelopes several smaller structures, forming large irregular form (Pl. 19, Fig 3). The particular shells within the same algal structure usually do not contact each other. In larger spherical structures pores may occur. In many cases the algal structures are densely packed forming special network of the rock. Pores occur between the spherical structures. Matrix is scanty, dolomitic, fine-crystalline and does not contain terrigenic material. Animal remains are rare. These are foraminifers, fine bryozoan fragments and brachiopod shell chips. The rocks of that microfacies are frequently recrystallized and due to high porosity impregnated with anhydrite or gypsum.

Several varieties have been distinguished within the A_2 microfacies:

a) large algal forms situated at random in finer matrix;
b) medium-sized algal forms better sorted, nonoriented;
c) fine algal forms arranged in bands which is accentuated by banded anhydritization (Pl. 5);
c) large, elongated algal forms arranged in bands.

Microfacies A_3

These are rocks with algal spherules, frequently empty with scanty cement or devoid of it, almost without faunal remains.

Algal spherules approximately 0.6—1.0 mm in size, exceptionally up to 2 mm. Regularly spherical, oval in some cases (Pls 6—7). The ratio of wall thickness to spherule diameter is approximatelly 1 : 10. The spherules are very finely recrystallized. The carbonate crystals grow inwards in the wall and outwards from a thin, dark strip probably remaining after primary micrite which formed the walls (Pl. 20, Fig.

1). Some spherules are full and a concentric lamination may be observed inside them — alternating laminae with more or less densely distributed crystals. Some spherules show traces of a recrystallized, open-work texture inside, which usually is subjected to destruction, into loose crystals which concentrate at the bottom of the spherule. Such concentrations of small crystals near one pole of a spherule indicate the bottom direction (Pl. 20, Fig. 2).

Fine-grained carbonate cement is scanty with insignificant admixture of animal remains. Pores are frequent between the spherules and together with the empty spherules imply a considerable porosity of the rock. Sulphatic impregnations are less developed than it might be expected in such a porous rock. In many cases they dislodge the cement and fill in the pores not penetrating inside the spherules which seems to be connected with the preservation of the micritic aureole within the walls.

Bedding and bands frequently occur in this microfacies. These are alternating bands of larger and smaller or empty and full spherules, or stripes containing more abundant cement. Cross-bedding is also present in places.

An admixture of algal forms occurs in the microfacies A_3 identical to those which constitute microfacies A_2 — as in the A_2 microfacies an admixture of spherules which is typical in microfacies A_3.

The following varieties may be distinguished in the A_3 microfacies:

a) bedded rocks;
b) nonbedded rocks consisting of very fine densely packed spherules forming reticular network;
c) nonbedded rocks consisting of large thin walled spherules of fine and very fine sometimes irregular shapes, dispersed among spherules making the rock backround.

Microfacies A_4

Rocks containing very fine crystalline spherules, sometimes with traces of concentric texture, gradually passing into rounded crystals with dark interior.

This microfacies occurs in fine recrystallized rocks consisting partly of crystalline spherules, and partly of dolomite crystals. Both components show similar dimensions, 0.07 mm in average. Concentric texture is visible in some spherules, in others their centre is darker. The accompanying dolomite crystals which outnumber the spherules show banded texture as a rule and lightcoloured rims and rounded outlines. There are continuous passages from spherical forms to more and more crystallographic ones (Pl. 21, Figs 1—2). Large algae were observed in several samples from the Dobre Miasto *2* borehole. Inside they contain the same spherules with dark interiors and same dolomite crystals (Pls 8; 20, Fig. 3). Thus it seems that the spherules of microfacies A_4 may be of algal origin and resulted from destruction of external algal coatings and disintegration of the spherical elements involved in them. At the present state of investigations it is impossible to decide whether the spherical forms of microfacies A_4 and A_3 are interconnected or not. In the Klewno *1* borehole the rocks of microfacies A_4 underlie those of microfacies A_3.

Microfacies A_5

Rocks with numerous rounded pores, giving sponge-like appearance to the rock.

These are very fine-grained, slightly clayey rocks with abundance of rounded and oval pores of various size (usually 0.7—2.0 mm), without crystalline aureols. The pores are empty, as a rule arranged in bands, and give a sponge-like appearance to the rock (Pls 9; 21, Fig. 3). These rocks differ from spongeous postgypsum limestones (known to the authors from the Miocene of Poland and Iraq) in the lack of larger caverns and a much greater roundness and smaller dimensions of pores, which have probably originated from dissolution of algal spherules involved in the rock.

Microfacies A_6

Rocks containing abundant chlorophycean flora.

This microfacies is known from only one sample (Glądy *4* borehole). It is a very fine-grained dolomite, usually micritic, porous, strongly impregnated by anhydrite, banded with clayey substance and with foraminifers. Algal spherules typical for microfacies A_3 occur in the rock and besides numerous oblique and transversal sections similar to the elongated ones of *Mizzia* from Dasycladaceae group (Pl. 21, Fig. 4). *Mizzia* is a Permian alga common particularly in the Upper Permian rocks all over the world (Johnson 1961).

Interpretation of the algal sediments

The origin of the stromatolitic, onkolitic and spherule sediments of various type in the carbonate Zechstein rocks is a matter of studies since over 100 years.

Contemporary authors agree that all these sediments are of algal derivation (Johnson 1942; Mägdefrau 1953; Hecht 1960; Kerkmann 1967, 1969; Füchtbauer 1964, and others).

It is generally accepted that carbonate mud sticked to a cloggy Cyanophycean film thus forming successive coatings building an onkoid or other structure of this type.

Dunham (1969) presented a new interpretation of the origin of pizolits in the Capitan Reef (Permian of Texas). He claims that the pizolits have developed inorganically as early vadose concretions in the Permian caliche. He mentions, however, that at least three genetic types of pizolite concretions occur in that area: intergrown marine oolites, onkolites of probable algal origin, and the above mentioned early vadose concretions. Judging from descriptions and illustrations those early vadose concretions correspond to none of the algal structures described in the present paper.

Carozzi & Textoris (1967) have described as oolites structures from the Ordovician which are very similar to our microfacies A_1 (*op. cit.*, Table 3, Fig. 1) and to microfacies A_3 (*op. cit.*, Table 3, Fig. 2). They define the sedimentary environment as the seaward side of stromatolitic bioherms, a shallow one, subtidal zone, of high energy. The term oolite was used probably in the sense of Carozzi (1960) according to the classical theory of inorganic origin of such sediments.

According to Shearman & *al.*, 1970, oolites are formed with algal action by sticking of aragonite mud to algal mucilage on surfaces of rounded objects.

Stromatolites, onkolites and spherical forms are commonly named stromaria in the German Zechstein (Geinitz 1861 *fide* Hecht 1960). Various opinions have been expressed about their origin. Hecht states (*op. cit.*, p. 138) that the name stromaria "has embraced all structures of German Zechstein reefs, it should be pointed out, however, that various algal species may have contributed to their formation, the systematic arrangement of which is impossible because of bad preservation state".

Mägdefrau (1956), Hecht (1960) and Füchtbauer (1964) use the name stromaria for stromatolites and related structures.

Kerkmann (1969) has distinguished in the Lower Zechstein 29 forms of algal sediments differing in their morphology (*op. cit.*, Bild 19, p. 36 and following) and puts all of them under the name stromaria pointing to gradual passages between them.

The term stromaria is not used in this paper. The distinguished forms differ in morphology and occur in different sediments and show different geographic ranges. The microfacies A_1 is characterized by abundant carbonate cement with an admixture of terrigenic material, contrary to microfacies A_2 and A_3 with poor, porous cement and without terrigenic admixture.

Faunistic microfacies (F)

Micro- and macrofaunal fragments are strongly scattered in the investigated material — approximately 2—3 specimens per 400 square millimetres of a thin slide. The rocks showing over 20 animal remains per thin slide are classified here as faunistic microfacies. 5 microfacies are distinguished on the basis of dimensions of the faunal remains and presence or lack of detrital quartz.

Microfacies F_1

Rocks with fauna of large dimensions, with admixture of detrital quartz.

Fauna is mainly bryozoans, brachiopods, and gastropods with addition of foraminifers (chiefly uniserial), ostracods and serpulae (Pl. 10). The remains are preserved in calcite, in some cases are dolomitized. Serpulae may be preserved in kolophane substance. Larger faunal fragments are usually rounded. The cement is fine-grained with admixture of quartz pelite and clay, and some feldspars and micas. Micritic pellets were noted in some samples. Texture may be either directional or nonoriented.

Microfacies F_2

Rocks with large invertebrate without admixture of detrital quartz.

Bryozoans, brachiopods, some ostracods and foraminifera occur in this microfacies. Gastropods are lacking (Pl. 11). Algal structures frequently accompany the fauna. The cement is fine-crystalline.

Microfacies F_3

Rocks with fauna of various size, without admixture of detrital quartz.

Fauna of small dimensions (mainly uniserial foraminifera and ostracods) prevails over that of larger dimensions (brachiopods and bryozoans — Pl. 12). Serpulae occur locally. Frequent are algal structures typical of microfacies A_2, strongly recrystallized as a rule. The cement is fine crystalline, with some lamination with clayey material. The organic remains sometimes are horizontally arranged. Gypsum and anhydrite pseudomorphoses after organic remains are frequent.

Microfacies F_4

Rocks containing small fauna with admixture of detrital quartz.

Here occur abundant foraminifera, mostly uniserial, ostracod shells, pelecypod and brachiopod chips, serpulae, polychaete burrows and koprolites(?) (Pls 13; 22, Fig. 3). The cement is usually very fine-grained, argillaceous, sometimes with pellets, quartz pelite and mica flakes and grains of feldspars. Texture is directional, less frequently nonoriented.

Microfacies F_5

Rocks containing small fauna, without admixture of detrital quartz. Here belong uniserial foraminifera, ostracods, fragments of bryozoans and brachiopods and algal structures. The cement is fine-grained, argillaceous with nonoriented or weakly directional texture.

Laminated microfacies (L)

Here are classified carbonate, nonorganogenic rocks of directional textures.

Microfacies L_1

Rocks with stripes or laminae of clayey and micritic substance with admixture of detrital quartz.

Here belong usually fine-grained rocks, frequently micritic with various content of clayey substance (Pl. 14). Argillaceous or clayey-ferruginous substance is disseminated in the rock and occurs in form of flakes, nodules, lenses and bands. The rock contains detrital quartz, and frequently small crystals of anhydrite and pyrite. Mica flakes and feldspars grains are sporadically found. Small pores are sparsely distributed. Few fine animal remains are represented chiefly by foraminifera, obliterated nodules of probable algal origin, undeterminable shell fragments and sporadically occurring ostracods and brachiopods. Traces of mudeaters are relatively frequent.

The oriented texture of the rock is marked either by directional arrangements of lenses and bands of clayey substance, or by alternating laminae with more or less abundant argillaceous cement. Some laminae are rich in quartz grains. Fine clayey laminae show wavy course enveloping carbonate fragments or aggregates of crystals and form delicate network penetrating the whole rock. Locally cross--bedding or disturbances in lamination occur. The anhydrytization advanced along the clayey laminae. Small lenses and grains of anhydrite are sometimes elongated parallel to lamination.

Microfacies L_2

Rocks with bands or laminae of clayey or micritic substance, without detrital quartz.

Here belong usually micritic rocks, less frequently fine-grained, argillaceous, sometimes slightly recrystallized (Pl. 15). Frequent are isolated crystals or feathery aggregates of anhydrite, sometimes crystals of pyrite. Fine, sparsely distributed pores are common. Sometimes they are horizontally elongated. Infrequent, small organic remains are represented by foraminifera, and algal structures. Traces of mudeaters were also noted.

Lamination is formed by fragments of clayey-ferruginous substance which are directionally arranged, or by delicate bands of clayey substance or micrite-argillaceous substance which in some cases are wavy. Cross-bedding was noted as well.

Microfacies L_3

Rocks with laminae differing in size and in packing of grains.

Here belong rocks similar to the two last mentioned microfacies — fine-grained or micritic with admixture of quartz pelite or without it, porous with crystals of anhydrite and pyrite. Several varieties of lamination occur there:

a) laminae alternately consisting of coarser and finer grains;
b) laminae with densely packed grains alternated with those with grains less densely packed in more abundant cement;
c) laminae alternately with or without pores.

Nonlaminated microfacies (N)

These are carbonate inorganic rocks of nonoriental textures.

Microfacies N_1

Rocks without lamination, poor in organic remains with admixture of detrital quartz.

Here belong partly fine-grained, partly micritic rocks more or less argillaceous. The clayey or clayey-ferruginous substance is disseminated in the rock and forms lumps, lenses and few stripes. Quartz pelite, some mica flakes and feldspar grains are also present. Grains and concentrations of pyrite and of anhydrite (feathery concentrations of crystals) are frequent. The rock is weakly porous or nonporous. The scanty organic material consists of foraminifera, ostracods and brachiopods as well as doubtful algae. Traces of worm burrows were noted.

Microfacies N_2

Rocks without lamination and admixture of detrital quartz, poor in organic remains.

Here belong micritic rocks containing pellets in places, elsewhere recrystallized with small grains of pyrite and idiomorphic crystals of anhydrite.

Intraformation breccias embrace rocks of various microfacies and are described in the chapter devoted to sedimentary textures.

BASIN CHARACTERISTIC

Palaeogeographic situation

The Peri-Baltic depression formed a gulf of the Polish-German Sea at the Lower Zechstein times. It stretched about 150 km to the East beyond the state boundary of Poland into the territory of Lithuania and Latvia (Suvejzdis 1963) and was bordered from the South by the land of the Mazury-Suwałki elevation and from the West by shoals of the Łeba and Koszalin-Chojnice elevation (Fig. 1). The northern shore of the gulf is not clear — it lies somewhere in the Baltic Sea. The investigated area embracing an area of about 3000 square km forms a fragment of this gulf. The boreholes studied in this paper are distanced from the ancient shore from 25 (the Klewno *1* drilling) up to 85 km (the Krynica Morska *2* drilling).

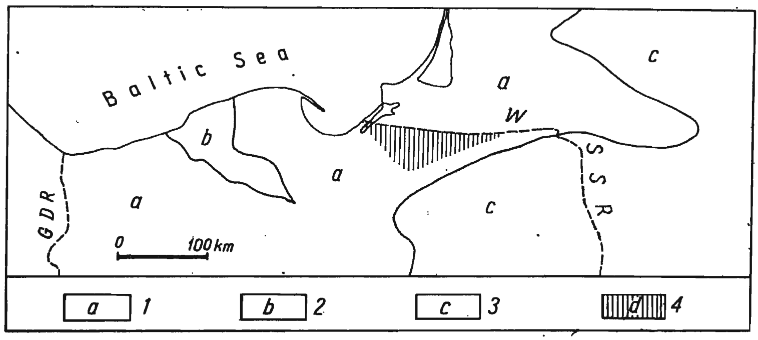

Fig. 1

Zechstein palaeogeography in Northern Poland (*after* J. Poborski, 1970)

1 sea, *2* sea-shoals of the Koszalin-Chojnice area, *3* Mazury-Suwałki land, *4* investigated area, *5* state boundary

The substratum of the Zechstein in the Peri-Baltic depression is formed mainly by clastics of the Silurian and locally by clastic Rothliegendes. The adjacent Mazury-Suwałki land consisted of granites and metamorphic rocks (Znosko & Pajchlowa 1968). The Zechstein limestone usually rests on the copper-bearing shales with the exception of the Dębowiec Warmiński *2* borehole in which it lies on eruptive rocks and in the Pieszkowo *1* drilling where it is underlain by conglomerate.

In the boreholes Klewno *1*, Henrykowo *1* and Głębock *1* the so called *basal limestone* which is similar in its lithology to the Zechstein limestone occurs under the copper-bearing shale.

Thickness

Thickness is of importance for the zonal differentiation in the Zechstein limestone. According to Füchtbauer (1972) two main facies occur in the German Zechstein limestone, namely a near-shore dolomitic one of average thickness of 15 m and that of an open sea, calcareous of average thickness of 4 m.

Similar observations in the area of the Fore-Sudetic monocline were given by Kłapciński (1964) and for the Łeba elevation by Szaniawski (1966). A reverse situation was presented by Herrmann (1956) according to whom the thickness of the Zechstein limestone in the southwestern margin of the Harz Mts increases toward the centre of the basin.

The thickness of the Zechstein limestone in the eastern part of the Peri-Baltic depression was calculated by Stolarczyk & Tyski (1972) who have taken into account the electric logging data of particular drillings.

The investigated area is divided into two zones of completely different thicknesses: the eastern zone of thickness values 20—100 m and

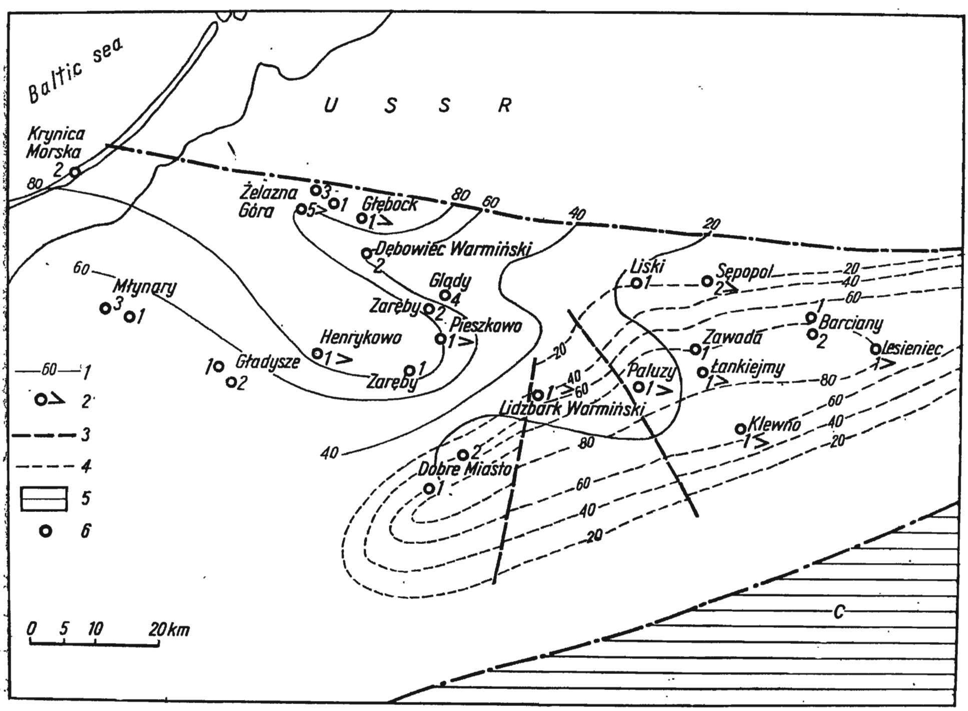

Fig. 2

Distribution of detrital quartz in the Zechstein limestone

1 isolines of percent content of the rocks with detrital quartz in the profile of the Zechstein limestone, 2 borehole in which cross-bedding was observed, 3 faults, 4 isopachytes of the Zechstein limestone, 5 Mazury-Suwałki land; 3, 4 and 5 after Stolarczyk & Tyski, 1972; 6 borehole

the western zone with thickness values below 20 m (Fig. 2). The zone of large thicknesses forms a belt parallel to the edge of the Mazury-Suwałki elevation 15—25 km broad and about 100 km long. Such a differences in thickness according to Stolarczyk & Tyski (1972), are connected with uneven morphology of the sea bottom and faults contemporary with the deposition. In result of those faults the elevated part of the area was favourable for carbonate sedimentation.

