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Aleksandra KOSTECKA [1]

THE LOWER MUSCHELKALK CARBONATE ROCKS OF THE SOUTH-WESTERN MARGIN OF THE HOLY CROSS MOUNTAINS (CENTRAL POLAND)

Part. I. Petrology and sedimentary environment

(Pl. I—VI and 3 Figs)

Utwory węglanowe dolnego wapienia muszlowego południowo-zachodniego obrzeżenia Gór Świętokrzyskich

Cz. I. Petrologia i środowisko sedymentacyjne

(Pl. I—VI i 3 fig.)

Abstract. The paper deals with general lithology of the Lower Muschelkalk and Röth, detail characteristics of allochemical components (skeletal remains, peloids and intraclasts) of carbonate rocks and dependence between rock types and conditions of deposition. Remarks concerning interpretation of sedimentary environment are presented.

INTRODUCTION

The paper deals with the results of studies on the Lower Muschelkalk (Middle Triassic) carbonates of the south-western margin of the Holy Cross Mts., between Wincentów and Obice (Fig. 1).

The first part of the work comprises: 1) general description of the Lower Muschelkalk lithologies with a short characteristic of the Röth sequence; 2) remarks on main allochemical components; 3) subdivision of carbonates by virtue of depositional conditions and processes, and 4) interpretation of sedimentary environment.

The second part of the work (Kostecka, 1978) presents the results of studies on diagenesis of the Lower Muschelkalk carbonates.

The Muschelkalk strata were subject of interest since the first half

[1] Academy of Mining and Metallurgy, Institute of Geology and Mineral Resources Al. Mickiewicza 30, 30-059 Kraków

of 19th century (for full references see Senkowiczowa, 1970). Recently, studies on stratigraphy, paleogeography, paleontology and sedimentation of Triassic include the works of Senkowiczowa (1957a, b, 1959, 1961, 1962, 1965, 1970, 1972), Senkowiczowa and Szyperko-Śliwczyńska (1961), Kaźmierczak and Pszczółkowski (1969), Trammer (1971, 1972a, b, 1973, 1974, 1975), Bialik et al., (1972), Głazek et al. (1973), Liszkowski (1973), Gaździcki and Kowalski (1974), Gaździcki et al. (1975), but problem of diagenesis has been treated marginally. The author hopes that her work will partly help to provide a missing link.

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GENERAL CHARACTERISTICS OF THE RÖTH AND THE LOWER MUSCHELKALK STRATA

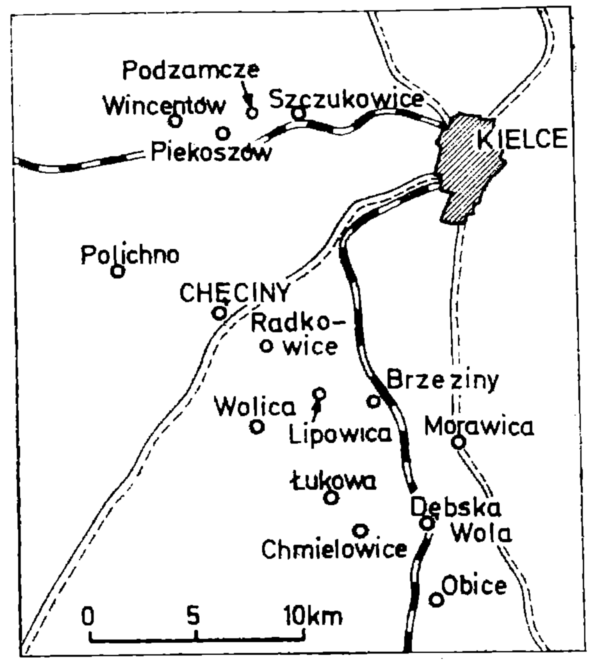
The Röth strata have been investigated mainly in outcrops at Brzeziny (Fig. 1) and Piekoszów vicinity (boreholes Piekoszów IG—1 and Podzamcze IG—1).

The full sequence of the Röth strata occurring in boreholes is about 100 meters thick (Fig. 2). It starts with grey and red arenaceous mudstones and marls with gypsum, followed by white, finely laminated dolomicrites and cross-bedded sandstones (Pl. I, Fig. 1). These are overlain by mudstones and marls with dolomicrite intercalations as well as organodetritic limestones containing intraformational conglomerate. Upwards there appear crumpled limestones and dolomites strongly bioturbated (Pl. II, Fig. 1), followed by cross-bedded sandstones and siltstones with intercalations of dolomicrite and dolomite breccia (Pl. I, Fig. 2). Higher in the sequence occur dolomites, marls and dolomitic mudstones, oolite and organodetrital limestone. The uppermost part of Röth consists of partly dolomitized limestones with intraclasts. Dolomitization disappears from 4 — 6 meters beneath tha Röth/Muschelkalk boundary.

Structural and textural features of dolomicrites (extremely fine grains, lamination, bioturbations and syn-sedimentary erosional structures) allow to consider them as early diagenetic. Their association with sandstones and presence of gypsum seem to indicate the sedimentary environment like the contemporary sabkha (cf. Illing et al. 1965, Evans et al. 1969, Wood and Wolfe, 1969).

To the predominant fossils belong ostracods, pelecypods, gastropods and lingulids. In places are observed accumulations of *Costatoria costa-*

Fig. 1. Sketch-map of investigated area
Fig. 1. Szkic sytuacyjny badanego obszaru



ta (Zenker) shells forming valve-pavement and coquina layers. In some cases coquinas are composed almost entirely of lingulid shells. Echinoderm fragments (crinoids and ophiuroid arm plates) are scarce. It is noteworthy that they appear relatively low in the Röth sequence.

Among non-calcareous fossils fish teeth and scales as well as vertebrate bones are common.

Deposits of the uppermost Röth and the lowest unit of the Lower Muschelkalk do not show any lithological difference; the biostratigraphic boundary is marked by disappearence of the index Röth fossil *Costatoria costata* (Zenker) (Senkowiczowa, 1957a, b, 1961, 1970).

The informal division of the Lower Muschelkalk strata into four lithological units introduced by Senkowiczowa (1957a) has been accepted here (fig. 3). These are as follows:

Lima striata Beds, Łukowa Beds, Wellenkalk, Wolica Beds.

According to Trammer (1972, 1975) these units are equivalent to the Lower Anisian (Hydaspian) and Pelsonian.

W o l i c a B e d s. The unit consists of biosparites and biomicrosparites with intraclasts and intercalations of microsparite and marly limestone. In many cases top surfaces of layers are erosional, small scours appear commonly. Among skeletal remains pelecypods are the main rock-forming elemetnts, locally echinoderm fragments (crinoids and ophiuroid arm plates, see Głazek and Radwański, 1968), gastropods and ostracods are numerous.

The thickness of the Wolica Beds does not excceed 6 to 8 meters.

Wallenkalk. It is represented by wavy-crumpled micritic limestones accompanied by coquina-like biomicrosparites, marly limestones and marls. In some of the microsparites cross lamination has been recorded (Pl. III, fig. 2).

The wavy-crumpled structures are probably the result of deformational processes in an unstable sequence, which prior to deformation consisted of horizontal layers, with repeated instability in density stratification (cf. Bogacz et al. 1968). The crumpled structure predominates over wavy bedding. The former is chiefly made up of tightly packed, irregular fragments of thin, calcareous layers, which may merge into a vaguely outlined mosaic of intraformational breccia (cf. Bogacz et al. 1968, Trammer, 1975). In many cases, crumples show signs of pressure-solution (cf. Schwarz, 1975). In the wavy-crumpled limestone trace fossils are numerous.