Colours of rocks

The rocks of the Zechstein limestone show various hues of brown and cream colours. Colours of numbers *10 YR 7/2* and *5 Y 7/1* prevail (Rock-Color Chart, 1963). Almost white colour occurs exceptionally in the upper part of the profile of the Zechstein limestone in the Lesieniec *1* borehole (*10 YR 9/2*), and in few intercalations there were noted colours *5 YR 3/2*, *5 Y 3/1* and *N5*. The spots of blue anhydrite show *5 PB 6/2* colour.

Füchtbauer (1972) states that in the German Zechstein basin light-coloured rocks in near-shore parts become darker toward the center of the basin. He explains this by slower sedimentation rate of carbonates in the center of the basin and resulting higher clayey admixture in the rocks. Higher pyrite content in the central parts of the basin also accounts for darker rock colouration there.

Similar darkening of rock off the shores toward the basin center was observed in the Permian basin in Texas and New Mexico (Newel 1953, Tyrrell 1969).

Such colour pattern were not observed within the Peri-Baltic Gulf. Possibly the darkening of the Zechstein limestone rocks takes place in the open sea west of the shoal zone of Koszalin-Chojnice. This is suggested by dark hues of the Zechstein limestone near Szczecin.

In the Peri-Baltic Gulf a belt of lighter rocks occurs near and outside the zone of large thicknesses (Liski *1*, Paluzy *1*, Lidzbark Warmiński *1*, Dobre Miasto *2* boreholes).

Out of 27 boreholes examined, 14 show complete material of equal brightness. In two drillings (Dębowiec Warmiński *1* and Henrykowo *1*) the marly rocks are darker at top than the underlying ones, and in 11 drillings the rocks of the Zechstein limestone become lighter near its top. This occurs in boreholes Klewno *1*, Lesieniec *1*, Barciany *1* and *2*, Sępopol *2*, Zawada *1*, Łankiejmy *1*, Paluzy *1*, Lidzbark Warmiński *1*, Głębock *1* and Żelazna Góra *1*. This phenomenon is unexplained, but certainly it is unconnected with the clayey content.

The number of samples of the lightest rocks (lightness degree 8—9) was counted per particular microfacies groups. About 49 per cent of samples represent recrystallized microfacies, about 22 per cent — algal ones, 18 per cent — laminated, 6 per cent — faunal, and 5 — nonlaminated.

Sedimentary and diagenetic textures

Cross-bedding and disturbances developed in loose sediment are most common prediagenetic textures preserved.

Small scale cross-bedding occurs in two groups of microfacies, namely in the laminated and algal ones. It was noted in drillings Żelazna Góra *5*, Głębock *1*, Henrykowo *1*, Pieszkowo *1*, Lidzbark Warmiński *1*, Paluzy *1*, Sępopol *2*, Łankiejmy *1*, Klewno *1* and Lesieniec *1*. Its existence proves deposition by currents which took place in all zones of the Peri--Baltic Gulf.

Besides numerous bioturbations occurring in various microfacies, there are also those of inorganic origin. They are expressed by disrupted lamination and formation of irregular bands and lenses of more or less argillaceous sediment. In some places they bear the character of breccias, in which light poorly rounded carbonate fragments are embedded in dark, carbonate basal cement. Such disturbances frequently accompany suture--like surfaces (Radlicz 1966), *i. e.* incompletely developed stylolites which have developed in nondiagenised sediment. The suture-like surfaces occur, first of all in the laminated microfacies (63 per cent) then in the recrystallized (18 per cent) and in the algal and faunal ones (9 per cent each). Intraformational breccias and suture-like surfaces have been noted in boreholes: Żelazna Góra *5*, Głębock *1*, Henrykowo *1*, Paluzy *1*, Łankiejmy *1* and Zawada *1*. In the last mentioned one there occurs a breccia of tectonic character as well. In the fissures of that breccia solutions were active during several phases which have caused leaching of fragments of the breccia. The same solutions then have precipitated dolomite, anhydrite and crystalline calcite in fissures.

According to Smith (1958) breccias in the Permian of England were formed on the external steep reef slope in result of submarine slumps. The breccias of the Zechstein limestone of the Peri-Baltic Gulf are scattered over large area and show very small thicknesses. They were probably formed by local disturbances of nondiagenised sediment and are not connected with a definite facies in the basin.

The "true" stylolites developed in diagenised rocks join the suture--like surfaces through transitional forms. Both horizontal and oblique and vertical stylolites are rather common in the Zechstein limestone. According to Helmuth (1968) the stylolites are more common in the middle part of the Zechstein limestone in Germany (horizons *Ca 1β* and *Ca 1γ*), than in the lower and upper parts (*Ca 1δ* and *Ca 1α*). Similar observations were carried out by Alexandrowicz (1970) and Alexandrowicz & Preidl (1971) in the Fore-Sudetic monocline where stylolites are most common in horizon β.

In the area under investigation thick Zechstein limestones in some boreholes (Paluzy *1*, Łankiejmy *1*, Zawada *1*, Barciany *1*) show stylolites concentrated mainly in the middle part of the profile. In other boreholes, however, stylolites either do not occur at all (*e. g.* Lesieniec *1*, Zaręby *1*, Lidzbark Warmiński *1*) or occur in the lower or upper part of the profile, or are irregularly scattered throughout the profile of the Zechstein limestone.

The calculated per cents of samples with stylolites per groups of microfacies (without suture-like surfaces) show that stylolites, with the exception of breccias, have nothing in common with the microfacial character of rock. Only in breccias at the boundary of fragments and cement particularly favourable conditions exist for the development of stylolites (Table 2).

Table 2

Distribution of stylolites among groups of microfacies

	Microfacies					Breccias	Shales
	laminated	algal	recrystallized	faunistic	nonlaminated		
Thickness percent of the Zechstein limestone per group of microfacies	37.1	29.7	20.1	8.7	2.4	1.3	0.7
Percent of samples with stylolites per group of microfacies	34.0	30.0	14.6	11.3	1.6	8.0	–

Distribution of microfacies of inorganic rocks and terrigenic material

The inorganic and nonlaminated rocks (microfacies *N*), very fine-grained and micritic ones occur as thin intercalations at Żelazna Góra *5*, Glądy *4*, Lidzbark Warmiński *1*, Paluzy *1* and Liski *1*. Their presence proves local and transient lack of water movement. Microfacies N_2 occuring in the Liski *1* borehole represents particularly calm conditions of deposition.

Laminated rocks (microfacies *L*) prevail in the western part of the area (Fig. 3) leaving an "island" in the area of the boreholes Zaręby *2* and Glądy *4*. In the eastern part a belt of weakly developed laminated sediments (20—50 per cent of thickness of the horizon) stretches through Lidzbark Warmiński *1*, Paluzy *1*, Zawada *1*, Łankiejmy *1* and Barciany *1*. This points to variability of sedimentation in this area and changing conditions of non recifal deposition.

Laminated rocks with admixture of detrital quartz occur in most boreholes (microfacies L_1). The same rocks without such admixture (microfacies L_2) prevail over the microfacies L_1 in the boreholes Barciany *1*, Dobre Miasto *1*, Lesieniec *1* and Łankiejmy *1*, and occur without assistance of microfacies L_1 in boreholes Liski *1* and Klewno *1* (Fig. 3). This microfacies represents calmer sedimentation than the L_1 one. This, aside of lack of detrital quartz, is suggested by finer grains.

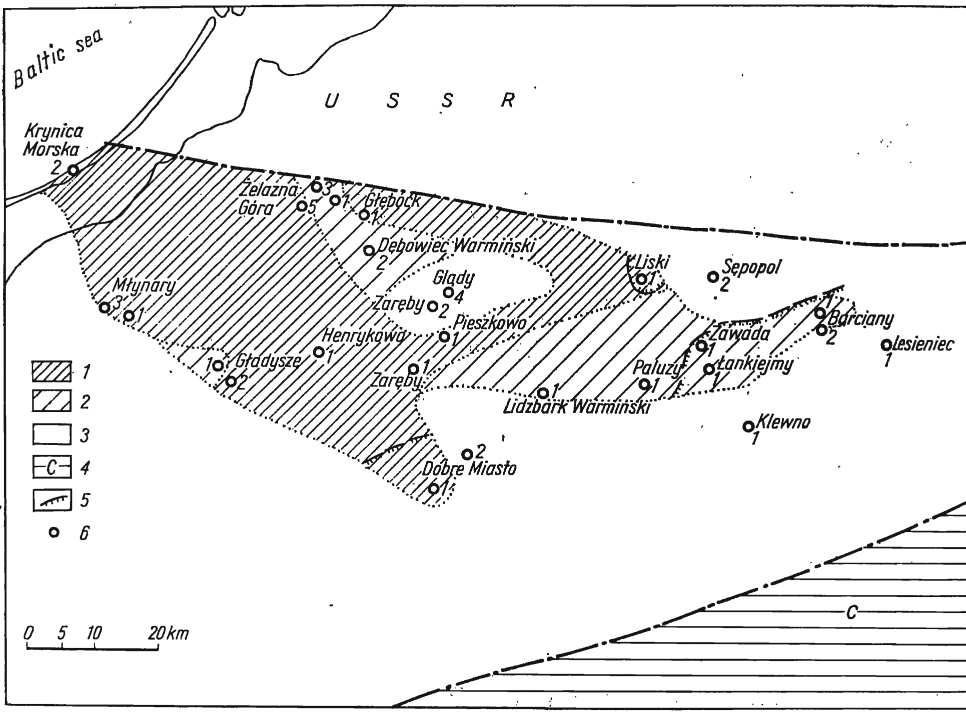

Fig. 3

Per cent distribution of thickness of the laminated microfacies of the Zechstein limestone

1 — over 50%, *2* — 20—50%, *3* — 0—20%, *4* — Mazury-Suwałki land, *5* — area of prevalence of microfacies L_2, *6* — borehole

The terrigenic material is represented mainly by clayey substance and to a lesser extent by detrital quartz, mica flakes, feldspar [1] and heavy mineral grains.

The clayey and clayey-ferruginous substance is represented in all the rocks in the area in question, whereas detrital quartz is irregularly

[1] Aside of few terigenic feldspars in the rocks of the Zechstein limestone horizon there are some autigenic feldspars as well.

distributed there. Basing on microscopic observations calculations were done of the thickness per cents per each borehole of the rocks with admixture of detrital quartz and these data were plotted on the map (Fig. 2). The pattern of per cent isolines of detrital quartz seems to suggest transport of clastic material not from the southeast — *i.e.* from the Mazury-Suwałki land, but from the West along the line Krynica Morska *2* — Zaręby *1* — Paluzy *1* boreholes. Taking into account usually incomplete coring in some boreholes, the isoline pattern thus obtained was compared with the distribution of boreholes with greater total rock thickness with detrital quartz. The boreholes in which such thicknesses exceed 7 m are: Krynica Morska *2*, Żelazna Góra *1* and *3*, Głębock *1*, Dębowiec Warmiński *2*, Henrykowo *1*, Zaręby *1*, Pieszkowo *1*, Lidzbark Warmiński *1*, Paluzy *1*, Łankiejmy *1* and Barciany *1*. All these drillings follow the above mentioned direction extending it farther eastward up to the Barciany *1* borehole.

Comparing these data with the distribution of cross-bedding (Fig. 2) it maybe stated that in the western part of the area the boreholes of smaller quarz content — Młynary *1* and *3*, Gładysze *1* and *2*, Dobre Miasto *1* and *2*, Glądy *4*, Zaręby *2* also do not contain cross-bedded sediments. A connection exists there between the presence of detrital quartz and cross-bedding. In the eastern part the relations are much more complicated. The sediments with algal detritus show locally cross-bedding on both slopes of the belt of large thickness regardless of cross-bedding in the laminated, inorganic sediments.

According to observations by Stolarczyk (1972), south of this belt the share of terrigenic material increases which proves a supply from the Mazury-Suwałki land. The conclusions of Czajor (1972) are similar, on the basis of reconstruction of the sequence of erosion of igneous and metamorphic rocks in the above mentioned land from the analysis of heavy minerals. In her opinion this land was the only area which has supplied the terrigenic material and the transport direction was toward NW (SE-NW). On her maps (*op. cit.*) the western part of the area in question is not shown in the zones distinguished by her. Hence, there is no contradiction with our view, that the material in the Zechstein limestone of the Peri-Baltic Gulf derives from two directions. The southern zone was alimented from the Mazury-Suwałki land. It is probable that the argillaceous intercalations at the top of the Zechstein limestone derive from that direction (Lesieniec *1* and Zawada *1* boreholes). A reef belt formed a barrier that stopped, at least in part, the material supply from the South. The fore-reef zone was alimented, probably very weakly, by a current parallel to the reef most probably coming from the West and carrying poor sandy material from shoals and islands of the Łeba elevation and the Koszalin-Chojnice zone.

Fauna

The following faunal groups are represented in the area (sample quantities in which these groups were noted are given in parentheses): foraminifera (99), bryozoans (65), brachiopods (46), ostracods (31), pelecypods (14), worms (14)[2], gastropods (8), echinoids (3), trilobites (2), crinoids (1).

Three zones may be distinguished on the basis of the distribution of fauna (Fig. 4).

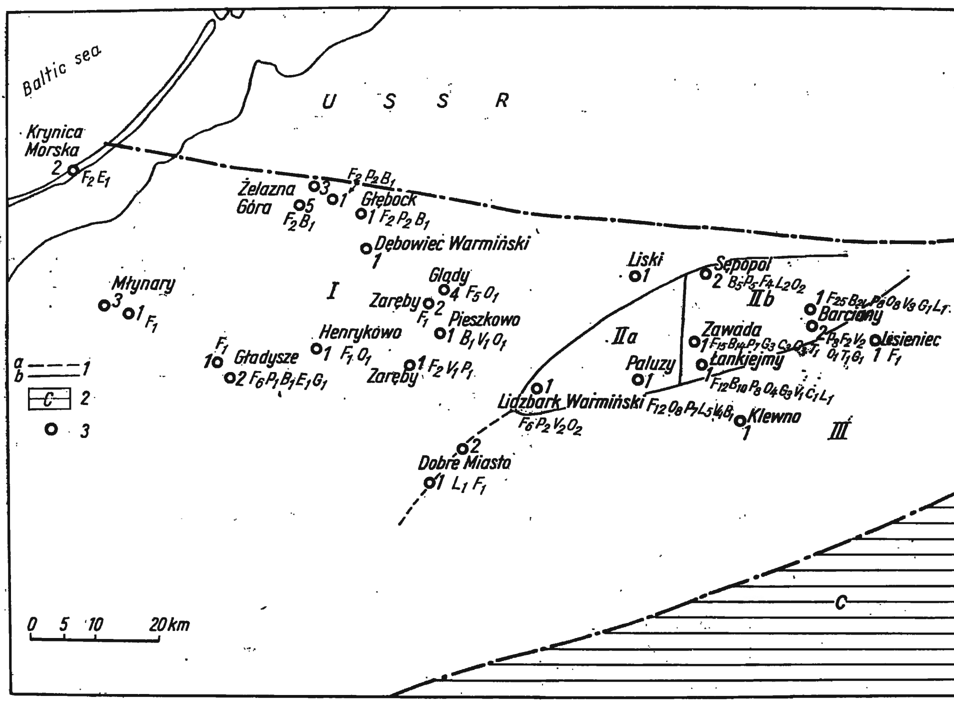

Fig. 4

Distribution of fauna in the Zechstein limestone

1a inferred boundary, *1b* boundary between the zones, *2* Mazury-Suwałki land, *3* borehole *I* northwestern zone, poor in fauna; *IIa* western part of the central zone with rich fauna and abundant bryozoans; *III* southern zone, poor in fauna

F foraminifera, *P* brachiopods, *B* bryozoans, *O* ostracods, *L* pelecypods, *V* worms, *G* gastropods, *E* echinoids, *T* trilobites, *C* crinoids

Numbers by letters indicate the number of samples in which a given faunal group was encountered

1. The northwestern zone with poor fauna consisting mainly of foraminifera with some other forms.

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[2] Only preserved Annelidae are mentioned here whereas the worm burrows are omitted.

2. Central zone (Lidzbark Warmiński *1*, Paluzy *1*, Zawada *1*, Łankiejmy *1*, Sępopol *2*, Barciany *1* and *2* boreholes) with relatively rich fauna which is fairly diversified in the eastern part. About 90 per cent of all brachiopods and bryozoans occur in this zone.

3. Southern zone, closer to the coast (Klewno *1* and Lesieniec *1* boreholes) with very poor fauna consisting of few foraminifera, pelecypods, brachiopods and worms.

The fauna of the Zechstein limestone has been usually redeposited. The specimens lie with their longer axes parallel to bedding, bryozoans are frequently broken; out of crinoids only trochites are preserved and of echinoids — spines.

Foraminifera occur almost in the whole area and in almost all microfacies. The genera *Ammodiscus, Agathamina, Nodosaria, Dentalina, Spondelinoides, Geinitzia* and *Reophax* were observed.

Bryozoans (*Fenestella, ?Thamniscus, Acanthocladia* and others) occur in faunistic microfacies (43 per cent) [3], algal microfacies (30 per cent), and laminated ones (26 per cent); they are absent in nonlaminated microfacies. In the faunistic microfacies they occur together with all other groups of fauna first of all with brachiopods, foraminifera, and ostracods. Bryozoans usually occur as horizontaly situated fragments and they do not form the framework, of the rock. In laminated microfacies they occur together with terrigenic admixture and are obviously redeposited. They occur in the northwestern and central zones, and in the southern zone they are lacking. They are abundant in the boreholes Zawada *1*, Łankiejmy *1* and Barciany *1* in the eastern part of the central zone.

Brachiopods (*Dielasma*, Productidae, Spiriferidae and other) occur in algal microfacies (37 per cent), faunal microfacies (34 per cent), laminated ones (24 per cent) and nonlaminated (5 per cent). In boreholes Barciany *1* and Łankiejmy *1* brachiopods and bryozoans occur in microfacies A_2. Brachiopods occur sporadically in the northwestern and southern zones and are abundant in the central zone where aside of bryozoans and foraminifera are the main faunal components.

Ostracods were noted in all groups of microfacies; in faunal 46 per cent, algal and laminated 23 per cent each, nonlaminated 8 per cent. They occur in the central and northwestern zones frequently with terrigenic admixture.

The remaining faunistic groups occur first of all in the faunal microfacies and in the laminated and algal ones.

Serpulae occur in all three zones and occupy uniform area (boreholes Zaręby *1*, Pieszkowo *1*, Lidzbark Warmiński *1*, Paluzy *1*, Łankiejmy *1*,

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[3] The percents were calculated with the omission of the recrystallized microfacies.

Klewno *1*, Barciany *1* and *2*). Spirorbis is abundant in the Barciany *2* borehole.

Pelecypods were noted only in the central and southern zones. They occur usually in nests, many specimens in the particular samples.

Gastropods occur in the eastern part of the central zone (boreholes Zawada *1*, Łankiejmy *1*, Barciany *1* and *2*) and rarely in the northwestern zone (Gładysze *2*).

Echinoids represented mainly by spines are rare (Krynica Morska *2* and Gładysze *2* in the northwestern zone and Barciany *1* in central zone).

Trilobites were observed only in the central zone (Zawada *1* and Barciany *2*) in the faunal microfacies.

Crinoidal trochites were noted only in one sample (Łankiejmy *1*).

The faunal content and distribution leads to the following conclusions:

1. The fauna of the investigated area is much poorer as a whole than that of the open Zechstein sea known to the authors from drillings in Western Pomerania. Extreme scarcity of typically marine groups such as crinoids and lack of corals points to abnormal conditions probably resulting from increased salinity in the Peri-Baltic Gulf separated from the open sea by shoals of the Koszalin-Chojnice zone.

2. The northwestern zone corresponds to fore-reef conditions. According to Kerkmann (1969) in Thuringia in this zone (off reef and fore reef) occur foraminifers, brachiopods and redeposited fragments of other fossils. In the Permian of Texas (Newell 1957) in analogous area there occur ammonites, brachiopods, siliceous sponges, radiolarians, few pelecypods and gastropods.

In our northwestern zone there occur mainly foraminifers and few brachiopods, ostracods, bryozoans, worms, echinoids and gastropods. A part of this fauna is redeposited.

3. Central zone rich in all faunal groups corresponds in its eastern part of a reef area (Sępopol *2*, Łankiejmy *1*, Zawada *1*, Barciany *1* and *2* boreholes).

In Thuringia according to Kerkmann (*op. cit.*) this area is characterized by abundance of bryozoans and brachiopods on the windward side (external). On the leeward side there are less fossils among which there occur pelecypods, gastropods and among the bryozoans — *Thamniscus*. Algae are common in both parts of the reef.

According to Smith (1958) in Durham, England, the external part of a Permian Reef is characterized by abundance of crinoids, brachiopods, and bryozoans and the internal side — by gastropods and pelecypods with few bryozoans.

In the Capitan Reef in Texas and New Mexico (Newell 1957) there occur mainly brachiopods, calcareous sponges, bryozoans, foraminifers, corals and echinoderms with few molluscs.

In our area the boreholes Sępopol *2*, Zawada *1*, Łankiejmy *1* and Barciany *1* represent the external part of the reef. There are many bryozoans and brachiopods with considerable admixture of other groups of fauna. Crinoids occur sporadically also in that area. The western part of the central zone (Paluzy *1*, and Lidzbark Warmiński *1* boreholes) with some characters of back reef slope (scarcity of bryozoans) equals the eastern part in its thickness, nevertheless, cannot be regarded as back reef slope because of its palaeogeographic position. It consitutes a prolongation of a reef belt but the fauna becomes poorer and poorer westward. The closest analogy here is Newell's (1957) "bank" facies of the Guadalupe Mountains area, as it shows large thickness and is situated between the basin and back reef zones. Both the lithology and fauna of the "bank" facies differ from the reef as it does not contain so much algal detritus nor its fauna of bryozoans and brachiopods is abundant.

4. The southern zone corresponds to the back reef area. In Thuringia (Kerkmann 1969) a prevalence of algal structures (mostly algal spherules) over the faunal elements is to be observed. Fauna is represented by few bryozoans, brachiopods, pelecypods, gastropods, ostracods and spiral foraminifera.

The back reef in Texas (Newell 1957) is rich in algae and foraminifera. Beside that there are some gastropods, pelecypods and scaphopods. This fauna occurs near the reefs. Algal pizolites form the entire rock at a distance of 0.5—1 mile from the reef.

An extreme scarcity of fauna was encountered in our area in that zone with considerable development of algae. Only few foraminifera, pelecypods, brachiopods and worms were noted there.

Distribution of microfacies of organogenic rocks

Clear differences exist in the geographical range among the algal microfacies between the microfacies A_1 (stromatolites and onkolites) on the one side, and the remaining microfacies on the other.

The microfacies A_1 forms, aside of the laminated ones, the main element in the western part of the investigated area (Fig. 5). It forms intercalations in the lowest part of the profiles of the Zechstein limestone in the boreholes Łankiejmy *1* and Barciany *1*.

The microfacies A_2 forms a belt centrally situated in the zone of large thicknesses (Łankiejmy *1* — Barciany *1* boreholes) and an isolated site in the Głądy *4* borehole, where it occurs together with the microfacies A_6 (Chlorophyceae). In that zone the belt of A_2 microfacies separates two regions differing in their algal microfacies. North of that belt in the Sępopol *2* borehole there occurs the microfacies A_5. South of it there is a region in the western part of which microfacies A_4 dominates (Dobre

Miasto *2* borehole) giving way eastward to the microfacies A_3. In the Klewno *1* borehole both microfacies occur in comparable quantities and in the Lesieniec *1* borehole the microfacies A_3 dominates with addition of microfacies A_5.

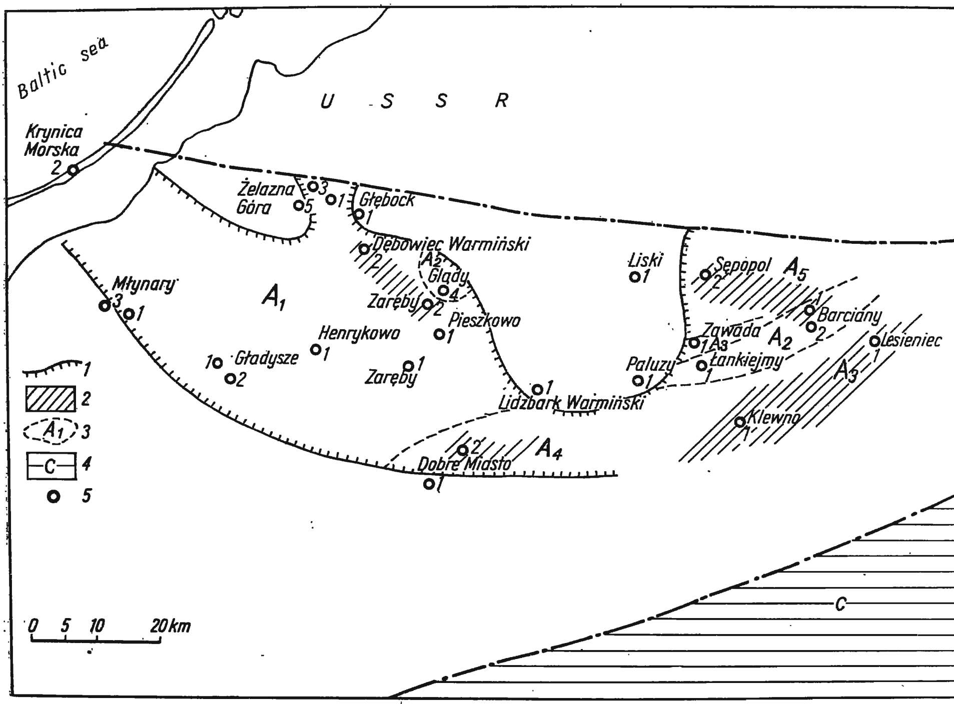


Fig. 5

Distribution of algal microfacies in the Zechstein limestone

1 extent of the algal microfacies, *2* areas in which the algal microfacies constitute over 50 per cent of thickness, *3* area of prevalence of microfacies A_1 (analogically A_2, etc.), *4* Mazury-Suwałki land, *5* borehole

It seems probable that the belt of microfacies A_2 with best developed algal structures corresponds to "reef" environment, and the southern region (Klewno *1* — Lesieniec *1* boreholes) embracing sediments of a character of algal scree — to the back-reef zone. The Sępopol *1* borehole represents probably farther part of an external reef slope.

The faunal microfacies are concentrated entirely within the area of large thicknesses (Barciany *1* and *2*, Łankiejmy *1*, Zawada *1*, Sępopol *2*, and Paluzy *1* boreholes). They mark the zone of most intensive development of fauna. The microfacies with fauna of larger dimensions (F_1, F_2, F_3) occur in all those boreholes with the exception of the Paluzy *1* drilling. This agrees with the classification of the last mentioned drilling to the "bank" facies and the remaining ones — to the "reef" facies.

Dolomitization

Most rocks of the Zechstein Limestone horizon in the investigated area are dolomites (Fig. 6). Limestones occur only in "islands". One of them occurs within the area of large thicknesses (Zawada *1* — Łankiejmy *1* — Barciany *2* boreholes), another one in the western area (Gładysze *1* and *2*).

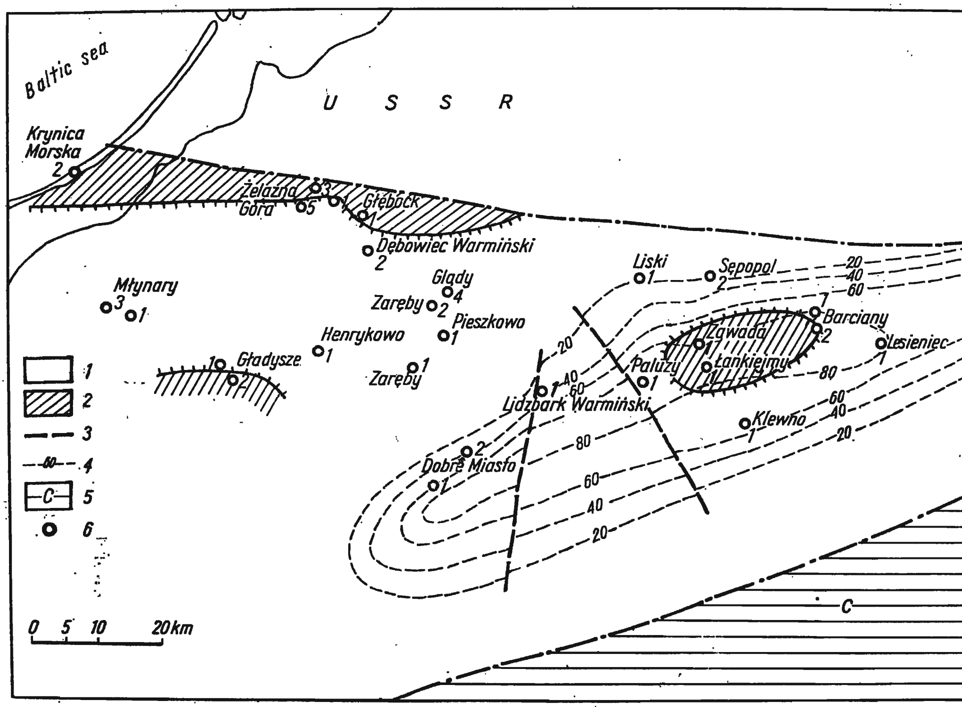


Fig. 6

Distribution of dolomites in the Zechstein limestone

1 area of prevalence of dolomites, *2* area of prevalence of limestones, *3* faults, *4* isopachyte of the Zechstein limestone, *5* Mazury-Suwałki land, *6* borehole; *3*, *4* and *5* — after Stolarczyk & Tyski, 1972

It seems, however, that toward the North the dolomites pass into limestones which is suggested by the prevalence of the latter over the former in the boreholes Krynica Morska *2*, Żelazna Góra *3* and Głębock *1*.

An increase of dolomite share toward the margins is, according to Füchtbauer (1972), a rule in the German Zechstein Basin. Another rule is an increase of dolomite share upwards in the profile. The latter phenomenon has recently been observed by Dietrich (1965) and others and in the Łeba elevation by Szaniawski (1966), in the Northern Sudetes by Krason (1964). According to Kerkmann (1967) in the reefs of Thuringia the base and cap of the reef are formed by dolomites and the centre of the reef — by limestones.

No dolomite increase was noted in the upper portion of the Zechstein limestone in the investigated area.

The degree of dolomitization was different in various groups of microfacies which is illustrated in Table 3. The algal microfacies were most easily dolomitized and the faunal and laminated ones the most resistant to this process. Certainly these are only approximations as it is not known which primary microfacies are represented by recrystallized rocks.

Table 3

	Microfacies					Breccias and shales
	laminated	algal	recrystallized	faunistic	nonlaminated	
Thickness percent of the Zechstein limestone rocks per group of microfacies	37.1	29.7	20.1	8.7	2.4	2.0
Thickness percent of dolomites in the horizon of the Zechstein limestone per group of microfacies	32.0	39.0	22.4	3.0	3.6	-

In the algal microfacies the dolomitization is stronger in the algal structures than in the cement. Good state of preservation of the dolomitized algal structures suggests that this was an early diagenetic process. The microfacies A_5 is an exception in this case in which the dolomitization and recrystallization have destroyed almost completely the algal structures.

The faunal microfacies exhibit usually a lower degree of dolomitization. The remnants of fauna are preserved as a rule in calcite and are more easily replaced by anhydrite and gypsum than by dolomite.

Signs of dedolomitization were frequently observed in the material under study. These phenomena were dealt with in the Zechstein rocks of the Fore-Sudetic monocline by Podemski (1973).

Figure 2 in Pl. 22 shows a case of development of secondary calcitic cement, in which numerous dolomite grains are dispersed. Rhombohedrons of dolomite with calcite aureole and calcite pseudomorphoses after dolomite were noted as well.

The calcium sulphate was probably the main factor causing dedolomitization (Michard 1969). In few cases a lense of sparry calcite was formed around the anhydrite concretions (Pl. 18).

Anhydrite and gypsum

Calcium sulphates occur in the Zechstein limestone in the following forms:

— intercalations or bands accentuating the bedding,
— concretions several millimeters up to some centimeters in size,
— vein infillings,
— pseudomorphoses after organic remains,
— cement, which prevails over the carbonate parts frequently accentuating lamination,
— radial concentrations of crystals of large dimensions (up to several millimeters) which abound with small relic dolomite rhombohedrons,
— isolated crystals scattered in the rock, usually of idiomorphic outlines.

Anhydrite of blue or white colour is the main sulphate mineral. In places it maybe replaced by gypsum which forms aureoles around the anhydrite concretions. Sometimes small idiomorphic anhydrite grains occur inside large crystals of gypsum (Pl. 20, Fig. 1) and vice versa.

Dislodgements of carbonates by anhydrite, *e.g.* dissolution and replacement of carbonate cement between the algal structures, forming pseudomorphoses after organic remains, relic rhombohedrons of dolomite in feathery anhydrite crystals were observed in many cases. The process of anhydritization was definitely selective. The cement was more easily subjected to it than the algal structures. Remnants of some groups of the fauna (*e.g.* brachiopods and gastropods) were more easily anhydrytized than other forms. The dislodgement of carbonates by sulphates has caused farther distortion of organic structures left after dolomitization and recrystallization.

The sulphates of the Zechstein limestone derive mostly from the solutions which have migrated during the deposition of the Werra Anhydrite from the basin bottom down the rocks of the Zechstein limestone. This is suggested among other by the abundance of sulphates in the algal microfacies which represented most previous rocks. Therefore the zone of large thicknesses of the Zechstein limestone consisting to considerable extent of porous algal microfacies (microfacies A_2, A_3, A_4 and A_5) is particularly rich in sulphates. Replacement of the algal spherules by anhydrite veinlets implies an age of anhydritization later than the rock lithification, at least partly.

Simultaneous deposition of a part of the sulphates together with the carbonates cannot be excluded.

Variability of sedimentation

Out of the 27 investigated boreholes in ten the top and bottom of the Zechstein limestone was pierced, in two only the top, and in seven — the bottom. In the remaining eight boreholes neither top nor the bottom were pierced.

In order to restore in most general outline the course of sedimentation in the area in question the sequence of inorganic rocks (microfacies *L* and *N*) and organogenic rocks (microfacies *A* and *F*) without the recrystallized ones and breccias (*R* and *B*) was examined.

Out of 17 boreholes in which the columns were obtained of the bottom of the Zechstein limestone, in eleven ones the profiles start with inorganic rocks, and in six[4] others with organic rocks. The distribution of those deposits points out (Fig. 7) that during the initial period of sedi-

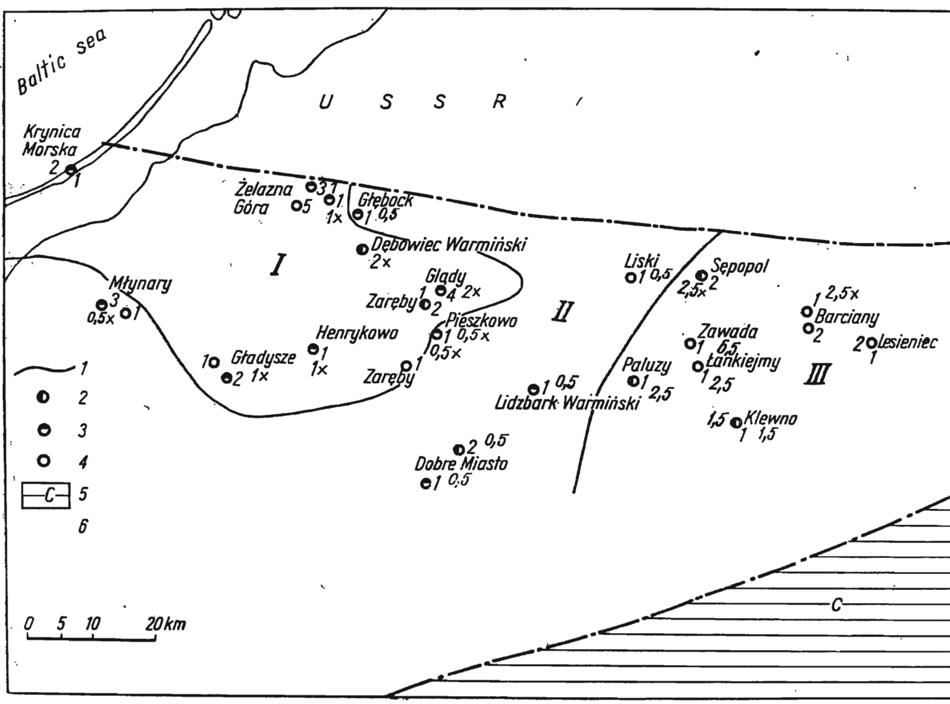


Fig. 7

Variability of sedimentation of the Zechstein limestone

1 boundary between the differentiated areas, *2* borehole in which deposition started with organogenic sediments, *3* borehole in which the deposition started with inorganogenic sediments, *4* borehole in which the development of the lowest part of the Zechstein limestone is unknown, *5* Mazury-Suwałki land

Numbers by boreholes indicate the number of cycles (inorganic-organic sediment). *x* marks that the borehole has embraced the entire profile of the Zechstein limestone together with its top and bottom

I northwestern area of small variability of deposition, *II* central area of lack of variability of deposition, *III* eastern area of large variability of deposition

[4] A possibility of error exists in the Zaręby 2 borehole (reversion of column). In this case the number of boreholes should be 12 and 4 instead of 11 and 5.

mentation of the Zechstein limestone in the western part of the area inorganic sediments were laid down, and the organogenic ones — in the eastern part. In the transitional zone (between the meridians of Głębock *1* and Lidzbark Warmiński *1* boreholes) either the organogenic or inorganic sediments were deposited. In later deposition phases in most of the boreholes the organic microfacies intercalate with the inorganic ones. Conditions of sedimentation became more uniform in the highest part of the Zechstein limestone, prior to the deposition of the anhydrites. Out of 12 boreholes with pierced top of the horizon in nine it ends with organogenic sediments.