Intercalations of intraformational conglomerate appear locally in the Wellenkalk (Pl. IV, Fig. 1). They have been recorded at Wincentów (cf. Bialik et al. 1972) and in the borehole Piekoszów IG—1. Scours and small erosional channels (cf. Bialik et al. 1972) are quite common.

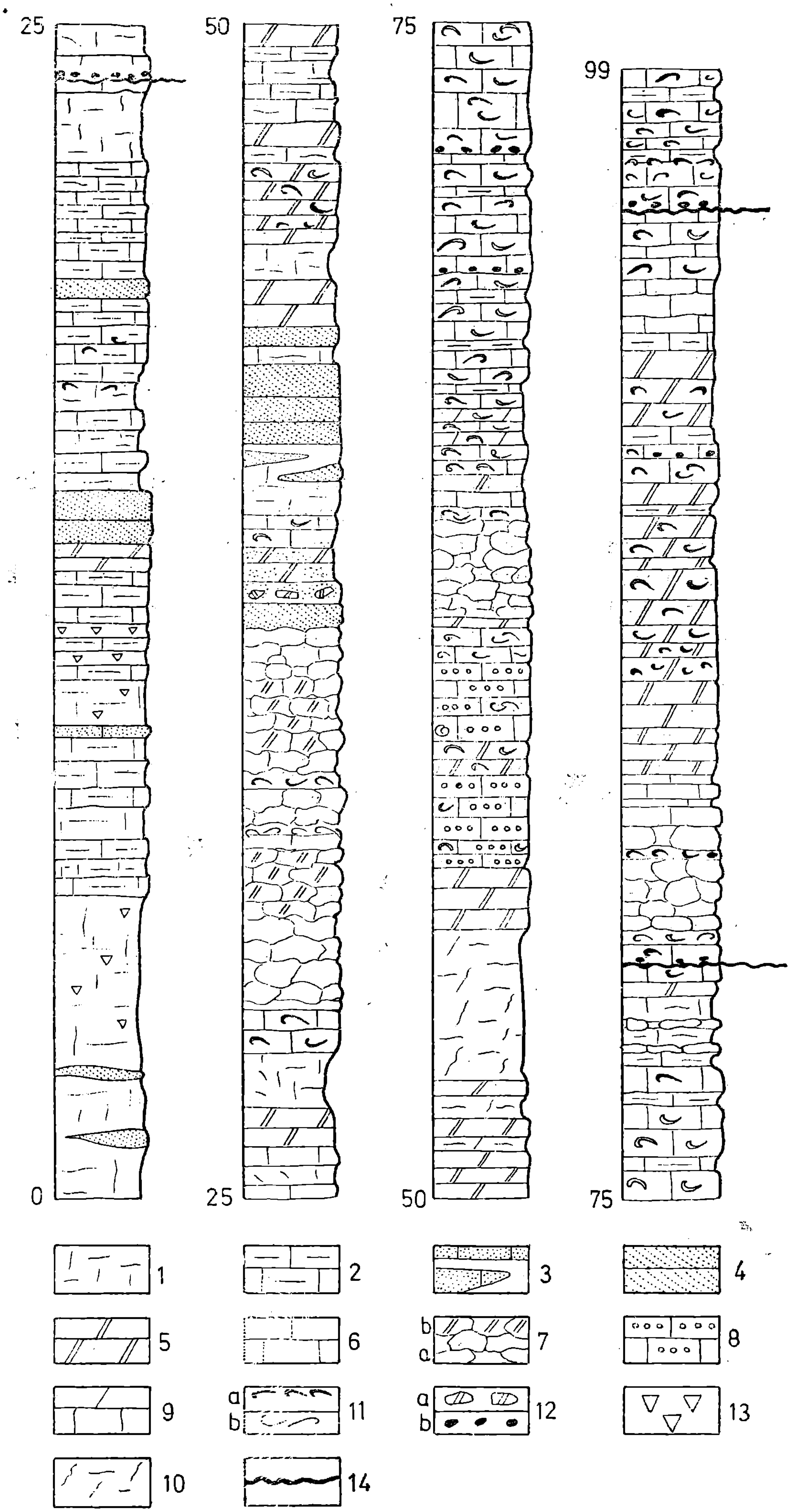
Fossils are irregularly distributed. Pelecypods dominate in biomicrosparites. In places they form coquinas and valve pavements built of shells of one species (e. g. *Lima* or *Gervilleia* shells). The ratio of right /left valves (1 : 1) indicates their transport over a short distance (cf. Boucot et al. 1958). In some layers there are numerous crinoids, ostracods and gastropods, wherear foraminifers are scarce. Microsparites are almost completely unfossiliferous but they contain abundant coprolites (Pl. I, Fig. 3, Pl. III, Fig. 1).

The Wellenkalk thickness varies between 22 and 25 metres.

Łukowa Beds. The Łukowa Beds consist of microsparites, biomicrosparites, pelmicrosparites and biopelsparites. They are often horizontally and/or cross laminated (Pl. II, Fig. 2). Deformational structures common in the lower part of the unit were recorded at Wolica (Bialik et al. 1972), Obice and in the boreholes of the Piekoszów area.

Fig. 2. Lithological sequence of Röth. Piekoszów IG—1. 1 — Mudostone and claystone; 2 — marls and marly limestone; 3 — intercalations of quartzose sandstone; 4 — cross bedding; 5 — dolomite; 6 — limestone; 7a — crumpled limestone; 7b — crumpled dolomite; 8 — oolite; 9 — dolomitic limestone; 10 — dolomitic mudstone; 11a — valve pavement; 11b — fossils; 12a — dolomite breccia; 12b — intraclasts; 13 — crystals and patches of gypsum; 14 — erosional surface

Fig. 2. Profil litologiczny utworów retu. Piekoszów IG—1. 1 — mułowce i iłowce; 2 — margle i wapienie margliste; 3 — wkładki piaskowców kwarcowych; 4 — warstwowanie przekątne; 5 — dolomity; 6 — wapienie; 7a — struktury gruzłowe w wapieniach; 7b — struktury gruzłowe w dolomitach; 8 — oolit; 9 — wapienie dolomityczne; 10 — mułowce dolomityczne; 11a bruk muszlowy; 11b — fauna; 12a — brekcja dolomitowa; 12b — intraklasty; 13 — kryształy i gniazda gipsu; 14 — powierzchnie erozyjne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In the middle and upper parts of the Łukowa Beds appear horizons with U-shaped channels considered to be the burrows of *Enteropneusta* (cf. Kaźmierczak and Pszczółkowski, 1969). They are filled with bioclastic material and intraclasts. Some intraclasts and bottom surface were occupied by boring and encrusting organisms. Borings of *Trypanites* Mägdefrau type were noted (cf. Kaźmierczak and Pszczółkowski, 1969, Trammer, 1975) sometimes together with (?) *Placunopsis* (cf. Bachman, 1973). The succession of burrowing, boring and encrusting forms was probably related to a gradual change in the consolidation of the bottom sediment from the soft to the hard stage (cf. Kaźmierczak and Pszczółkowski, 1968, 1969). Beds with burrows were subjected to erosional processes which resulted in some intraclasts and destroyed the outlet parts of burrows.

Among the organic remains echinoderm fragments (mainly crinoids) pelecypods and gastropod are common. Among foraminifers, a large variety of species and an increase in number compared to the two lower units can be observed. Moreover, ostracods, calcareous algae (cf. Gaździcki and Kowalski, 1974) and calcified sponge spicules are also present. At the upper part of the Łukowa Beds appear lens-like or irregular cherts.

The thickness of the Łukowa Beds is from 25 to 30 m.

Lima striata Beds. They start with a layer of coarse, bioclastic limestone with single, well rounded interclasts. This layer is about 20 cm thick and passes upwards into bioclastic crumpled limestones. Besides intraclasts, it is composed of crinoids, thick-shelled pelecypods, worm tubes, numerous small foraminifers and, deserving special attention, brachiopods (*Coenothyris, Spiriferina*), which are very rare in the lower units.