If a sequence inorganic-organogenic sediment or vice versa may be defined as a cycle and the number of such cycles will be counted for each of the drillings then we obtain the data presented in Table 4.

Table 4

Borehole	Number of cycles	Top and bottom of the Zechstein limestone traced in coring
Barciany 1	2.5	-
Barciany 2	0.5	top
Dębowiec Warmiński 1	2.0	top and bottom
Dobre Miasto 1	0.5	bottom
Dobre Miasto 2	0.5	top and bottom
Glądy 4	2.0	top and bottom
Gładysze 1	1.0	-
Gładysze 2	1.0	top and bottom
Głębock 1	0.5	bottom
Henrykowo 1	1.0	top and bottom
Klewno 1	1.5	bottom
Krynica Morska 2	1.0	top and bottom
Lesieniec 1	2.0	-
Lidzbark Warmiński 1	0.5	bottom
Liski 1	0.5	-
Łankiejmy 1	2.5	-
Młynary 1	1	top
Młynary 3	0.5	top and bottom
Paluzy 1	2.5	bottom
Pieszkowo 1	0.5	top and bottom
Sępopol 1	2.5	top and bottom
Zaręby 1	1	-
Zaręby 2	1	bottom
Zawada 1	6.5	-
Żelazna Góra 1	1	top and bottom
Żelazna Góra 3	1	bottom
Żelazna Góra 5	0.5	-

It results from the above data that there are three zones differing in deposition (Fig. 7).

1. The northwestern area of small variability of deposition in which the Zechstein limestone usually consists of two members — inorganic laminated sediments and the overlying algal ones. A repetition of such cycle is observed in some cases.

2. The central zone with uniform deposition where the whole profile consists of one type of sediments — most frequently inorganic.

3. Eastern zone of great variability of deposition embracing the "reef" and "associated-reef" sediment in which the character of sediments frequently changes from inorganic to organic and vice versa.

Such a variability suggests that it is impossible to subdivide the Zechstein limestone in a uniform way in the investigated area as it was done in the center of the basin in Germany (*e.g.* Helmuth 1968), or in the Fore-Sudetic monocline (Alexandrowicz 1970, Alexandrowicz & Preidl 1971). Motyl-Rakowska (1971) is probably right saying that the German subdivision of the Zechstein limestone into four horizons may be applied in the Fore-Sudetic monocline but not in the more northern parts of the basin.

CONCLUSIONS

The investigated part of the Peri-Baltic depression may be subdivided into two facial areas, namely the western and eastern ones (Figs 8 and 9). A boundary between these two areas runs slightly north of the Dobre Miasto *1* and *2*, Lidzbark Warmiński *1* and Sępopol *2* boreholes.

The differences between these areas are the following:

Western area	*Eastern area*
thickness of the Zechstein limestone less than 20 m	more than 20 m, up to 100 m
fauna poor or lacking	usually rich fauna
lack of faunal microfacies	out of 11 boreholes in 6 faunal microfacies are present
prevalence of stromatolites and onkolites among the algal structures (microfacies A_1)	prevalence of spherical forms among the algal structures (microfacies A_2, A_3, A_4, A_5)
small variability of sedimentation	large variability of sedimentation
over 40 per cent of the rocks contain admixture of detrital quartz	less than 40 per cent of the rocks contain admixture of detrital quartz
out of 11 boreholes in which the bottom of the Zechstein limestone was cored in 9 the deposition started with inorganogenic sediments	out of 6 boreholes in which the bottom of the Zechstein limestone was cored in 4 the deposition started with organogenic sediments

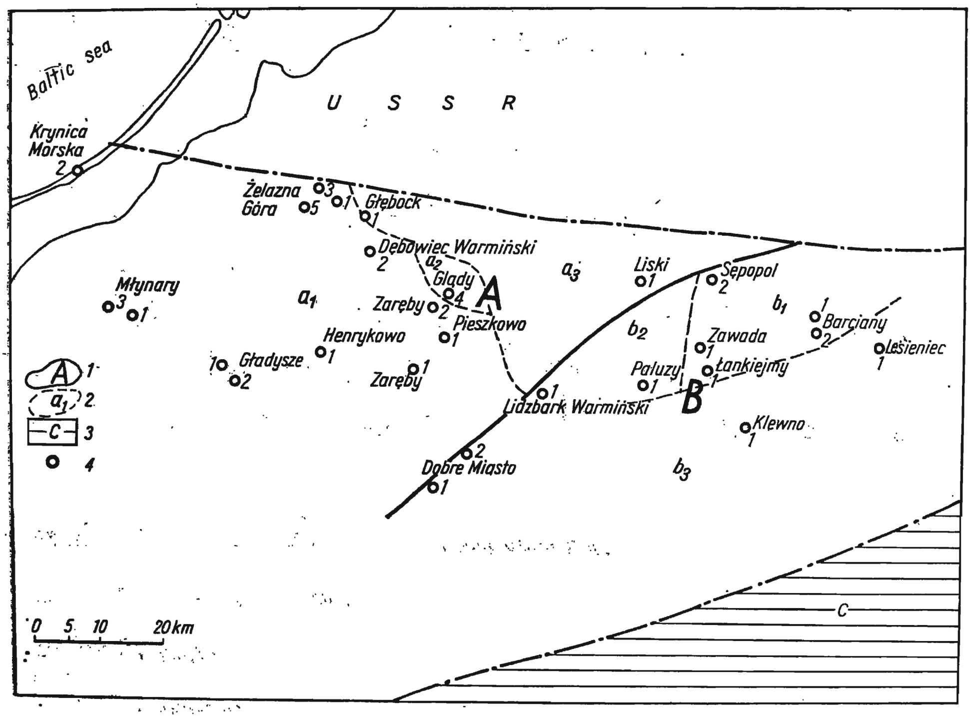


Fig. 8

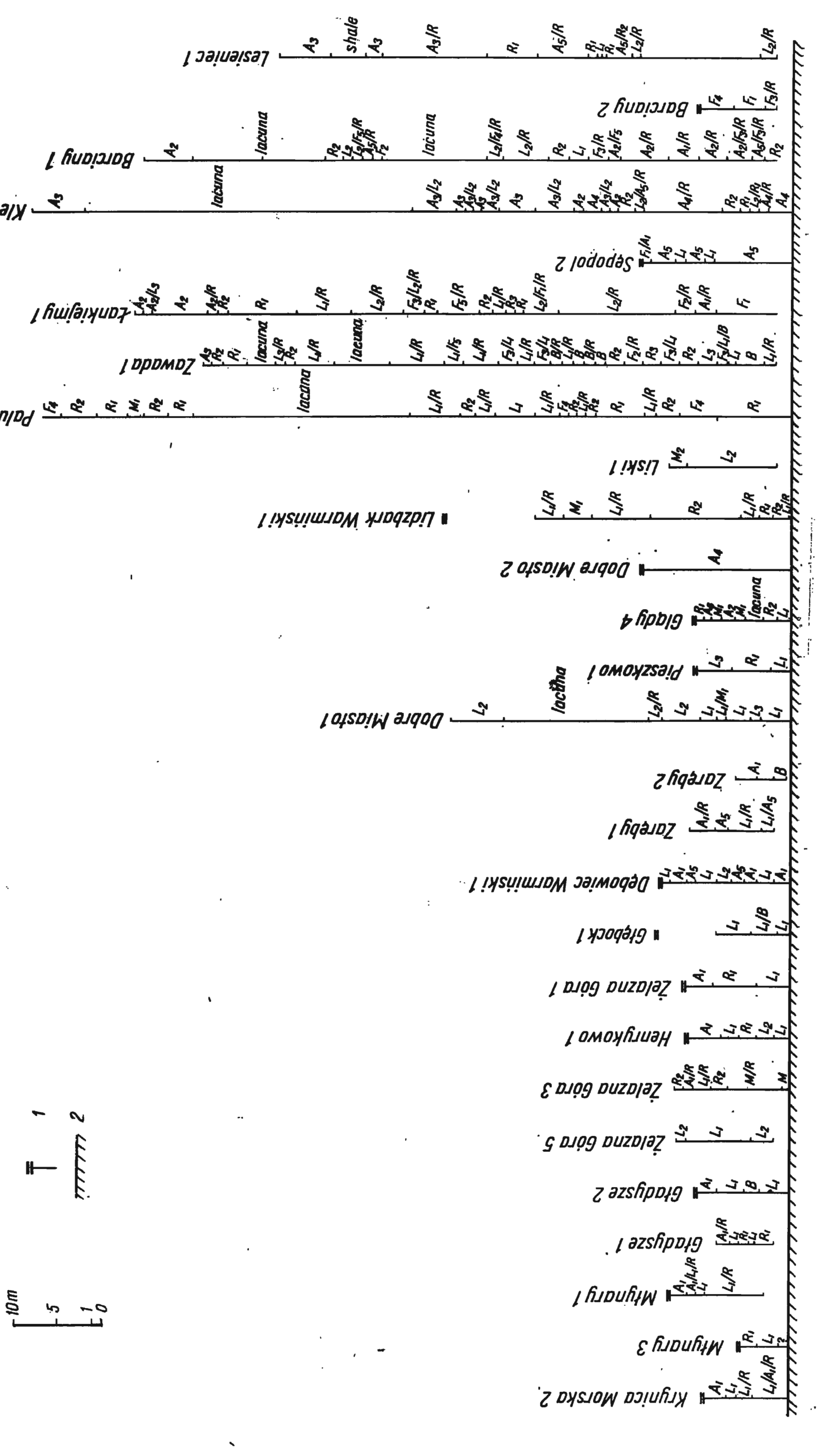
Facial zones of the Zechstein limestone

1 extent of the area, *2* range of a facial zone, *3* Mazury-Suwałki land, *4* borehole

A western area of small thicknesses, *B* eastern area of large thicknesses; a_1 zone of broad, shallow sea of calm deposition of laminated mud (silt) and oncoliths with poor fauna; a_2 zone of calm deposition of nonlaminated silt with algal bioherms with poor fauna; a_3 zone of calm deposition of laminated silt without algal microfacies, with very poor fauna; b_1 zone of quick deposition with rich fauna, abundance of bryozoans, algae — "reef"; b_2 zone of quick deposition with fairly abundant fauna, without bryozoans, nor algal microfacies — "bank" facies; b_3 zone of quick deposition, mainly algal with very poor fauna — back reef facies

Distinction of these two extremely different areas is relatively easy. But farther subdivision of them into smaller facial zones is rather artificial. The profiles of the Zechstein limestone differ from drilling to drilling. Changes in deposition along a given direction are usually gradual and placing a boundary between the facial zones is more or less subjective. An introduction of such slightly artificial subdivision aims to make the characterization of the deposition in that area easier.

Three facial zones were distinguished in the western area (Fig. 8). The *Ia* zone is characterized by a large share of laminated microfacies (L_1), common admixture of detrital quartz, occurrence of algae almost entirely within microfacies A_1, scarcity of fauna, small variability of sedimentation.


Lesieniec 1
Barciany 2
Barciany 1
Klewno 1
Sępopol 2
Łankiejmy 1
Zawada 1
Paluzy 1
Liski 1
Lidzbark Warmiński 1
Dobre Miasto 2
Gładys 4
Pieszkowo 1
Dobre Miasto 1
Zaręby 2
Zaręby 1
Dębowiec Warmiński 1
Głębock 1
Żelazna Góra 1
Henrykowo 1
Żelazna Góra 3
Żelazna Góra 5
Gładysze 2
Gładysze 1
Młynary 1
Młynary 3
Krynica Morska 2
lacuna
shale
10m
5
1
0
1
2

The *Ib* zone embracing the Glądy *4* borehole differs from the former in the occurrence of algal microfacies A_2 and A_6 (presence of Chlorophyceae) and prevalance of nonlaminated microfacies over the laminated ones.

The *Ic* zone differs from the *Ia* one in a complete lack of algal microfacies and lack of any variability of sedimentation.

It seems that the *Ia* zone represents conditions of a shallow, large sea with calm deposition during which a slight shallowing had taken place in result of which the sediments of the laminated limy mud were replaced by stromatoliths and algal onkoliths. Weak westerly currents brought some quartz pelite and argillaceous substance. The *Ib* zone represents probably small algal bioherms which have developed alternately with nonlaminated carbonate sediment under calmer sedimentation conditions than those of the *Ia* zone. The *Ic* zone represents undoubtedly calm deposition. It is situated beyond the influence of organogenic sedimentation within the area of large thicknesses and it was not involved in the algal deposition of the West. This makes it closer to the adjoining *IIb* zone of the eastern area, which is devoid of algal microfacies as well. Light colours of the sediments of the *Ic* zone do not allow to ascribe to it greater depths, nevertheless, it was deeper then the *Ia* and *Ib* zones.

Three facial zones — *a, b* and *c* have been distinguished in the eastern area. The *IIa* zone differs from the others in the abundance of fauna which embraces about 90 per cent of all bryozoans, and brachiopods observed in the area in question, and most of all the remaining faunistic groups. The faunistic microfacies occur only in this facies (with the exception of interbeds of microfacies F_4 in the Paluzy borehole — zone *IIb*). Microfacies A_2 dominates among the algal ones in which it is known outside that zone only from the Glądy *4* borehole. The rocks representing laminated microfacies never constitute more than 50 per cent of thickness of a horizon, and microfacies L_2 (without detrital quartz) dominates over the L_1 one. The admixture of detrital quartz is insignificant. A variability exists within the zone *IIa* where microfacies A_3 and A_5 (poorly represented in boreholes Zawada *1* and Sępopol *2* respectively) increase northward at the expense of microfacies A_2. The zone *IIa* best corresponds to a recifal enivironment out of all facies represented in the investigated area. This is proved by a typical fauna of the Zechstein reefs most of all bryozoans and brachiopods, and by the domination of the algal microfacies A_2 which contains best developed algal structures. Nevertheless,

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Fig. 9

Distribution of microfacies in the boreholes

1 Werra anhydrites, *2* copper-bearing shales
Symbols of microfacies are explained in the text

the studied rocks of that zone do not exhibit the character of a reef but rather a scree of recifal fragments reworked by erosion. The zone *IIb* is characterized by considerable thickness of sediments consisting mainly of laminated and recrystallized microfacies. Foraminifera and ostracods dominate among rather abundant fauna whereas a scarcity of bryozoans is striking. This fauna becomes poorer and poorer westward. There are no algal facies in that zone. The quantity of detrital quartz is rather high. Variability of sedimentation which is large in the Pałuzy *1* borehole diminishes westward in the Lidzbark Warmiński *1* borehole. The zone *IIb* probably represents the "bank" type known from the Guadalupe Mts (Newell 1957). Its thickness and position between the basin and "back reef" seems to correspond to reef facies, although its lithology and fauna are of a non reef character. The combination of these characters corresponds to the "bank" facies described by Newell (*op. cit.*).

The zone *IIc* embraces the boreholes in which the Zechstein limestone is developed as algal sediment. The above mentioned variability exists there, namely microfacies A_4 occurs in the Dobre Miasto *2* borehole, and microfacies A_3 and A_4 — in the Klewno *1*, and microfacies A_4 in the Lesieniec *1* borehole. These microfacies embracing spherical algal structures correspond to the back reef environment. The fauna is extremely poor, limited to few foraminifers, brachiopods, pelecypods and worms. Laminated microfacies (with the exception of the Dobre Miasto *1* borehole) form but a small admixture.

The position and facial development of the columns of the Zechstein limestone in the Dobre Miasto *1* and *2* boreholes are a difficult problem. In the Dobre Miasto *2* there are entirely algal microfacies (A_4) thus the Zechstein limestone there corresponds to the back-reef zone and by its position within the zone of large thicknesses it corresponds to the "bank" facies. The difficulties in interpretation are increased by the profile of the Zechstein limestone in the Dobre Miasto *1* borehole consisting completely of laminated microfacies.

An attempt to interpret these facts is as follows:

Stolarczyk & Tyski (1972) have marked two faults in the zone of large thicknesses (Fig. 3 and 6) with downfaulted western parts. It may be assumed that the downfaulted part of the more westerly of these two faults during the deposition of the Zechstein limestone has formed a local depression near the Dobre Miasto *1* and *2* boreholes. This depression was then filled by algal sediments of the back-reef zone from the South and East and by the laminated ones of limy mud from the West. Such interpretation explains the advance of the algal sediments of the back-reef zone into the external part of the zone of large thicknesses and the rapid facies change between the boreholes Dobre Miasto *1* and *2*.

The investigated area as a whole formed a part of a vast gulf of the Zechstein sea during the deposition of the Zechstein limestone. This gulf was poor in fauna, rich in algae, with weak inflow of terrigenic material, weak westerly currents parallel to the coast. It was a warm (occurrence of *Mizzia*), shallow (algae, stromatolites in particular) sea of nontypical, probably increased, salinity (scarcity of fauna, lack of corals, extremely few crinoids).

Algal structures and chemically precipitated calcium carbonate were the main components of the sediments.

The rocks of the Zechstein limestone were subjected to early diagenetic dolomitization and late diagenetic anhydritization combined with dedolomitization. They were also subjected to some extent to secondary dolomitization as well as to gypsification and degypsification.

These processes have completely changed one fifth of all the rocks of the Zechstein limestone and embraced all of them by some changes.