The lower part of Lima striata Beds is dominated by biosparites and pelsparites horizontally or cross-laminated with intercalations of marls and marly shales. They are accompanied by crumpled biosparites. Higher up biomicrosparites and microsparites prevail. In these rocks common are horizontal tunnels filled with coprolites (Pl. IV, Fig. 4) being traces of the activity of burrowing organisms. Going upwards the proportion of clay increases (over 50% by weight) and also appears an admixture of quartz silt and sand. Biomicrosparites give way to marls and mudstones. In these rocks there are sometimes observed small ripple marks, cross lamination (Pl. VI, Fig. 3), traces of burrowing organisms, erosional scours, intraclasts and patches of authigenic gypsum (Pl. IV, Fig. 3). Thick-shelled pelecypods prevail among the organic remains. Brachiopods relatively frequent in the lower part of the sequence, appear rarely here. There are also echinoderms, gastropods, very small foraminifers (Pl. III, fig. 3) and siliceous (sometimes calcified) sponge spiculs (Kostec-

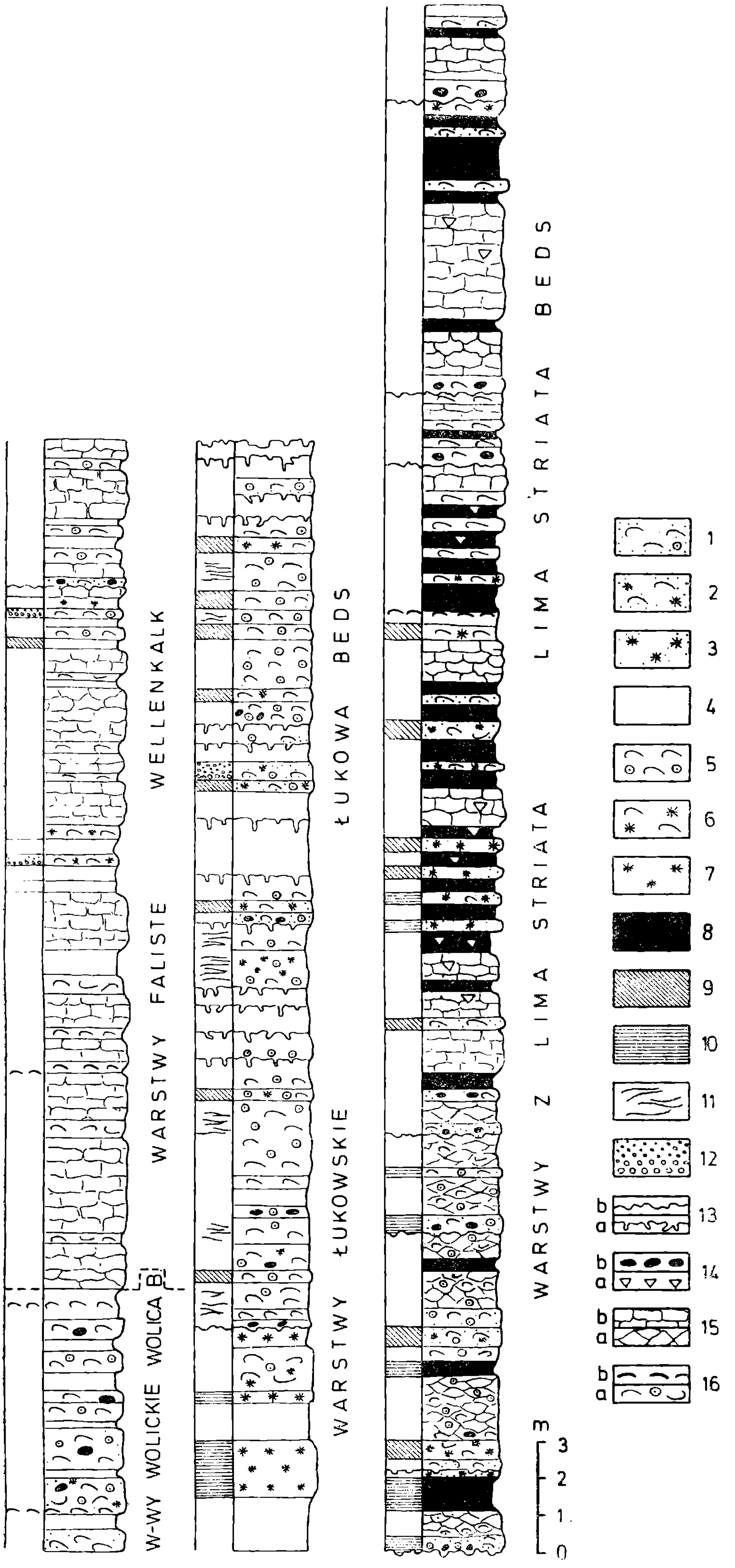

Fig. 3. Lithological sequence of the Lower Muschelkalk based on outcrops and borehole Piekoszów IG—1. 1 — biosparite; 2 — biopelsparite; 3 — pelsparite; 4 — microsparite; 5 — biomicrosparite; 6 — biopelmicrosparite; 7 — pelmicrosparite; 8 — marls and mudstones; 9 — cross lamination; 10 — horizontal lamination; 11 — wavy lamination; 12 — graded bedding; 13a — enteropneustan burrows; 13b — erosional surface; 14a — gypsum patches; 14b — intraclasts; 15a — crumpled structure of the Lima striata Beds; 15b — wavy-crumpled structure; 16a — fossils; 16b — valve pavement

Fig. 3. Profil litologiczny utworów dolnego wapienia muszlowego na podstawie odsłonięć i otworu wiertniczego Piekoszów IG—1, 1 — biosparyty; 2 — biopelsparyty; 3 — pelsparyty; 4 — mikrosparyty; 5 — biomikrosparyty; 6 — biopelmikrosparyty; 7 — pelmikrosparyty; 8 — margle i mułowce; 9 — laminacja przekątna; 10 — laminacja pozioma; 11 — laminacja falista; 12 — uziarnienie frakcjonalne; 13a — jamki jelitodysznych; 13b — powierzchnie erozyjne; 14a — gniazda gipsu; 14b — intraklasty; 15a — struktury gruzłowe w warstwach z Lima striata; 15b — struktury falisto-gruzłowe; 16a — fauna; 16b — bruki muszlowe

ka, 1972, Trammer, 1975). All organisms disappear in the top part of the described unit.

Cherts form discontinuous flat lenses and irregular concretions in the Lima striata Beds at Wolica. They have not been found in boreholes.

The complete sequence of the Lima striata Beds is not known from outcrops. In the quarry at Wolica appears only the lowest part of the sequence about 9 m thick. At Chmielowice, where deposits of the Lower and Middle Muschelkalk are partly exposed, only the approximate thickness could be calculated (34 to 36 m). In the borehole Piekoszów IG-1 the complete sequence of the Lima striata Beds is 40 m thick. In opposite to Trammer (1975) the Lima striata Beds may not be interpreted as a condensed unit.

The upper boundary of the Lima striata Beds is not very distinct. The fossil bearing limestones occurring as intercalations in marls and mudstones are replaced by thin layers of unfossiliferous limestone. The disappearence of fauna is considered as a marker point delimitating the boundary between the Lower and Middle Muschelkalk.

The Middle Muschelkalk strata start with mudstones and marls with limestone intercalations. Higher up occur dolomicrites and mudstone with patches of gypsum.

COMPONENTS OF CARBONATE ROCKS

Carbonate rock components have been divided into two categories: allochemical and orthochemical (cf. Folk, 1959, 1962). The first of them, being grains, could have been transported before final deposition. Organic remains (bioclasts), peloids, intraclasts and ooids belong here. The ooids have not been found in the Lower Muschelkalk, they appear only in Röth.

The orthochemical components are represented by carbonate precipitates: mud particles and cement. Mud particles are considered as forming by chemical or biochemical precipitation in sea water or by abrasion of skeletal debris. Cement (sparry calcite) generally forms as pore-fillings, precipitated in place within the sediment. Non-carbonate authigenic minerals such as quartz, gypsum and the like as well as the product of recrystallization of the oryginal calcium carbonate — pseudospar (cf. Folk, 1965) are also among the orthochemical components.

Micrite and microspar correspond to the carbonate mud in the lithified rock.

The third category of rock components includes terrigenous material: quartz silt and sand and clay. The terrigenous material has not been examined.

ALLOCHEMICAL CARBONATE ROCK COMPONENTS

Skeletal material

I. Pelecypods

Precise taxonomic designations of the skeletal remains were not made, apart from several exceptionally well preserved specimens from which after identification thins sections were cut to examine the microstructure of the skeleton. The works of Bøggild (1930), Majewske (1969), Horowitz and Potter (1971) and Bathurst (1971) were used when describing the microstructure. The complete list of identified species has been presented by Senkowiczowa (1970).

Pelecypod remains were found as unseparated shells (rarely), as single valves concave or convex side up (frequently), as valves convex side up forming valve pavements and crushed, angular fragments.

The crushing of skeletons took place: a) during transport; b) after deposition as a result of burrowing; c) under the sediment pressure. In the first case the elongated elements are usually parallel to the sediment surface, in the second the arrangement of the remains is largerly chaotic, whereas in the third, skeletal material is dense packed and the elongated elements when broken are fit one another.

Pelecypods are main components of biomicrosparites of the Wolica Beds and Wellenkalk. In biosparites they are abundant too, but often show a high degree of rounding and micritization.

An original microstructure is found only in calcite shell layers. Skeletons built of aragonite were completely dissolved and aragonite has been replaced by calcite cement. Shells both with partly preserved primary microstructure and partly recrystallized in situ were presumably built of high Mg-calcite. The negative results of staining with Feigl's solution (cf. Friedman, 1959) confirm this.

Four types of pelecypod skeletons have been distinguished on the basis of the manner of fossilization:

— Type I includes cement casts of skeletons (Pl. III, Fig. 1). Shells or shell layers built of aragonite dissolved during diagenesis and replaced by calcite cement, belong here. The cement may be represented by one or two generations of calcite (see Part II). In the first case it is always the second generation of cement, the ferroan blocky calcite. The lack of the first generation cement indicates that dissolution of primary mineral has taken place during the late stage of diagenesis. In the latter case, besides the ferroan blocky calcite (generation II) there is also palisade calcite of the first generation, which in turn indicates the dissolution of the primary mineral in the early stage of diagenesis, before the crystallization of the first generation cement.

— Type II includes elements with preserved primary microstructure of calcite layers. The layers are most often prismatic, foliated or homogenous-prismatic. The originally aragonite layers accompanying them are preserved as cement casts. The typical example is *Lima striata* shell.

— Type III includes shells neomorphosed (recrystallized) in situ. The neomorphic calcite is pale brown and pleochroic (cf. Hudson, 1962). In many pseudospar-filled shell walls, a linear arrangement of inclusions (the remains of organic matter) cuts accros the calcite mosaic.

— Type IV includes a special casts found only in the Lima striata Beds. They are called clastic casts because spaces left after dissolution of shells are filled with skeletal debris and mud coming from above (Pl. III, Fig. 4).

The above mentioned casts have been found in marly limestone. It contains fragments of echinoderms and relatively numerous pelecypod shells preserved either as cement casts built exclusively of the second generation cement or calcite shell layers with primary microstructure. Clastic casts appear only when shells were in contact with the upper (erosional) surface of the bed. The mineral matter of shells was dissolved before deposition of the overlaying deposit. The molds thus formed retained the shapes of shells and acted as traps for material transported along the bottom. The formation of clastic casts must have been preceded by lithification of the deposit, giving the chance to preserve the molds of the dissolved skeletons.

The reason for the dissolution of skeletons in contact with erosion surface is not clear. One of the causes might have been an increase of CO_2 content in the pore water, created by the decay of organic matter. In this case however, one would have expected the dissolution of other organic remains. Such phenomena have not been reported. On the contrary, casts built exclusively of second generation cement indicate a long period of stability of skeletal mineralogy.

On the other hand, presence of early diagenetic gypsum in the Lima striata Beds, a gradual impoverishment of the fauna (especially the complete disappearence of foraminifers in the middle part of the above mentioned unit) point to the increase in salinity of the sea and restriction of the basin (see Hughes Clarke and Keij, 1973). The concequence of the salinity increasing and removal of Ca ions forming carbonates and gypsum, should have been a higher ratio Mg/Ca (cf. Illing et al., 1965, Deffeyes et al., 1965, Butler, 1969 and others), which in turn affects the stability of aragonite and Mg-calcite (cf. discussion in: Bathurst 1971, Lippmann, 1973) being constituents of skeletal remains.

In the light of the above data the author assumes local, presumably brief emergnece of some parts of the sea bottom and inflow of the fresh water diluting the saline water and dissolving the organic aragonite. Dissolution of carbonate occurred on a small scale affecting only the skeletons in contact with bed surface.

II. Gastropods

Gastropods being less abundant than pelecypods are nevertheless wide-spread both in Röth and the Lower Muschelkalk. Locally they form rich accumulations.

Generally speaking the modes of fossilization of gastropods and pelecypods are similar. There appear:

- cement casts;
- cement casts and calcite layers with primary microstructure;
- shells neomorphosed in situ with ghost lines of primary microstructure.

The first mode of fossilization is the most frequent. This is connected with the mineral content of gastropod shells as aragonite is their main component (Bøggild, 1930). There have been found only a few examples with an outer calcite layer with prismatic microstructure and only one specimen with homogeneous-prismatic calcite layer.

In the neomorphosed shells crystals of pseudospar are pale brown and pleochroic because of organic matter relics (cf. Hudson, 1962).

Micrite envelopes are generally developed on the outer shell surfaces. But in some cases, micritization of the inner parts has been recorded when light penetrated into chamber of broken shell and its inner part were colonized by boring algae (Pl. I, Fig. 4).

Two kinds of micrite envelopes have been observed. The envelope of type I is formed as a result of activity of boring algae. By repeated boring, followed by vacation of the bore and the filling of it with micrite, carbonate grains are gradually and centripetally replaced by micrite (cf. Bathurst, 1964, 1966, 1971). The contact between the envelope and the skeletal core is irregular (Pl. 1, Fig. 4), in places tubes or their cross-sections filled with micrite can be observed. The envelopes of type II are very thin (up to 50 μm), they have a constant thickness and smooth outer and inner surfaces (Pl. I, Fig. 5). Borings do not accompany them. Similar micrite envelopes of type II were described by Davies and Kinsey (1973) from Recent beach deposits. According to these authors, the envelopes may form within algal mucilaginous sheaths as a result of mechanical trapping of mud or as a result of biochemical precipitation in micro-environment created by micro-organisms.

The chambers of the gastropod shells can be filled with:

- carbonate mud;
- mud and cement;
- cement

The shape of the shell is preserved when the chamber before shell dissolution had been filled with one or two of the above mentioned components. Gastropods are more susceptible to compaction stress than pelecypods because of large pore volume represented by their chambers, thus collapse structures are easily discernible.