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ANALIZA MIKROFACJALNA POZIOMU WAPIENIA CECHSZTYŃSKIEGO WE WSCHODNIEJ CZĘŚCI OBNIŻENIA PERYBAŁTYCKIEGO (OPRACOWANIE WSTĘPNE)

(Streszczenie)

Na podstawie materiałów z 27 wierceń Przemysłu Naftowego we wschodniej części obniżenia perybałtyckiego (fig. 1) wykonano analizę mikrofacjalną 372 płytek cienkich z wapienia cechsztyńskiego (*Ca 1*).

Wyróżniono mikrofacje rekrystalizowane, w których zatarty został pierwotny charakter skały, mikrofacje algowe o przewadze materiału algowego, mikrofacje faunistyczne (ponad 20 szczątków zwierzęcych na powierzchnię płytki cienkiej), mikrofacje nieorganiczne laminowane, nieorganiczne nielaminowane i brekcje śródformacyjne (fig. 9). Przeprowadzono podział utworów algowych (stromatolity, onkolity, utwory kuliste różnych typów). Stwierdzono występowanie Dasycladaceae (rodzaj *Mizzia*) w otworze Glądy *4*. Fauna, z reguły redeponowana, reprezentowana jest przez otwornice, mszywioły, ramienionogi, małżoraczki, małże, robaki i ślimaki oraz bardzo nieliczne jeżowce, liliowce i trylobity. Obok prostej laminacji substancją ilastą (fig. 3) często występuje warstwowanie przekątne (fig. 2) oraz zaburzenia osadu biogeniczne i nieorganogeniczne (brekcje wczesnodiagenetyczne i powierzchnie suturopodobne). Porównano wykształcenie mikrofacjalne z barwą skały, obecnością struktur sedymentacyjnych, rozmieszczeniem domieszki terrygenicznej, flory i fauny, z zasięgiem dolomityzacji i anhydrytyzacji. Badanie barwy skały pozwoliło stwierdzić, że w obrębie badanego terenu nie występuje powszechnie w morzach cechsztyńskich ciemnienie skał ku środkowi basenu. Najjaśniejsze barwy łączą się ze skałami rekrystalizowanymi. Stylolity (nie licząc powierzchni suturopodobnych) występują we wszystkich mikrofacjach z tym, że szczególnie częste są w brekcjach. Domieszka kwarcu klastycznego w skałach węglanowych maleje od zachodu ku wschodowi (fig. 2), co sugeruje donoszenie go prądami od zachodu z wyniesienia Łeby i płycizn strefy Koszalin-Chojnice. Dolomityzacja, w większości przypadków wczesnodiagenetyczna, objęła większą część skał badanego obszaru, pozostawiając „wyspy" wapieni (fig. 6). Ku północy, w kierunku szerszego morza dolomity prawdopodobnie ustępują miejsca wapieniom. Dolomityzacja szczególnie silnie objęła mikrofacje algowe, gdzie łatwiej dolomityzują się utwory algowe niż spoiwo. Szczątki fauny są odporne na dolomityzację, łatwiej ulegając anhydrytyzacji.

Anhydrytyzacja jest zjawiskiem bardzo powszechnym w badanych skałach i miała miejsce po lityfikacji skały. Działała również wybiórczo — silniej na spoiwo niż na utwory algowe. W badanym materiale występuje wyraźny związek między anhydrytyzacją i dolomityzacją.

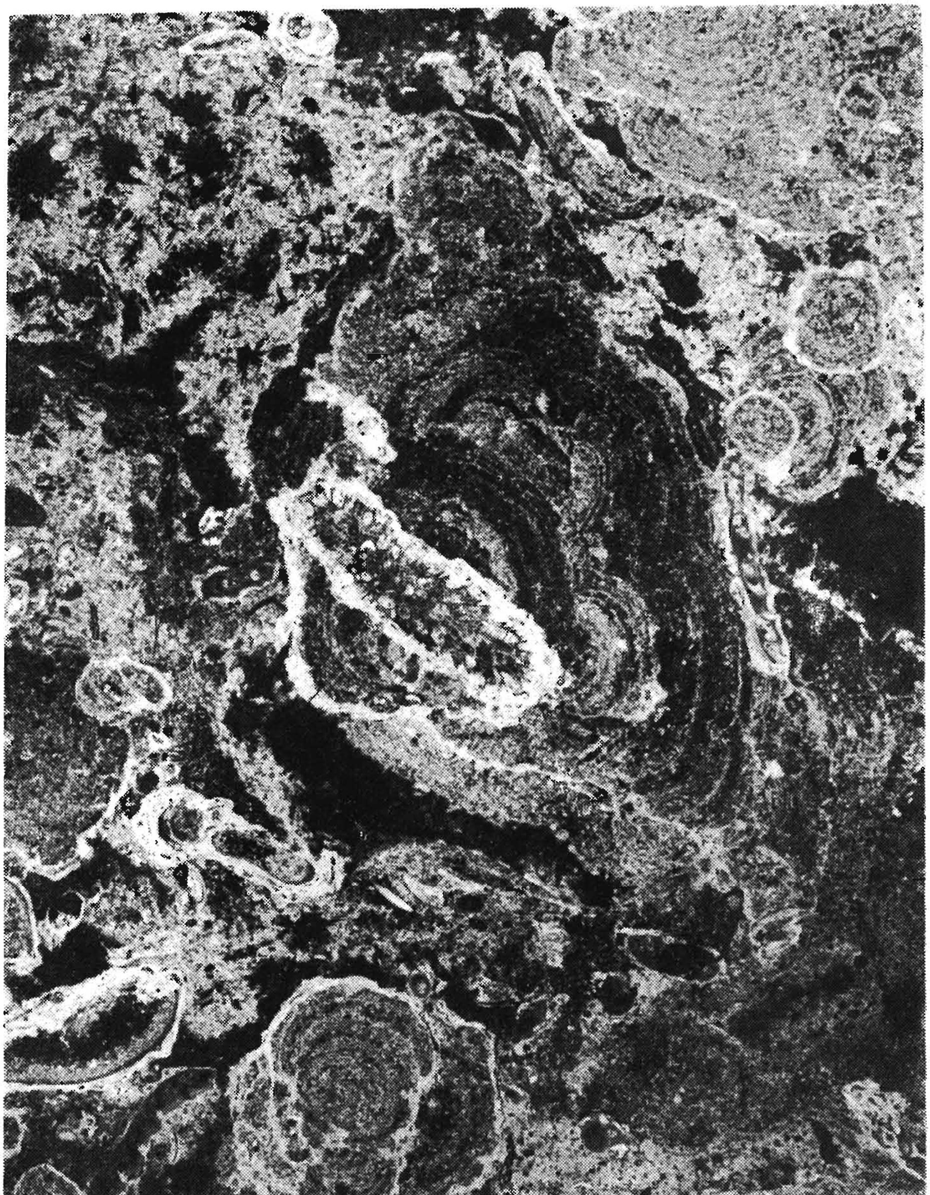
Zmienność sedymentacji w profilu wapienia cechsztyńskiego mierzona ilością zmian: osad nieorganogeniczny — osad organogeniczny, jest w zachodniej części badanego obszaru niewielka (fig. 7), lokalnie żadna, natomiast we wschodniej duża.

Na podstawie rozmieszczenia mikrofacji wyróżniono na badanym terenie dwa obszary (fig. 8).

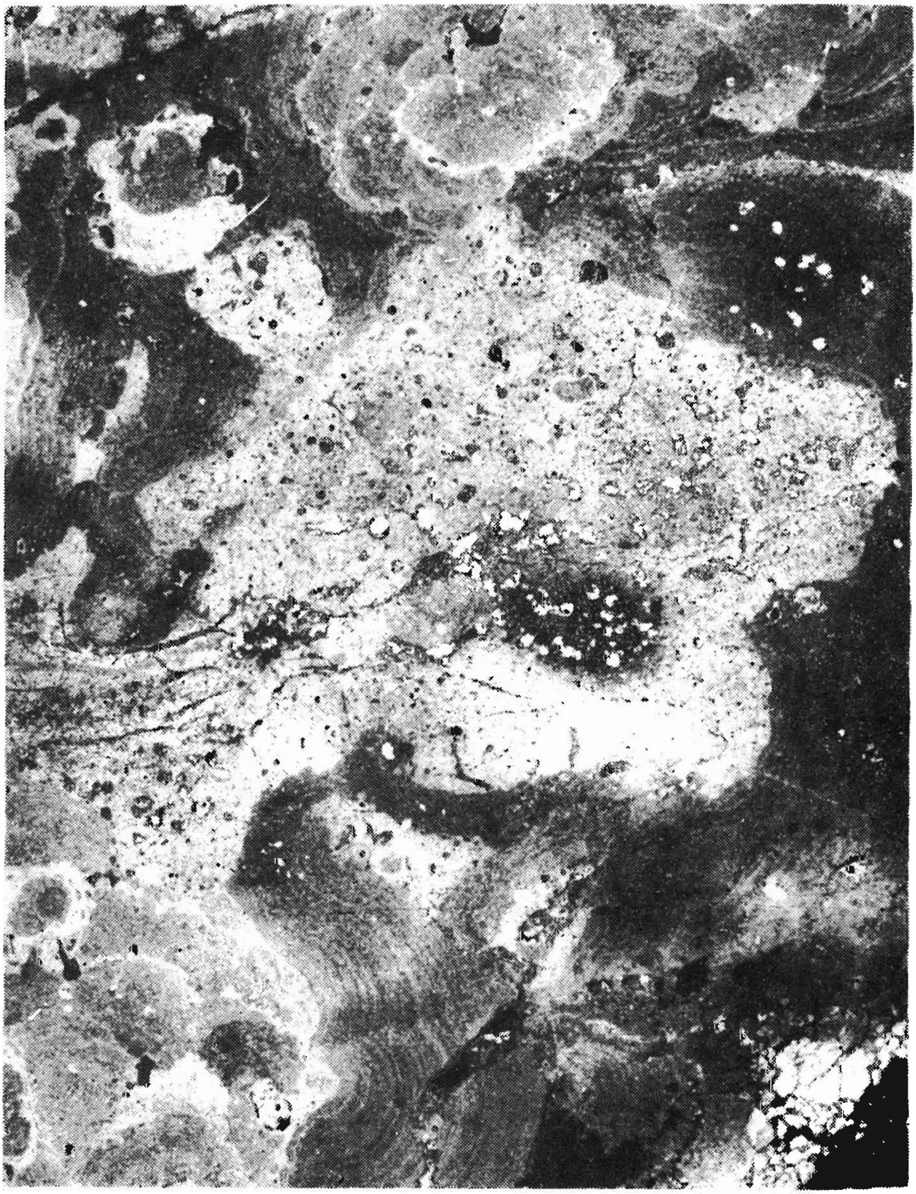
Obszar zachodni charakteryzuje się małymi miąższościami (poniżej 20 m), ubogą fauną, przewagą form onkolitowych i stromatolitowych nad innymi utworami algowymi (fig. 5), częstą domieszką kwarcu klastycznego, niewielką zmiennością sedymentacji oraz rozpoczęciem sedymentacji najczęściej osadami nieorganogenicznymi. W obszarze tym profil otworu Glądy *4* wyróżnia się występowaniem zielenic oraz przewagą osadów nielaminowanych nad laminowanymi.

Obszar wschodni cechuje się stosunkowo dużymi miąższościami (20—100 m), często bogatą fauną, przewagą algowych utworów kulistych, małym rozprzestrzenieniem kwarcu klastycznego, stosunkowo dużą zmiennością sedymentacji i rozpoczęciem sedymentacji najczęściej osadami organogenicznymi. W obszarze tym wyróżnić można strefę reprezentującą środowisko zbliżone do rafowego, z liczną fauną, zwłaszcza mszywiołów (fig. 4), z dobrze wykształconymi utworami algowymi (profile Łankiejmy *1*, Zawada *1*, Barciany *1* i *2*). Na południe od nich leży strefa z osadami złożonymi głównie z kulek algowych, która odpowiada środowisku zarafowemu (profile Klewno *1* i Lesieniec *1*). Ku zachodowi obszar rafowy przechodzi w ławicę prawie pozbawioną fauny mszywiołów i ubogą w algi (profile Paluzy *1* i Lidzbark Warmiński *1*), a następnie w miąższe utwory bądź typu zarafowego (profil Dobre Miasto *2*), bądź typu osadów basenu (profil Dobre Miasto *1*). Być może osady tworzyły się tutaj w zagłębieniu zasypywanym zarówno od strony zarafowej jak i od strony basenu oraz ławicy.

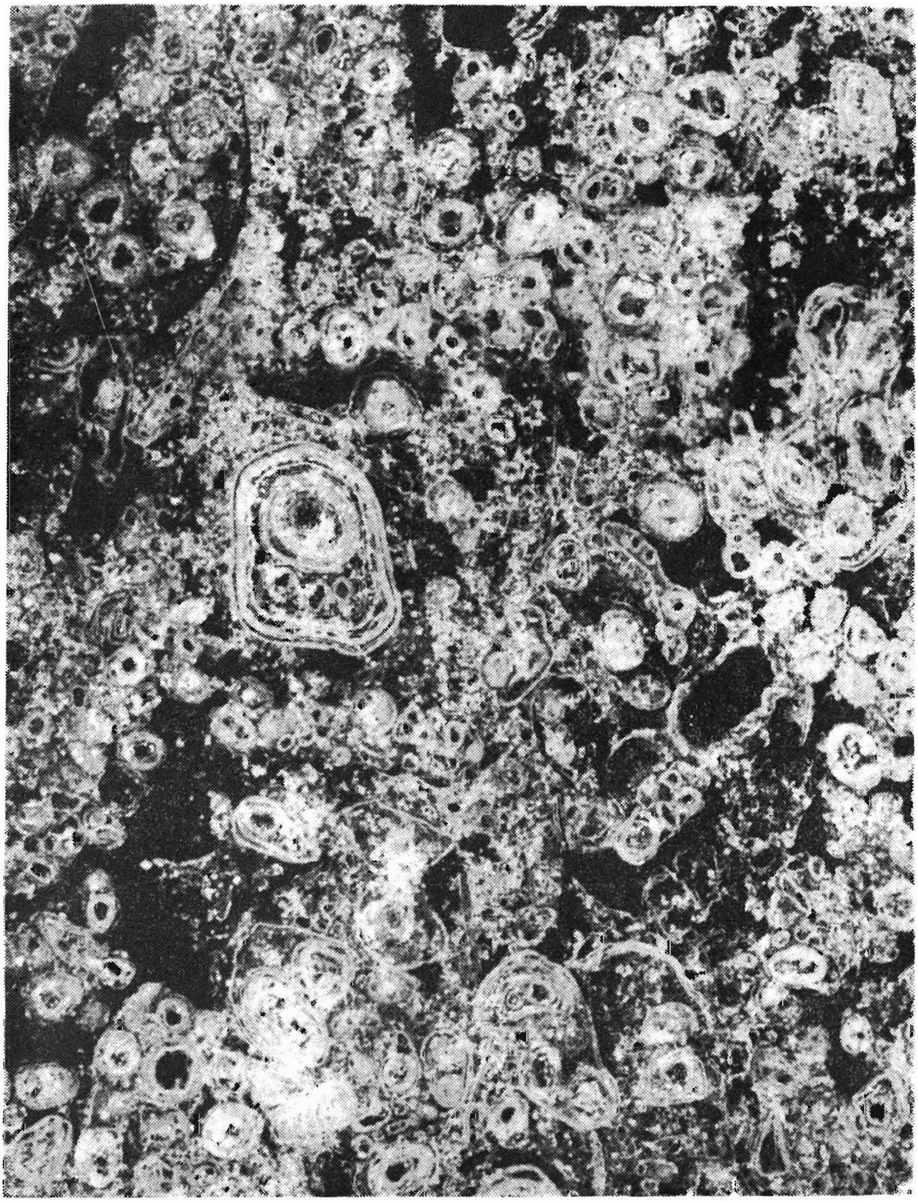
Microfacies A_1 — algal oncoids in basal carbonate cement; borehole Dębowiec Warmiński 2, depth 1670.2—1676.2 m; negative, × 10



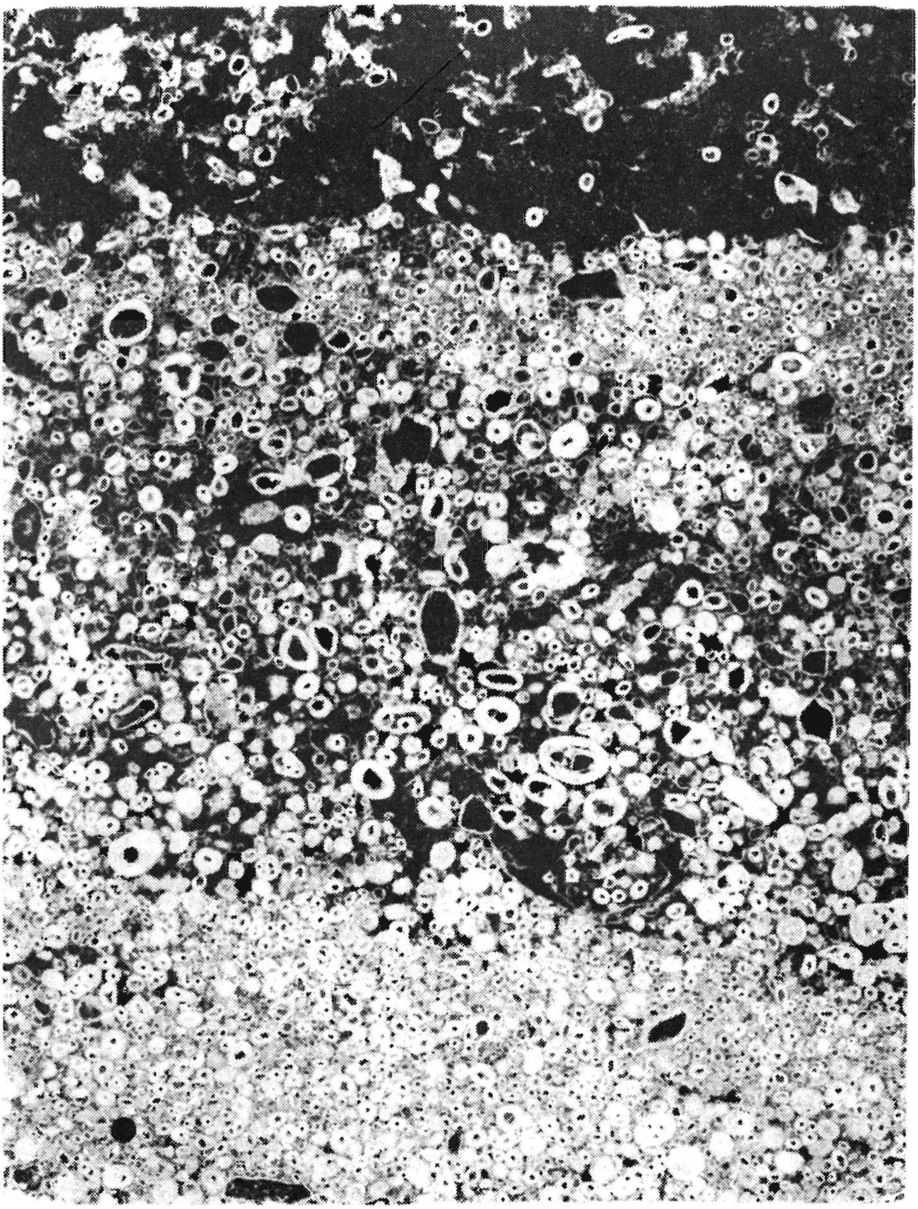
Microfacies F_1/A_1 — oncoids and algal stromatoliths; numerous fragments of fauna, some of them like a bryozoan in the center overgrown by encrusting algae (light) and embedded in stromatoliths; Sępopol 2, 1348.2—1355.2 m; negative, × 10