Collapse structures occur when:

— cement cast was not formed;
— mineral content of the skeleton was dissolved leaving only thin micrite envelope;
— the shell chamber was empty or partly occupied by mud;
— deposit was subjected to stress

The first generation cement which forms thin layer of steep-sided calcite crystals on the surfaces of micrite envelopes does not make the envelope resistant enough and does not prevent it from fracturing (Pl. I, Fig. 5). The lack of first generation cement on the fracture surfaces and their direct contact with the second generation cement indicates that compaction occurred after crystallization of the first generation cement and before crystallization of the second one (Pl. 1, Fig. 5).

The collapse structures may point to a degree of mud lithification (cf. Čatalov, 1971). It appears that before compaction took place, carbonate mud had been sufficiently consolidated, and collapse structures were formed only by breaking down of gastropod shells Nevertheless, examples of very early compaction in the unlithified mud and of dissolution of aragonite skeletons have been found in the Wolica Beds. It is evidenced by fragments of fractured micrite envelopes covered with the first generation cement and buried in mud (= microspar). In this case the dissolution of shells and the fracturing of the micrite envelopes had taken place before precipitation of the first generation cement.

The calcareous mud infiltrating to the shell chamber is usually identical to the matrix. However in some microsparites small gastropod chambers filled with micrite (Pl. V, Fig. 3) have been found. They are devoid of shell casts and show distinct signs of damage. Sometimes remnants of micrite deposit are „sticking" to them. In the same microsparites occur gastropods with preserved shell casts and chambers filled with microsparitic matrix. From comparison of the two gastropod groups it may concluded that micritic casts are allochtonic.

III. Echinoderms

Among the echinoderms, crinoid fragments are the most abundant, ophiuroid arm plates and echinoid spines occur rarely.

Crinoid fragments appear throughout the sequence of the Lower Muschelkalk forming encrinite intercalations or accompanying other skeletal remains. In the upper part of the Lima striata Beds they gradually disappear.

Echinoderms are built of calcite with variable $MgCO_3$ content (Pilkey and Hower, 1960, Schroeder et al., 1969) and are resistant to diagenetic changes. Sometimes they are silicified, and if dense packed, they undergo dissolution under pressure (pressure-solution).

Usually echinoderm remains are surrounded by syntaxial calcite overgrowth. However, if they appear as scattered fragments in microsparite matrix, cement overgrowth is weakly developed or absent. Micritization of the echinoderm remains varies from thin and discontinuous envelopes to thick and continuous. In a few cases on the surfaces of these fragments small structureless crusts have been observed, perhaps of algae origin. Typical oncolitic coatings have not been recorded.

The crinoid fragments in encrinite are usually well sorted. In the Łukowa Beds echinoderm remains form sometimes lense-like accumulations or streaks within finer-grained deposits and together with other bioclasts they fill erosional furrows.

IV. Foraminifers

Foraminifers have been the subject of detailed studies by Glazek et al. (1973) and Gaździcki et al. (1975). They are fairly common rock components in the Łukowa Beds and in the lower part of the Lima striata Beds. In the Röth strata only a few representatives of the family Ammodiscidae have been recorded.

In the bioclastic limestones of the Łukowa Beds foraminifers form sometimes 45% of all grain components. Among them *Ammodiscus, Glomospira* and *Glomospirella* sp. div. prevail.

In the lower part of the Lima striata Beds some layers with numerous foraminifers have been recorded. They are very small, from 100 to 250 μm in maximum diameter (Pl. III, Fig. 3) and mainly belong to the family Ammodiscidae, but *Meandrospira, Frondicularia* and *Nodosaria* sp. div. also occur.

Three kinds of wall microstructure have been recorded:
— granular microstructure found in agglutinated specimens;
— microgranular (porcellaneous) microstructure;
— radial-fibrous microstructure; this type of microstructure is characteristic for the family Nodosaridae.

V. Ostracods

Ostracods are common components in the Lower Muschelkalk. In small numbers they appear in almost all types of rocks, locally forming lense-like accumulations. Their calcite shells are little susceptible to diagenetic changes.

Among the ostracods there appear specimens with smooth valves as well as with ornamented ones. There size varies between 0,2 and 0,6 mm.

Two kinds of valve microstructure have been noted:

— Homogenous microstructure. In polarized light crystallites are imperceptible. Under crossed nicols light extinction occur as indistinct wave. The prismatic arrangement of crystallites has not been established with certainty (Pl. V, Fig. 1).

— Homogeneous-prismatic microstructure. The crystallities are arranged perpendicular to the valve wall. Under crossed nicols and stage rotation extinction is uniform.

VI. Other organisms

Worm tubes, calcareous algae, brachiopods, sponge spiculs and microproblematics belong to this group.

W o r m t u b e s. They appear in the Röth and the Lower Muschelkalk in small number. Their occurrence has been noted in the Gogolin Beds and the Pecten discites Beds (Gaździcki et al., 1975), they are also known from the German Muschelkalk (Wilczewski, 1967, Bachman, 1973).

Specimens from the Röth have very thin shell walls of concentric-lamellar microstructure. The cross-section of the tube is circular or slightly angular.

Specimens from the Lower Muschelkalk are characterized by thicker shell walls of concentric-lamellar microstructure. Their cross-sections are usually round or ovate.

In the Lima striata Beds there have been found specimens containing admixture of organic matter (?). They are brown coloured. The tube walls are relatively thick. Their microstructure is concentric-lamellar.

C a l c a r e o u s a l g a e. The green alga *Aciculella bacillum* Pia (Dasycladaceae) has been found in the Łukowa Beds by Gaździcki and Kowalski (1974). This species appears abundantly in the upper part of the Łukowa Beds. Algal fragments accompanied by grapestones and echinoderms are the main components of several cross-bedded layers.

B r a c h i o p o d s. In comparison with Silesia, brachiopods are surprisingly scanty in the Lower Muschelkalk of the Holy Cross Mts. Only phosphatic shells of lingulids are important rock components. They sometimes appear abundantly forming thin lumachelle layers within Röth-sequence. Modern lingulids live in tropical and subtropical regions, inhabiting tidal zone, the lower part of beach and sublittoral zone down to a depth of 45 m (cf. Fergusson, 1963). Appearence of lingulids in the Röth dolomicrites and dolomitic mudstones ideally fit to the suggested sedimentary environment.

Calcareous brachiopods (*Coenothyris, Spiriferina* and others) seldom occur; they are relatively common in the lower and middle part of the Lima striata Beds.

The shell of brachiopods consists of two layers, an outer layer and an inner one. The outer layer is seldom preserved, sometimes it reveals as a thin, bright rind. The inner layer consists of fibers usually oblique to the shell surface. Some shells have puncta.

No neomorphic changes have been observed within the calcareous shell It can be assumed that the primary carbonate was a low Mg-calcite. In some cases silicification of shells was recorded.

Sponge spicules. Siliceous sponge spicules have been found in the Łukowa Beds and the Lima striata Beds (Kostecka, 1972, Trammer, 1975). In most cases they have well preserved central canals filled with calcite cement. In some layers completely calcified spicules have been found (Pl. IV, Fig. 5). They supplied the silica for cherts, flints and silicified skeletons.

Microproblematics. They will be given special attention in a seperate study. It is noteworthy that the zoospores *Globochaete alpina* Lombard occur in the Lima striata Beds. This species has been reported in the Muschelkalk of the Opole region (Zawidzka, 1972).

Fish scales and teeth and other non-calcareous remains have not been investigated.

Peloids

The term „peloid" has been introduced by McKee and popularized by Bathurst (1971, 1975). This term includes all grains that are constructed of an aggregate of cryptocrystalline carbonate, irrespective of origin. It is a very useful term because origin of these aggregates is often in doubt and in many cases any particular mode of formation cannot be implied.