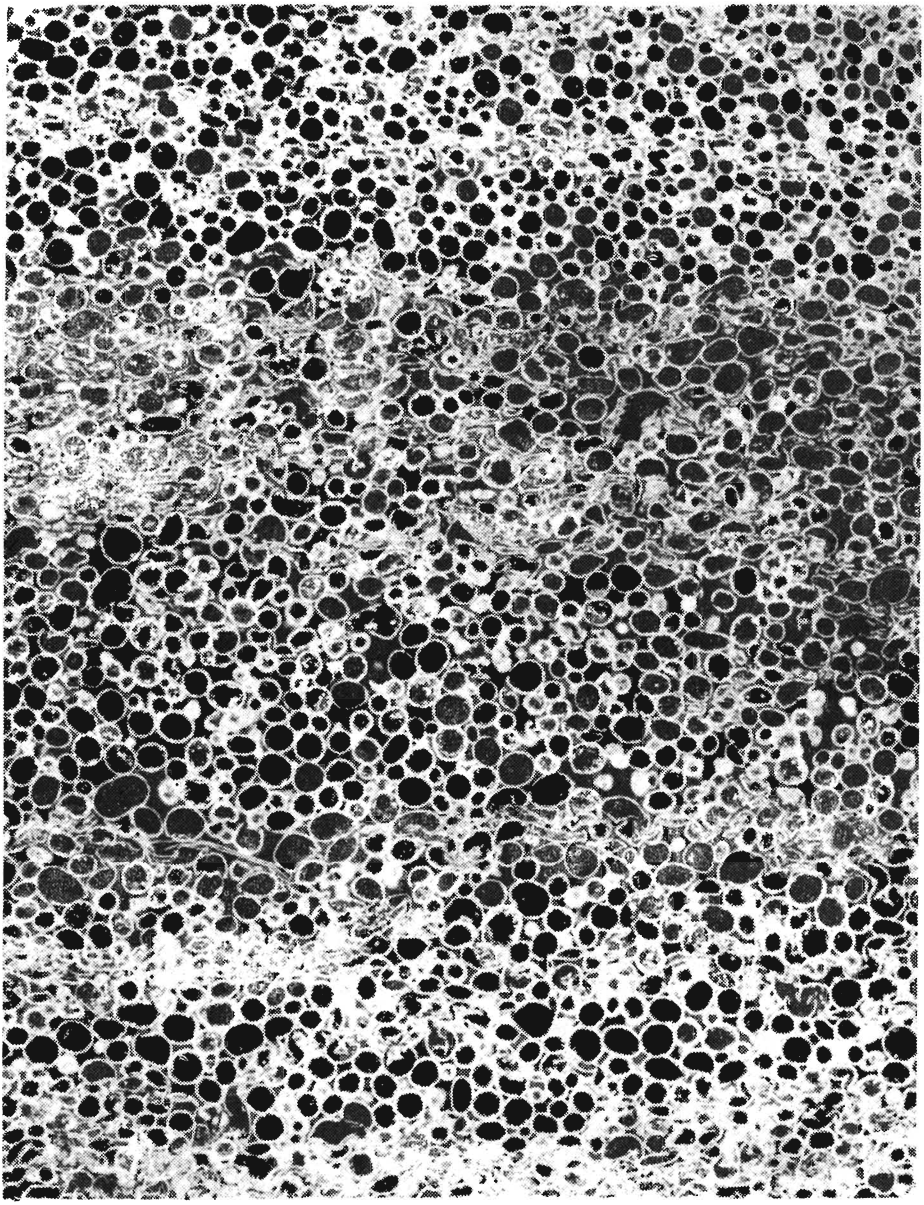
Microfacies A_1 — large stromatoliths; Żelazna Góra 1, 1654.7—1658.4 m; negative × 10



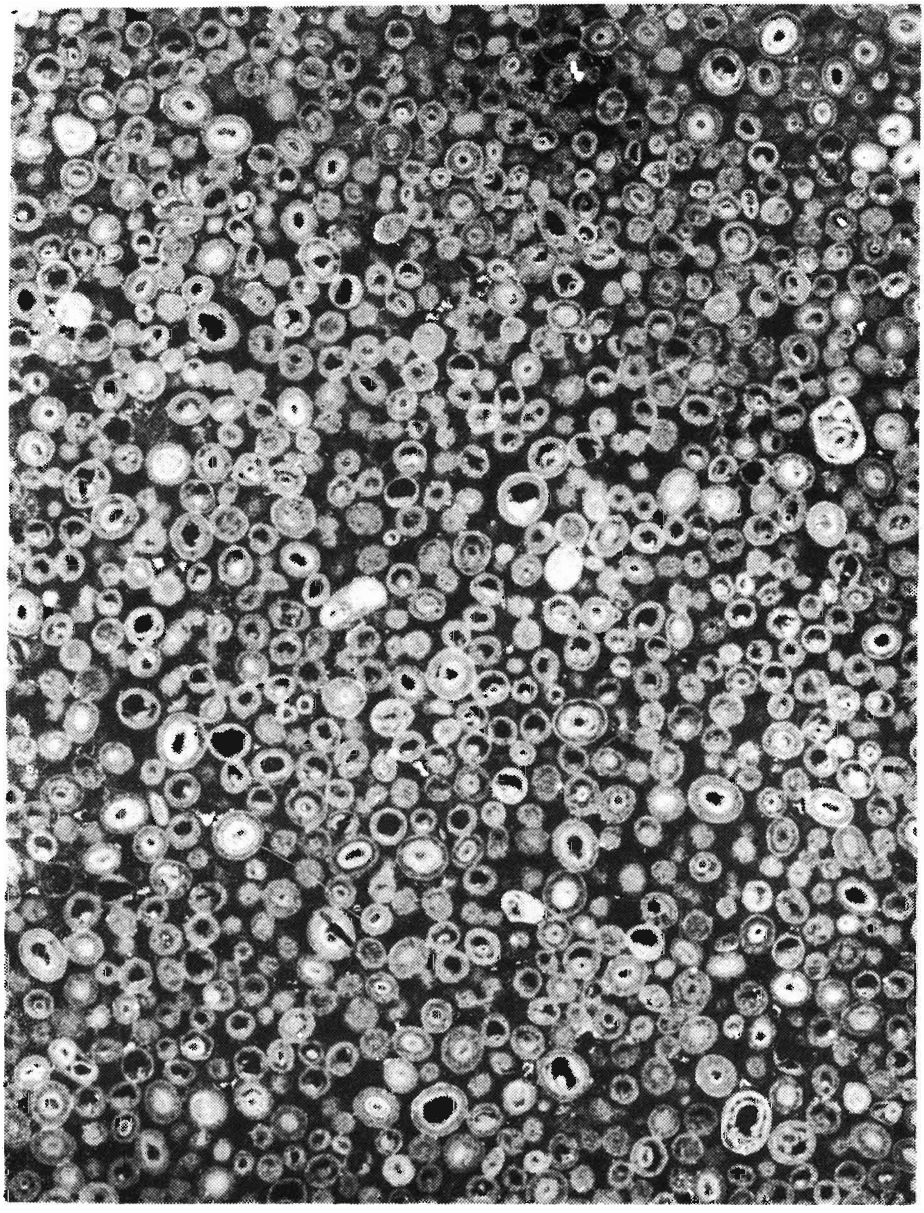
Microfacies A_2 — dark parts represent anhydrite cement; Barciany 1, 1216.0—1222.0 m; negative, × 10



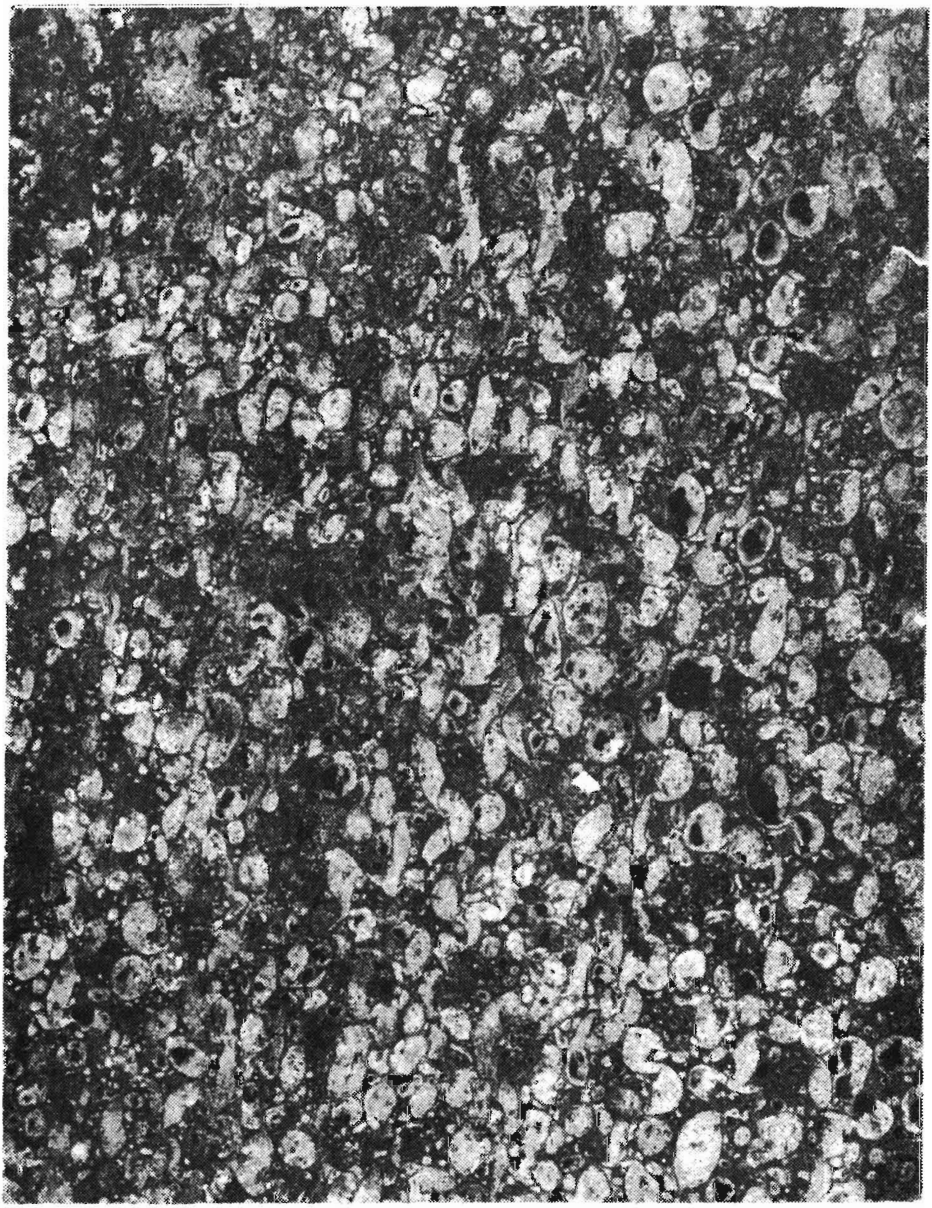
Microfacies A_2/L_3 — bedding marked by anhydrite cement (dark) and differentiation of dimensions of algal structures; some of these structures resemble spherules of microfacies A_3; Łankiejmy 1, 1367.3—1373.3 m; negative, × 10



Microfacies A_3 — empty spherules of thin walls, almost without cement; open-work internal texture observable in some spherules; Lesieniec 1, 1187.0—1193.0 m; negative, × 10



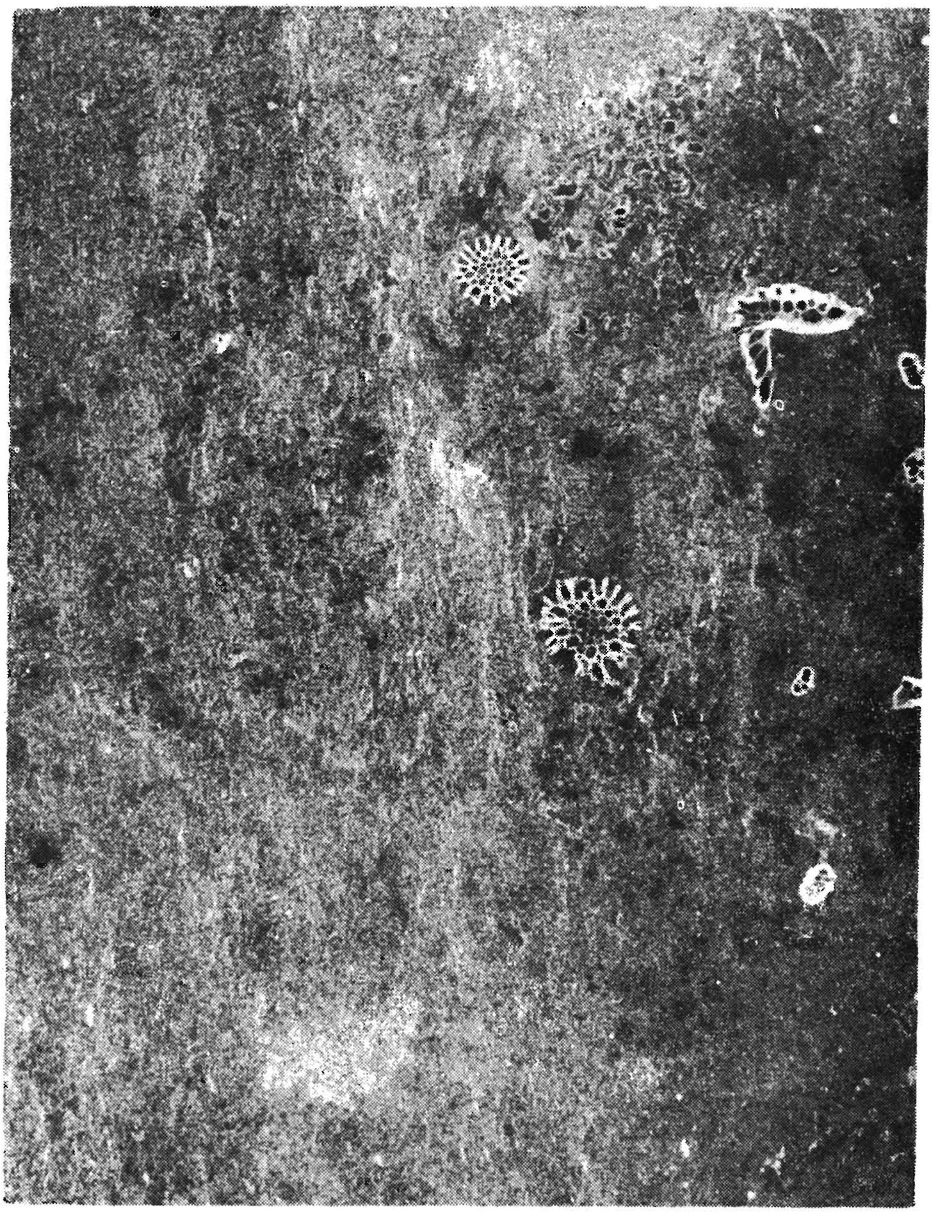
Microfacies A_3 — spherules of slightly thicker walls than those of Plate 6; Lesieniec 1, 1187.0—1193.0 m; negative, × 10



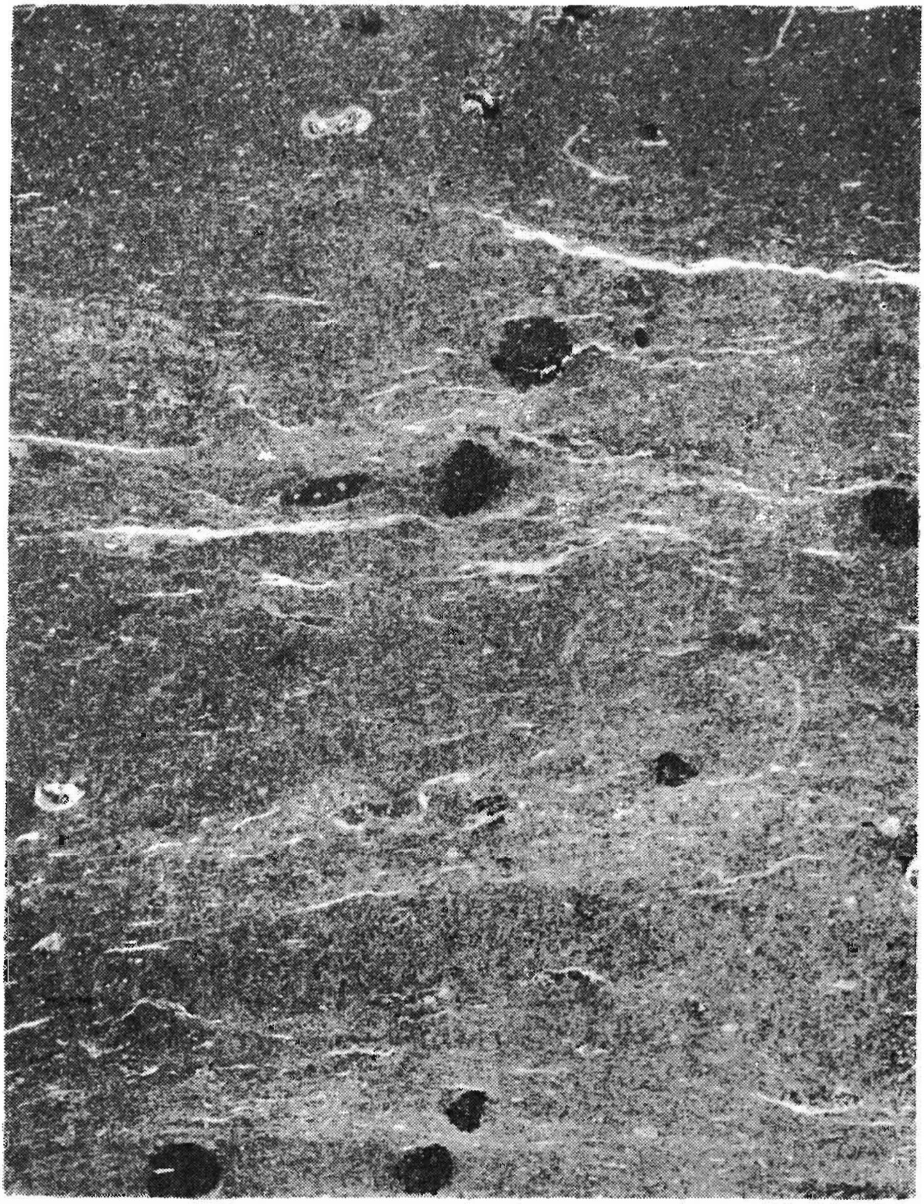
Microfacies A_4 — poke-like algal structures, filled with spherules; Dobre Miasto **2**, 1719.5—1725.6 m; negative, × 10