Peloids are present in almost all kinds of rock in small quantities, only in some types of limestone (pelsparite, pelmicrosparite) they are common rock components. Their size is from 0,03 to 1,2 mm.

Peloids are built of:

— microspar identical with that of the matrix;
— microspar with crystal diameters a little smaller than those of the matrix;
— micrite.

They can contain pyrite or products of its oxidizing and clay admixture. In the latter case after etching of the polished slab in weak hydrochloric acid, a thin whitish cover appears on the peloid surface, contrasting with the darker matrix (Pl. III, Fig. 1). If clay and iron compounds are absent and microspar of peloids is identical with that of the matrix then it is possible to distinguish them only when they are surrounded with cement.

The elements under discussion are characterized by different shapes which are largely due to their poligenetic origin.

Several groups of peloids have been distinguish:

— Group I includes peloids built of microspar with crystals of the same size as crystals of the matrix. In thin section they are round or ovate (Pl. I, Fig. 3). Many of them contain an admixture of clay. Their size is 0,1 to 0,4 mm and 0,5 to 1,2 mm. They usually appear in masses and are dense packed. They often form accumulations closely connected with traces of activity of deposit feeders (Pl. III, Fig. 1, Pl. IV, Fig. 3,4), for example *Rhizocorallium*. The peloids described have been designated as coprolites because of their similarity to *Coprolus oblongus* Mayer and *C. sphaeroideus* Mayer (Mayer, 1952, 1956). It is, however, impossible to distinguish the two forms in thin section. Anpelids are said to form them (Mayer, 1952). Identical coprolites have been presented by Bachman (1973) from the German Muschelkalk strata.

— Group II includes peloids built of microspar with crystal diameters from 4 to 5 μm and of micrite. Their shapes in thin section are ovate, rarely round, sometimes irregular. Their size varies from 30 to 200 μm, the most often from 50 to 150 μm. They are present in considerable quantities in rocks built of transported components: in the top parts of graded-bedded layers and in horizontally and cross- laminated layers. In the Lima striata Beds peloids are the main components of cross-laminated pelsparites (Pl. V, Fig. 4). Most of them correspond to the elements often illustrated and described in literature as fecal pellets (cf. Folk, 1959, 1962, Kornicker and Purdy, 1957, Beales, 1965), some of them could be mud aggregates (cf. Illing, 1954, Kutek, 1969).

— Group III is represented by peloids of irregular shapes, often modified by pressure-solution (Pl. VI, Fig. 1). These elements are relatively large, from 0,25 to 1,2 mm, most often from 0,5 to 1,0 mm. They are built of microspar or micrite, sometimes contain skeletal remains difficult to identify. The author regards them as compound grains called grapestone by Illing (1954). The component grains of grapestone are not distinguishable because of micritization or recrystallization (cf. Bathurst, 1966, Purdy, 1963, 1968). Grapestones have been found in the middle and upper part of the Łukowa Beds, where together with fragments of green algae, echinoderms and other remains belong to the main components of the cross-laminated biopelspatites.

— Group IV includes peloids being in the most cases micritized skeletal particles. Their size is between 0,09 mm to several mm. Some of them can be recognized as foraminifers and pelecypods because of relics of primary microstructure. Most of them, however, are not recognizable. Their shapes are modifield by abrasion and no relics of original microstructure are preserved (Pl. VI, Fig. 2). Within these elements calcite cement is often present (Pl. V, Fig. 2).

Grumeleuse structure

This term has been introduced by Cayeux (1935). *Grumeleuse structure* appears as many little clots of finely crystalline calcite embedded in a coarser-grained matrix.

The *grumeleuse structure* has been found in some of the biomicrosparites. Clots are built of microspar (crystal diameters from 4,5 to 7,5 μm) the interstitial calcite crystals are from 5 to 25 μm in diameter (Pl. IV, Fig. 2). Their size depends on the space between the clots (cf. Bachman, 1973). The clots are silt grade, having diameters of 50 to 150 μm.

The clots may apper as:

— individual elements;
— elements tending to merge into irregular aggregates;
— elements passing into homogeneous microspar,

Clots „floating" in a coarser-grained microspar have not been observed, they are densely packed and touch one another.

In a few cases the development of clotted structure recorded earlier by Bachman (1973) has been observed. The homogeneous mud gradually changes upwards into individualized aggregates which in turn pass into single elements. At the top of the sequence they are covered by skeleton. According to Bachman (1973) the clots correspond to the mud aggregates of Illing (1954), which after deposition underwent gradual homogenization. The degree of homogeneity was dependent on the properties of the clots themselves (brittleness, softness), on the density of packing, additional quantities of mud deposited in spaces between the grains and settling of the clots. The uppermost clots were not homogenized owing to the protection of the overlying skeleton.

One cannot rule out the formation of clots as individual grains. Nevertheless, their origin remains a topic of discussion (cf. Cayeux, 1935, Beales, 1956, 1958, 1965, Bathurst, 1970, 1971).

Intraclasts

The products of sediment reworking, redeposited within the same sedimentary basin, are called intraclasts (Folk, 1959).

In the Lower Muschelkalk intraclasts are common but they rarely form intraformational conglomerate. Their size varies from 1 mm to several cm. If the grain diameter is less than 0,5 mm, distinction between the intraclast and peloid is practically impossible.

Intraclasts are the products of reworking of:

— microsparite;
— biomicrosparite;
— marl and calcareous mudstone;
— biosparite (found only in the Lima striata Beds)

The majority of intraclasts is the result of erosion of microsparite. Grained deposit though also undergoing erosion, usually does not produce intraclasts. Presumably, it is caused, on the one hand, by the greater cohesion of carbonate muds (microsparite) in comparison with grained deposits, on the other hand, during erosion and abrasion grained deposit desintegrates into individual components.

The shape of intraclasts depends on the thickness of the parent layer, the degree of consolidation of deposit, mode and distance of transport etc. Thin and laminated layers produce flat pebbles, massive deposits — more or less sphaerical ones.

Intraclasts have been divided into three groups according to the degree of their consolidation during erosion of the parent layer:

1. Elements formed of weakly consolidated deposit. As a result of rolling along the bottom, intraclasts acquired an armour coating of shell debris. Sometimes intraclasts are not quite detached from the parent layer.

The intraclasts under discussion do not form the intraformational conglomerate. They appear as single elements accompanying bioclasts, and are relatively common in biomicrosparites of the Wolica Beds.

2. Group II includes intraclasts made up of microsparite or biomicrosparite of a higher degree of consolidation. In most cases their shapes are discoidal, though some pebbles are bent.

In some interclasts traces of activity of boring organisms have been observed (Pl. IV, Fig. 1). The shape and size of the borings are very similar to those described by Mägdefrau (1932) as *Trypanites* (see also Kaźmierczak and Pszczółkowski, 1969, Chudzikiewicz, 1975, Trammer, 1975). The presence of borings indicates, that before final deposition, intraclasts were sufficiently hardened.

The intraclasts of this group are the main components of intraformational conglomerates occurring in the Wallenkalk (cf. Bialik et al. 1972, Trammer, 1975). The matrix of conglomerate consists of sand size skeletal debris with a slight admixture of microspar. Pebbles are irregularly distributed in the matrix, the flat ones lie horizontally (Pl. IV, Fig. 1), sometimes they are imbricated or stacked.

The intraformational conglomerates of the Wallenkalk are regarded by Bialik et al. (1972) as mudflow deposits. Chudzikiewicz (1975) assumed a similar origin for the intraformational conglomerates of the Gogolin Beds.

In the opinion of the author such origin is contradicted by the following data:

— very low content of microspar (primary mud). Matrix is usually free of mud and built of skeletal debris cemented with calcite.

— a vertical preferred orientation of tabular intraclasts so common in mudflow, is very rare in the layer of intraformational conglomerate.