Microfacies A_5 — small pores in fine-grained carbonate background; Sępopol 2, 1361.8—1366.3 m; negative, × 10

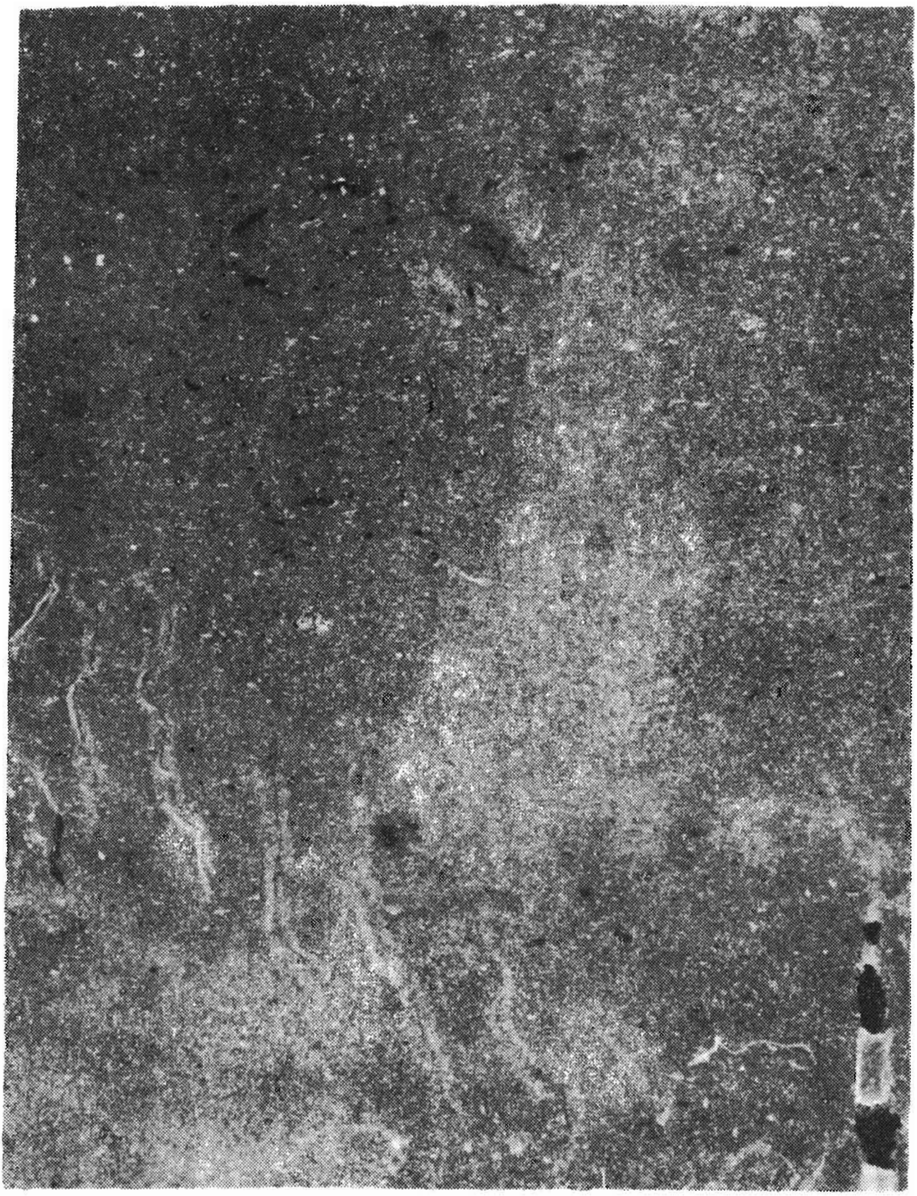
Microfacies F_1 — numerous sections of brachiopods and gastropods, in coarse-grained calcite amidst fine-grained cement; Barciany 2, 1222.0—1228.0 m; negative, × 10



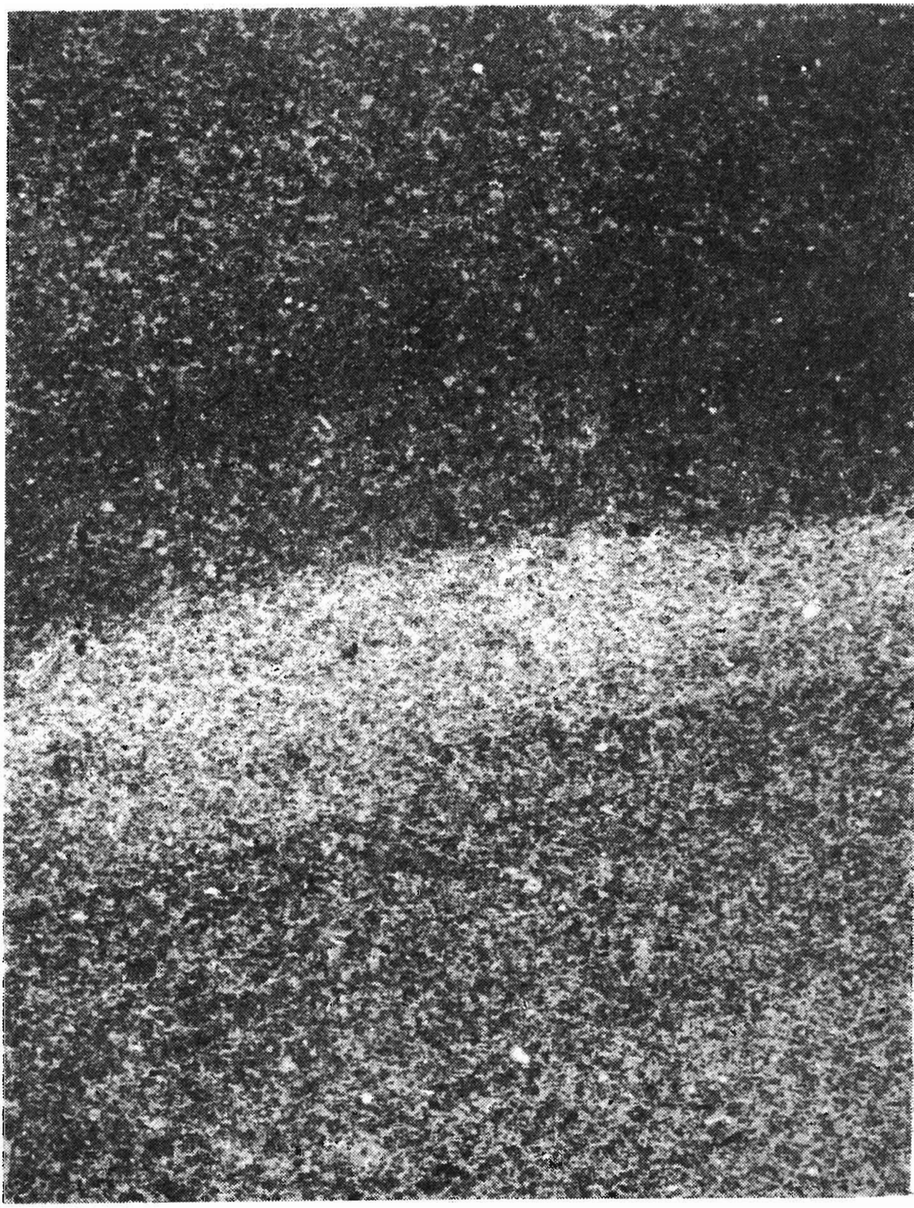
Microfacies F_2 — numerous fragments of bryozoans in fine crystalline background; Barciany 1, 1237.5—1244.0 m; negative, × 10



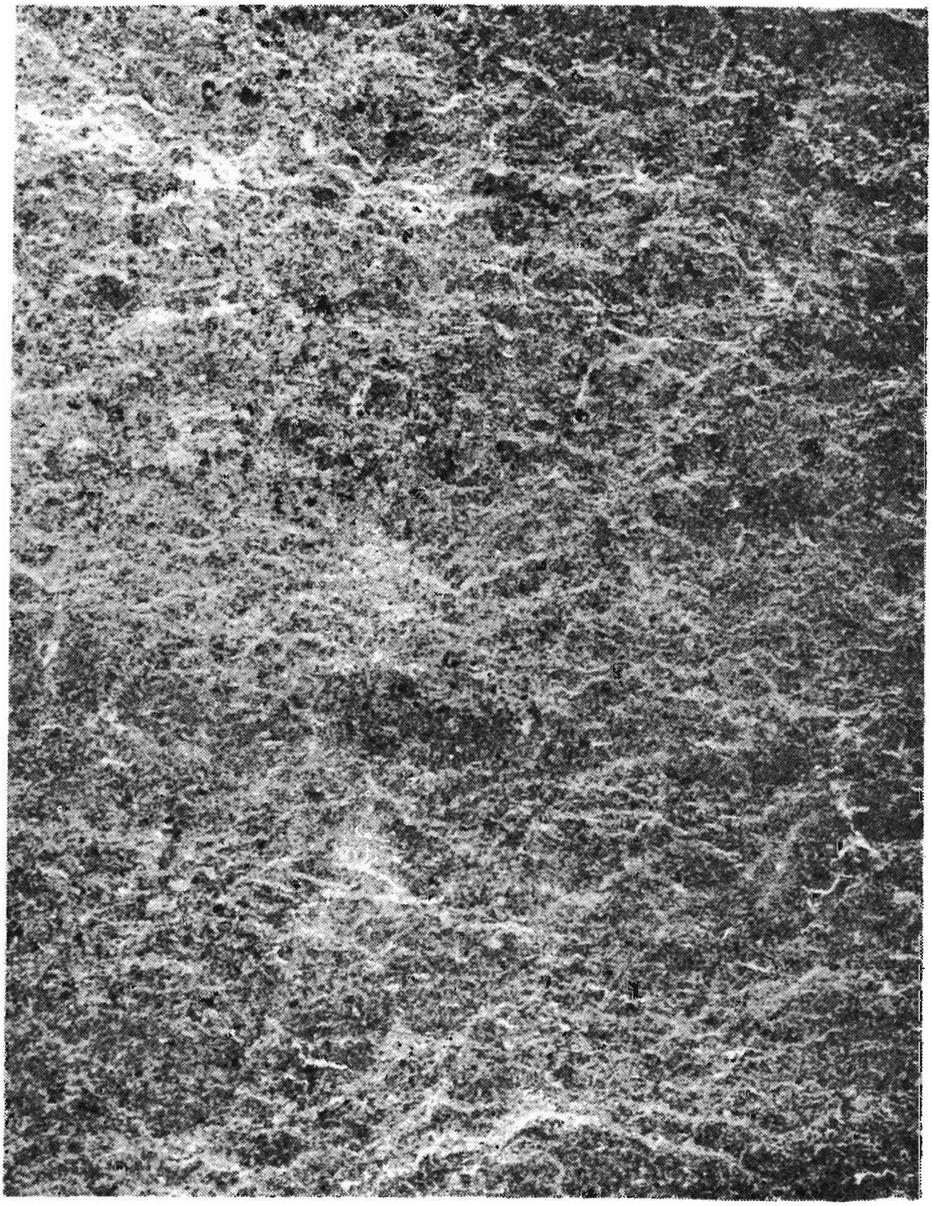
Microfacies F_3/L_1 — fine fragments of fauna (bryozoans), bands of argillaceous substance and anhydrite concretions (dark); Zawada 1, 1400.5—1407.0 m; negative, × 10



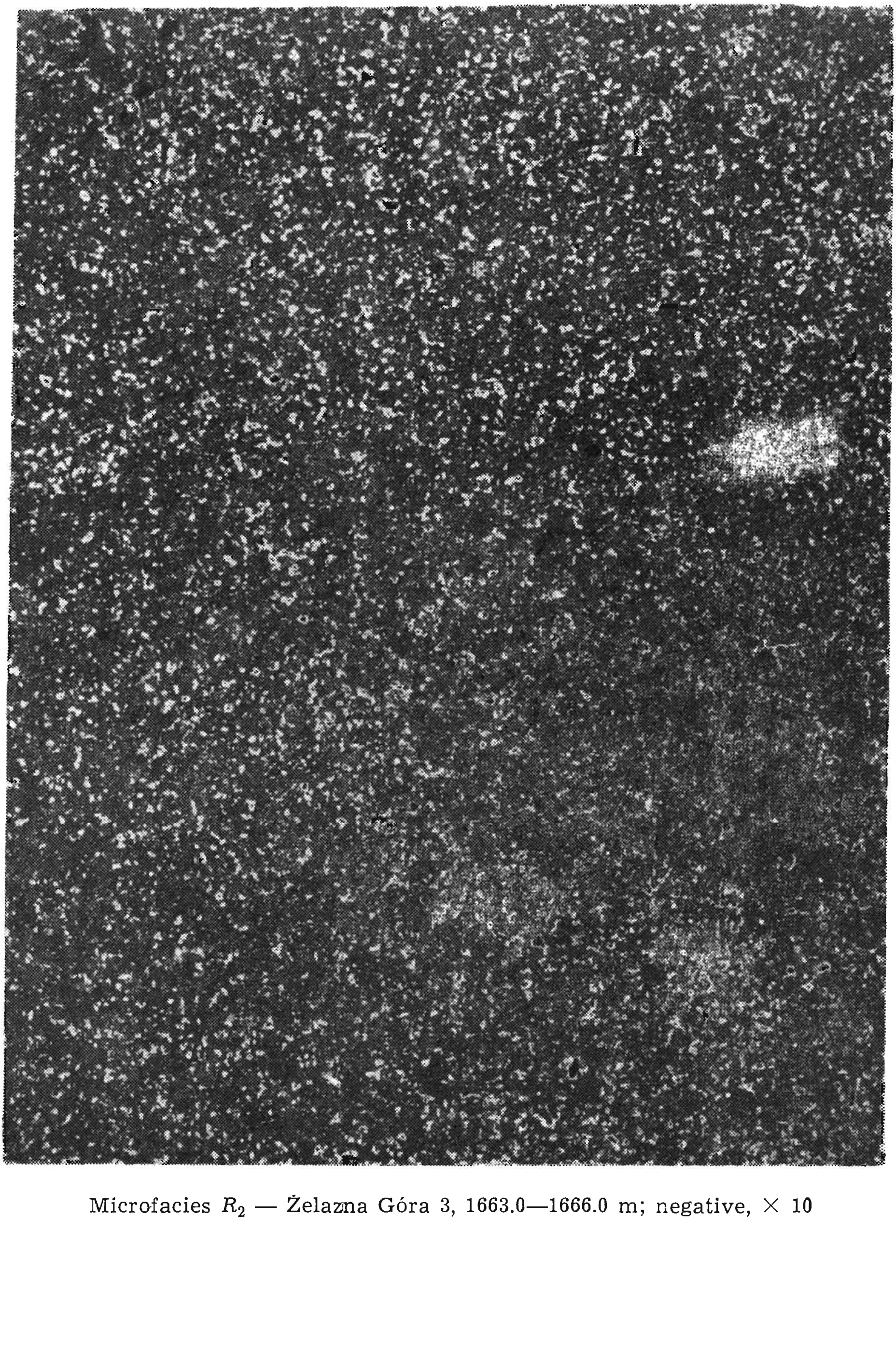
Microfacies F_4 — fine microfauna (foraminifera) and traces of worms(?); Paluzy 1, 1516.4—1522.3; negative, × 10