— taking into account the size of intraclasts (mostly 4—8 cm), the thickness of conglomerate layer (about 10—30 cm) and the ratio of matrix to the intraclasts (about 1 : 1 or 1,5 : 1) the likelihood of transport of relatively large elements within a relatively small volume of liquefied calcareous sand seems to be small.
— there is no evidence of an accentuated morphology of the sea bottom. Intraformational conglomerates are incorporated in crumpled limestones (cf. Bialik et al. 1972) formed on large, flat bottom (cf. Bogacz et al. 1968).

It is not necessary resort to mudflows to explain the formation of conglomerates. Erosional processes creating flat pebbles, transported along the bottom, overthrust on one another and covered up by bioclastic material, are known from contemporary shallow sea environments (cf. Jindrich, 1969). The insignificant roundness of pebbles indicates a very short transport. Their marked flattening presumably reflects the thickness of the original layers. In the author's opinion the intraformational conglomerates under disccusion are storm deposits (see also Kotański, 1954, Ball, 1971, Čatalov, 1972, Dżułyński and Kubicz, 1975).

3. Group III includes intraclasts formed of consolidated deposit. The size of these elements is from several to about 20 mm, their shape is usually spheroidal or elipsoidal. They are mostly well rounded, though angular ones sometimes appear. Borings of the *Trypanites* type have been occasionally found in some intraclasts.

The intraclasts described form small accumulations just above the hardgrounds, sometimes they occur in enteropneustan burrows. They are usually accompanied by bioclasts. Their occurrence has been noted in the upper part of the Łukowa Beds and in the lower part of the Lima striata Beds.

4. A special kind of intraclasts has been found in the upper part of the Lima striata Beds. The intraclasts are small, from about 0,5 to about 20 mm, their shape is irregular or grape-like. As a rule, they are made up of biosparite containing pelecypods, echinoderms, peloids and small admixture of quartz silt (Pl. IV, Fig. 4).

The layer with biosparite intraclasts is a clayey-calcareous mudstone rich in crushed skeleton fragments. Intraclasts embedded in the mud matrix show variable orientation: horizontal, diagonal as well as vertical. In many cases pressure-solution contact between the intraclast and the mud matrix is visible. The thickness of the mudstone layer with biosparite intraclasts is about 50 cm.

Biosparite intraclasts look like lumps or grapestones formed as a result of early cementation (Illing, 1954, Taylor and Illing, 1969). They differ from the previously mentioned grapestones (sse p. 225) both in size, and, above all, by well preserved components. Therefore they are not included to peloids typified by obscured inner structure, but to intraclasts.

Lack of roundness so characteristic for these elements is surely caused by short transport and, on the other hand, by the easy detachment of individual components.

Presumably the intraclasts were formed during synsedimentary cementation of calcareous beach sand or barrier sand and then as loose elements were transported and redeposited. Their presence is an additional argument for the emergence of some parts of sea bottom (see p. 219), resulted in a gradual restriction of the basin and probably, in turning it into lagoons with a limited exchange of waters.

SEDIMENTOLOGICAL CHARACTERISTICS OF THE MAIN TYPES OF CARBONATE ROCKS

The rock-forming elements described above (bioclasts, peloids and intraclasts), also microspar and cement discussed in the second part of the work, are the main components of the carbonate rocks of the Lower Muschelkalk. Among the non-carbonate components clay, abundant especially in the Lima striata Beds and early diagenetic gypsum are important.

Detailed petrographic description of numerous types of limestones is not the subject of the present study but it seems appropriate to distinguish the main groups of rocks being the base for determination of sedimentary environment and conditions of deposition.

Taking into consideration the following properties of the deposits:
— presence of calcareous mud and/or cement;
— packing of grain components;
— degree of abrasion of components;
— depositional, erosional and biogenic structures — three main groups of carbonate rocks have been distinguished:

I. Rocks rich in calcareous mud (= microspar) with or without organic remains;
II. Rocks containing calcareous mud, cement and grains in varying proportions, bearing clear signs of transport;
III. Grain-supported rocks, rich in cement, components transported.

Group I includes:
— Microsparites usually not showing internal depositional structures. Macrofauna is very rare here, whereas coprolites can appear commonly; they are accompanied by scarce microfauna. Lack of depositional structures is possibly caused by bioturbations.
— Biomicrosparites containing undamaged pelecypod and gastropod shells, scattered in the microspar matrix. The former are sometimes bivalved. Skeleton remains are accompanied by coprolites and other peloids.
— Marly limestones and marls. They differ from microsparite in higher

clay content. They usually contain coprolites and scattered microfossils.

— Calcareous-clayey mudstones and marls of the Lima striata Beds. They contain clay (about 50%), a varying but small admixture of quartz silt, scattered microfossils and numerous coprolites. There appear horizontal burrows filled with coprolites and U-shaped burrows with spreiten of *Rhizocorallium* type.

The first three types of rocks prevail in the Wellenkalk. Limestones with deformational wavy-crumpled structures and most of the tabular and marly limestones belong here. The large quantitity of mud (microspar) and fossils in situ or slightly transported point to quiet-water conditions of deposition. The numerous trace fossile in the form of horizontal burrows filled with coprolites are also indicative of such conditions (cf. Ager and Wallace, 1970, Frey, 1975). The sediments were presumably deposited beneath the normal wave-base, under low-energy condition. Quiet-water deposition was interrupted many times by erosion as it is evidenced by small scours, furrows and erosional surfaces.

The mudstones and marls of the Lima striata Beds were formed also under low-energy conditions. Their deposition, however, was connected with a basin of lagoon type with gradually increasing salinity. It is evidenced by presence of early diagenetic gypsum (Pl. IV, fig. 3) and extinction of fauna at the end of the Lower Muschelkalk.

Despite the very shallow-water environment mainly horizontal burrows (Pl. V, Fig. 4) have been recorded in the Lima striata Beds. It may be the behavioral response of burrowing organisms to gradients in salinity. Organisms living at depth deeper than 5 cm experience essentially an isohaline environment (cf. Rhoads, 1975). So, more variable salinity close to the surface on the one hand and quiet-water conditions on the other, can explain the presence of horizontal burrows withian marly-mudstone deposits.

Group II includes:

— horizontally and cross laminated microsparites (Pl. III, fig. 2);
— horizontally and cross laminated fine-grained biopelmicrosparites;
— graded bedded biomicrosparites;
— some crinoidal biosparites and biosparites;
— intraformational conglomerates

Cross lamination present in microsparite (Pl. III, Fig. 2) indicates that the carbonate mud was tranported like other components.

In the graded bedded deposits the coarse grained material in the lower part of the bed is usually free of mud. Up to the top of the bed grain diameters diminish, the quantity of mud increases and peloids take the place of bioclasts. In the top part of the bed mud with small peloids is the prevailing component. The lack of mud among the coarse fraction is the result of retarded deposition from suspension.

Horizontally and cross laminated biopelmicrosparites contain small bioclasts, peloids probably of faecal origin and mud. They often appear just above the graded bedded deposits. Presumably, their deposition is the result of current activity.

Crinoidal limestones usually contain small quantities of calcareous mud, but there are some encrinites with calcite cement exclusively. Crinoids are accompanied by foraminifers, pelecypods, ostracods and peloids. Within intergranular spaces free of mud there appears calcite cement in optical continuity with echinoderm remains. In some layers the material was laid down in two stages. In the first stage the bioclastic material free of mud was deposited and it was subjected to quick early cementation. In the second stage, infiltration of calcareous mud into the intergranular spaces put the end to further development of cement (cf. Evamy and Shearman, 1965). The mud is not of vadose origin (see Dunham, 1969), it is connected with immediately overlying bed.