Microfacies L_1 — Głębock 1, 1630.5—1634.6 m; negative, × 10

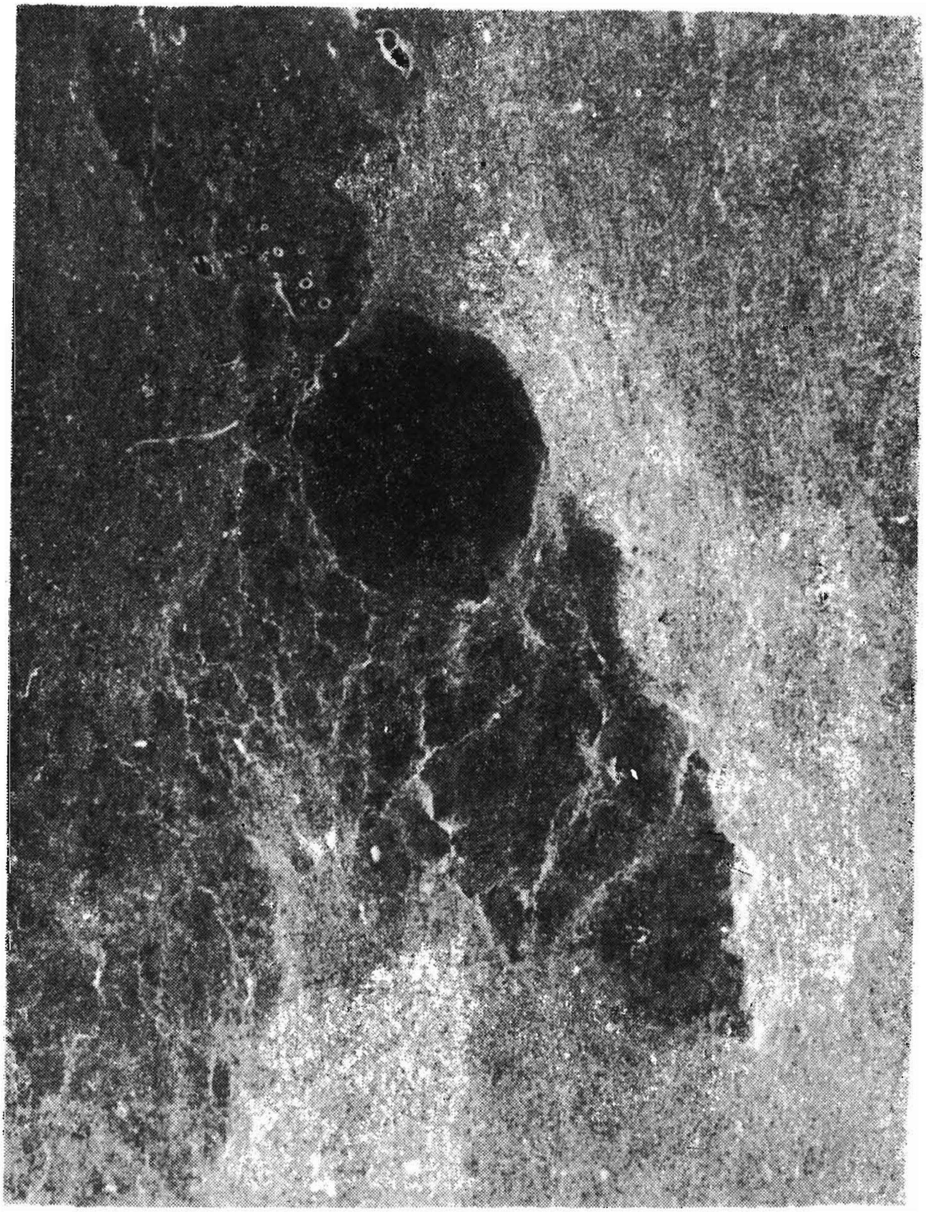


Microfacies L_2 — Barciany 1, 1256.0—1263.0 m; negative, × 10

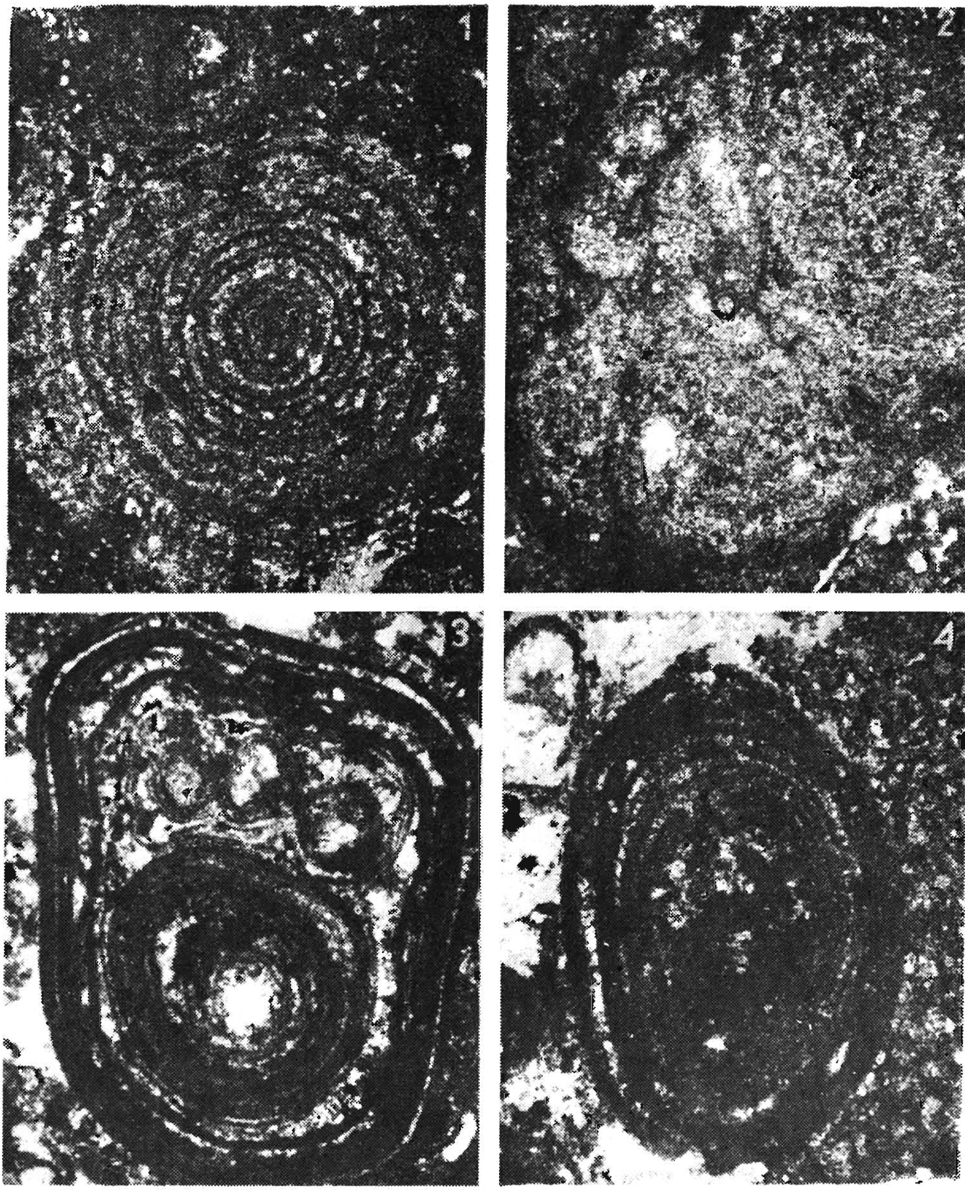


Microfacies R_2 — Żelazna Góra 3, 1663.0—1666.0 m; negative, × 10

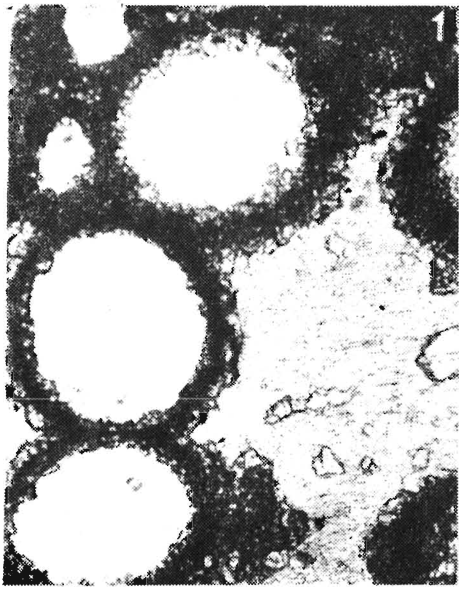
Microfacies R_2 — feathery concentrations of anhydrite crystals; spotty character is caused by the presence of anhydrite cement (dark); Lidzbark Warmiński 1, 1687.6—1693.8 m; negative, $\times$ 10

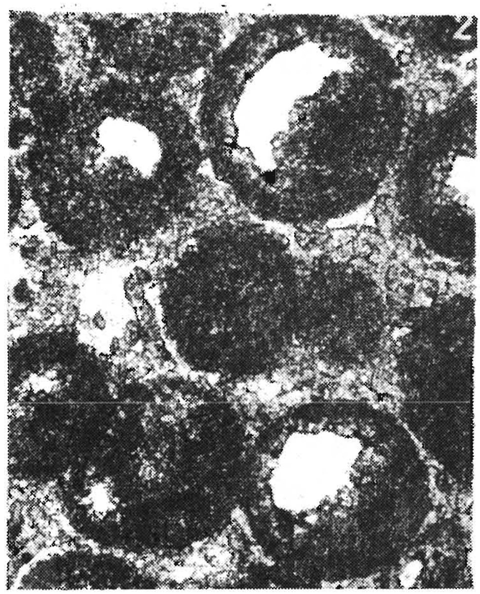


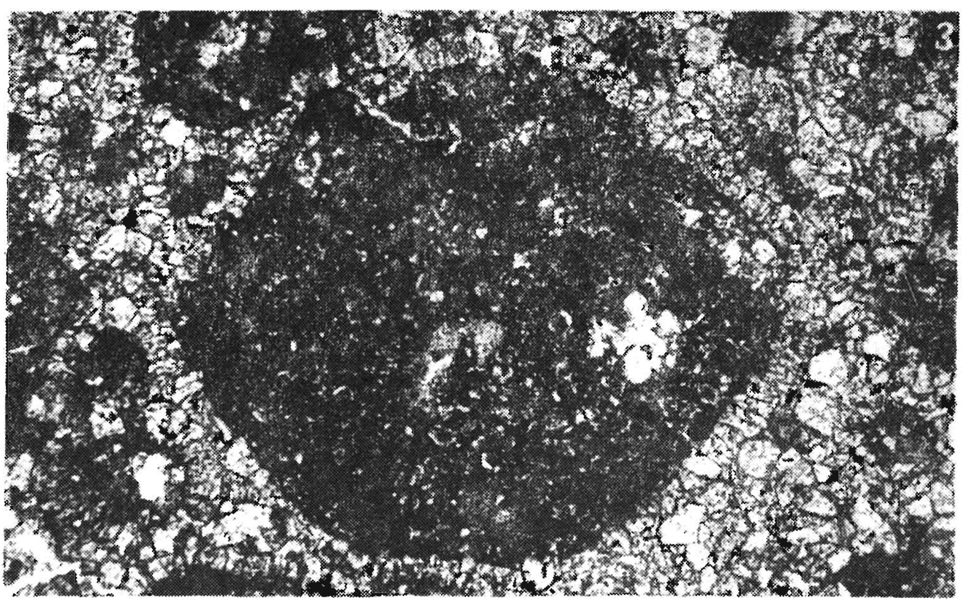
Microfacies F_2 — secondary calcitisation near the anhydrite-gypsum concretion; anhydrite concretion — black; coarsecrystalline calcite — dark gray, dolomite — lighter



1 — Algal oncoid of microfacies A_1; Dębowiec Warmiński 2, 1670.2—1676.2 m; positive, × 30.
2 — Algal oncoid of microfacies F_1/A_1; Sępopol 2, 1348.2—1355.2 m; positive, × 30.
3 — Algal structure of microfacies A_2; Barciany 1, 1216.0—1222.0 m; positive, × 25.
4 — Algal structure of microfacies A_2; ibidem; positive, × 30.



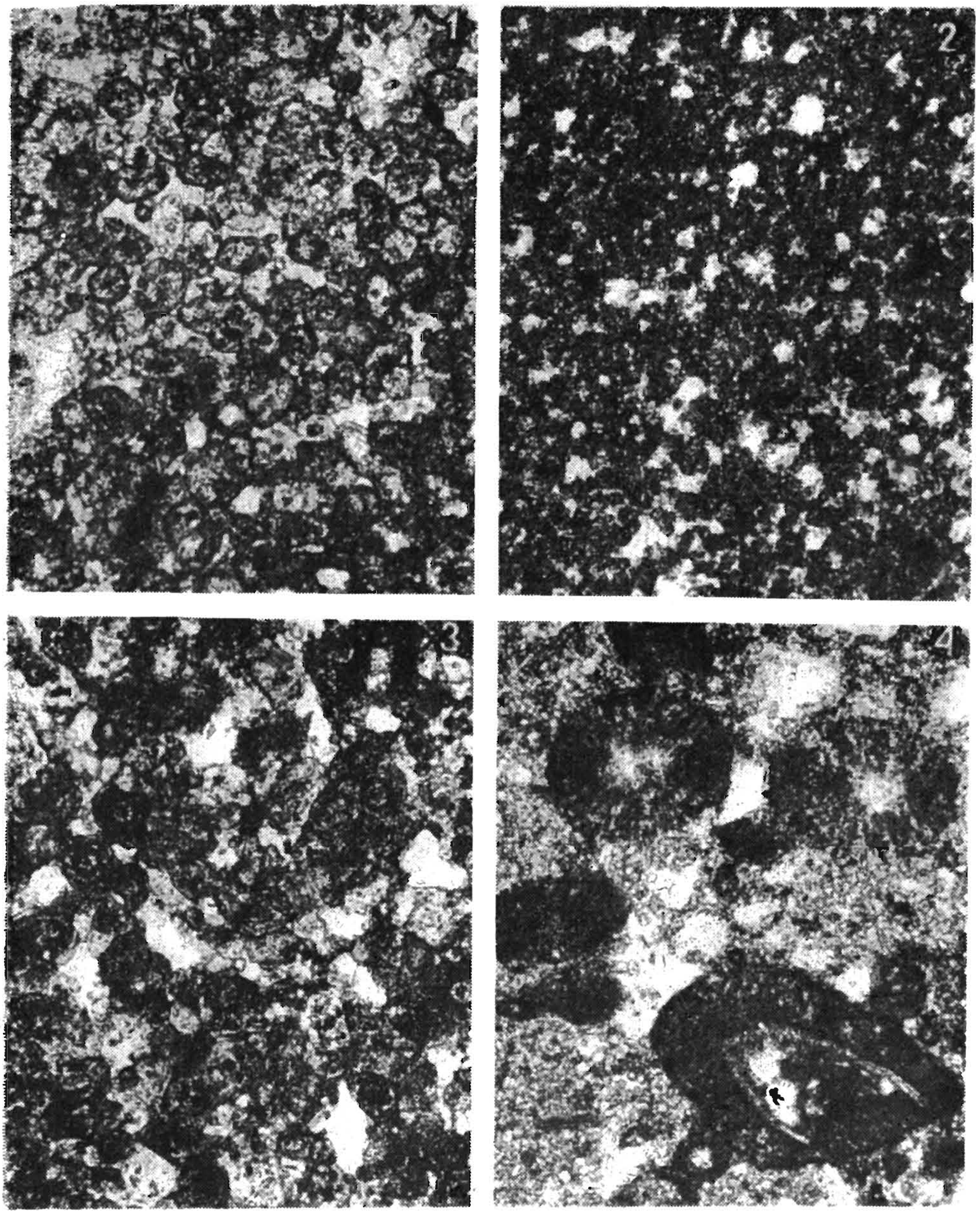




1 — Microfacies A_3 — empty algal spherules; dark micritic laminae visible in walls, dolomite crystals grow outwards and inwards; poikilitic gypsum cement with anhydrite crystals; Lesieniec 1, 1187.0—1193.0 m; positive, × 75.

2 — Algal spherules of microfacies A_3; weakly marked concentric texture in full spherules, in empty — ones — crystal aggregates on the bottom of spherules; ibidem; positive, × 50.

3 — Algal structure(?) of microfacies A_4, with visible aureole of coarser dolomite crystals; dark spherules inside; enlarged fragment of a photograph of Plate 8; Dobre Miasto 2, 1719.5—1725.6 m; positive, × 90.

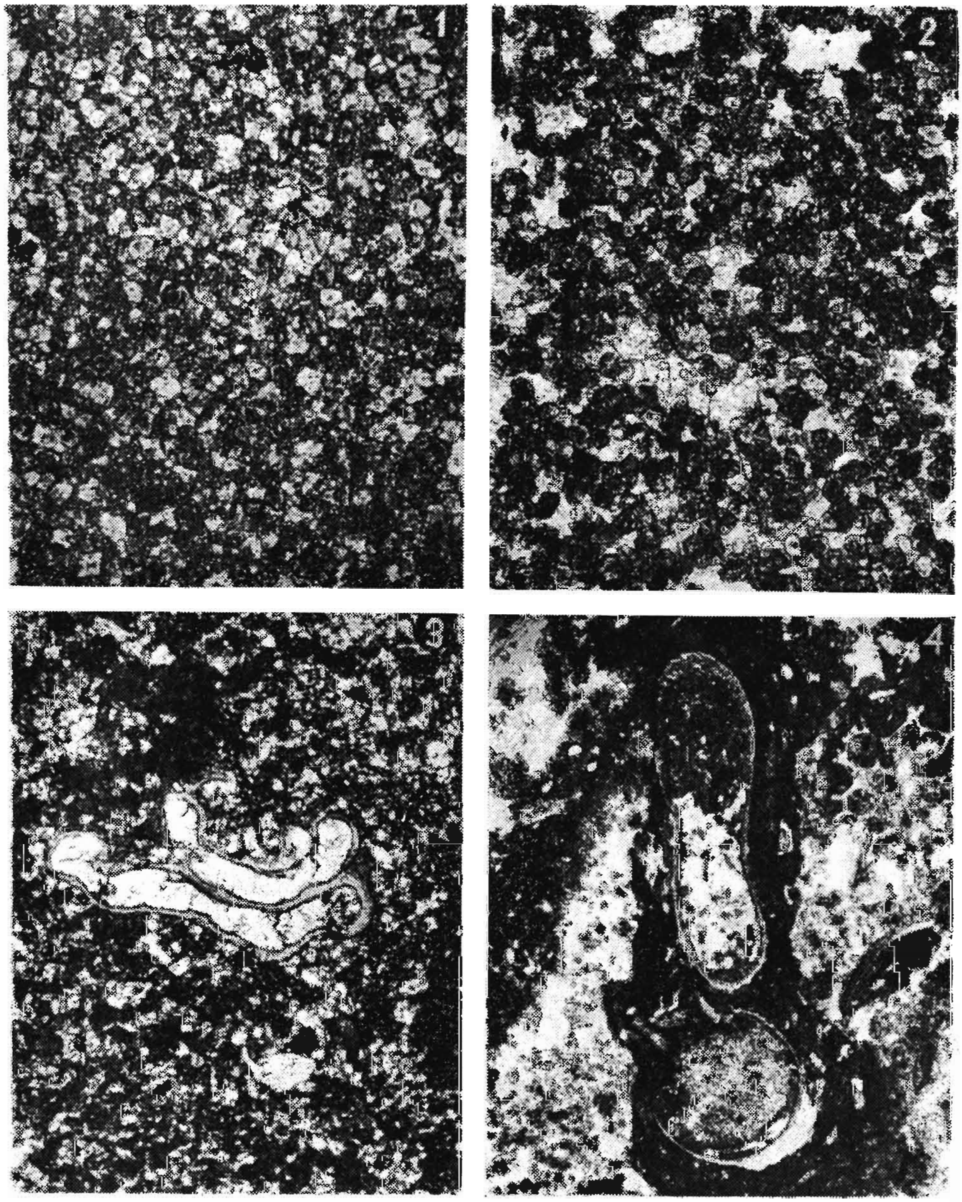


1 — Microfacies A_4/R; algal spherules(?), with dark interior and dolomite crystals of banded structure; Lesieniec 1, 1223.0—1229.0 m; positive, × 75.

2 — Microfacies A_4; algal spherules(?) as above; Klewno 1, 1432.0—1438.0 m; positive, × 100.

3 — Microfacies A_5 — pores in fine-grained carbonate; Sępopol 2, 1361.8—1366.3 m; positive, × 50.

4 — Microfacies A_6 — sections of *Mizzia;* Glądy 4, 1683.0—1684.5 m; positive, × 75.



1 — Microfacies R_2; Paluzy 1, 1516.4—1522.3 m; positive, × 35.

2 — Microfacies A_4; dolomite crystals frequently of banded structure, and isolated algal spherules(?) in secondary calcitic cement (light); Klewno 1, 1451.1—1455.6 m; positive, × 75.

3 — Microfacies F_4; phosphatized serpulite (Polychaet) in very fine-grained background; Barciany 2, 1220.2—1228.0 m; positive, × 100.

4 — Microfacies F_1/A_1 — a gastropod overgrown by encrusting algae; Sępopol 2, 1348.2—1355.2 m; positive, × 30.