Biomicrosparites with single intraclasts are rich in pelecypod shells. Shells are mostly crushed, in many cases they are arranged chaotically and densely packed. In many cases intraclasts are armoured and sometimes incompletely detached from the parent layer. These characteristics give evidence for reworking and quick redeposition of sediments.

The sediments of the second group were formed, generally speaking, at the same depth as those of the first group, but under different conditions. Their deposition is presumably connected with storms or strong winds causing the lowering of the wave-base and in consequence, erosion and reworking of older sediments (cf. Čatalov, 1972, Dżułyński and Kubicz, 1975). Fine grained, horizontally and cross laminated deposits are the result of gradually weakening currents.

Rocks of group II are present in all the units of the Lower Muschelkalk but they are most frequent in the upper part of the Wolica Beds, in Wellenkalk and in the lower part of the Łukowa Beds. Their boundaries with the underlying deposit are always erosional.

Group III includes rocks built of densely packed grain components, as a rule bound with cement. Calcareous mud (microspar) is absent or it may appear in small quantities.

The following rocks belong here:

— structureless biosparites, sometimes including intraclasts;
— coarse and fine-grained biosparites, biopelsparites and pelsparites horizontally and/or cross laminated.

The first of them are built mainly of rounded, partly micritized skeletons. On surfaces of some grains there are foraminifer encrustations and micrite crusts. All grains are bound with calcite cement of two generations (cf. Kostecka, 1978, part II).

Grain components generally show a high degree of maturity. Before final deposition they had presumably been reworked many times.

Formation of biosparites is connected with a shallow-water, high energy conditions, which rule out the deposition of mud. However periods of strongly agitated water were probably interrupted by periods of calm-water, as is indicated by foraminifer encrustations, micrite envelopes and crusts (Pl. V, Fig. 2).

The horizontally and cross laminated biosparites, biopelsparites and pelsparites are built of crinoids, foraminifers, pelecypods, algal fragments and peloids. The latter are represented by grapestones (Pl. VI, Fig. 1), faecal pellets and mud aggregates (Pl. V, Fig. 4) and micritized grains. All components are cemented with steep-sided and blocky calcite (cf. Kostecka, 1978). In very fine grained biopelsparites and pelsparites there sometimes appears a small admixture of carbonate mud. Cross lamination is developed on a scale of centimetres (Pl. II, Fig. 2, Pl. V, Fig. 4) and decimetres. Cross laminated limestones appear mainly in the upper part of the Łukowa Beds and in the lower part of the Lima striata Beds (Fig. 3).

Cross laminated biosparites and biopelsparites are made up of calcareous sand; their deposition was presumably connected with shoals (above wave-base).

Fine grained biopelsparites and pelsparites were probably formed in a very shallow environment of moderate energy. Similar contemporary deposits are known from shallow lagoons and tidal flats (Wagner and van der Togt, 1973).

Between the rocks under discussion and contemporary deposits, especially from the Persian Gulf, analogy can be drawn (cf. Purser, ed. 1973) if one takes into account both structural and textural properties and component association. This allows to suppose that the sedimentation in the Early Muschelkalk sea took place in an environment very similar to that existing in the southern part of the Persian Gulf.

INTERPRETATION OF THE SEDIMENTARY ENVIRONMENT

Röth and the Lower Muschelkalk represent part of the Triassic cycle of the ABCBCBA type in the Central Europe, where: A — terrestial sediments of the Lower Triassic; B — evaporitic sediments of the Röth; C — shallow marine sediments of the Lower Muschelkalk; B — evaporite sediments of the Middle Muschelkalk; C —shallow-marine sediments of the Upper Muschelkalk; B — evaporite sediments of the Keuper; A — terrestial sediments of the Upper Triassic (Schwarz, 1975). Röth and the Lower Muschelkalk of the south-western margin of the Holy Cross Mts. comprehend the main portion of the subcycle BCB. The last member of this sequence (B) includes the uppermost part of the Lima striata Beds and the Middle Muschelkalk.

The sedimentation of the lower part of the marine Röth is connected with a shallow littoral environment, presumably tidal flat or lagoon, and partly supralittoral with increased salinity.

Evidences for this interpretation are:

— presence of early diagenetic gypsum (cf. Masson, 1955, Butler, 1969, Kinsman, 1969 and others) in the form of single crystals and patches scattered in marly-mudstone deposits;

— appearence of early diagenetic dolomicrites (cf. Illing et al. 1965, Shinn et al. 1965, Deffeyes et al. 1965) massive and laminated and dolomite breccias (Pl. I, Fig. 2);

— considerable contribution of terrigenous quartz sand and silt, forming laminae within dolomites.

A recent example of a similar environment is the southern coast of the Persian Gulf with shallow lagoons and sabkhas (cf. Illing et al. 1965, Wood and Wolfe, 1969, Purser, 1973).

The upper part of the Röth, the Wolica Beds, the Wellenkalk, the Łukowa Beds and the lower part of the Lima striata Beds are open marine sediments in which Asiatic and Alpine faunas are recorded (Senkowiczowa, 1962, Trammer, 1975 and others).

The sedimentation of the upper part of the Röth and the lower part of the Wolica Beds at first took place in a shallow-marine and agitated sublittoral environment with a tendency toward gradual deepening of the basin. An outcome of this is the sequence of deposits: oolitic Röth limestone, biosparites of Röth and the Wolica Beds give way gradually to microsparites and biomicrosparites. The moving away shore line and the deepening of the basin was reflected in the disappearence of quartz supply and in the deposition of carbonate muds (microsparites) which are the main sediment in the Wellenkalk and partly, in the Łukowa Beds. Their deposition took place beneath the normal wave-base in an open, shallow epicontinental sea. Temporary lowering of the wave-base caused by storms or seasonal winds was fairly common. This resulted in erosion and redeposition of sediments (presence of intraclasts, intraformational conglomerates and scours). Currents, transporting material of different fractions, sometimes removed mud particles.

Gradual shallowing of the sea was marked in the middle part of the Łukowa Beds. It is evidenced by numerous horizons with vertical U-shaped burrows of organisms assumed to be Enteropneusta (cf. Kaźmierczak and Pszczółkowski, 1969). Recently, Enteropneusta form similar U or J-shaped burrows in the shallowest part of sublittoral zone (cf. Dörjes and Hartweck, 1975).

The upper surface of beds with burrows is usually erosional, and in the overlaying deposits there appear intraclasts, originating directly from beneath.

An additional argument for gradual shallowing is the presence of cross bedded biosparites and pelsparites, occurring in the upper part of the Łukowa Beds and in the lower part of the Lima striata Beds. Biosparites and pelsparites built of washed out calcareous sand presumably belong to an intermediate facies between that of microsparites with burrows (a moderate energy environment and slowed down sedimentation) on the one hand, and sediments of a high energy environment, typical of sand banks and shoals on the other.

The sedimentation of the upper part of the Lima striata Beds took place in restricted basin with increasing salinity, evidence for this being the presence of early diagenetic gypsum crystals within deposits of this unit. Presumably the Early Muschelkalk sea turned gradually into lagoons with limited exchange of waters and weakening energy of environment. Brief, local emergence of some parts of the bottom are not excluded.

Changes in life may be noted too. Macro-organisms were dominated by thick-shelled gastropods and pelecypods. Very small, agglutinated foraminifers, occurring abundantly in the lower part of the Lima striata Beds, suddenly disappeared just in the middle part of this unit. This may also be interpreted as result of increased salinity (cf. Hughes Clarke and Keij, 1973).

The sedimentary environment was probably shallow and relatively calm and the rate of deposition rather slow. These conclusions can be drawn from the horizontal arrangement of burrows (cf. Seilacher, 1967, Ager and Wallace, 1970, Frey and Howard, 1970, Howard, 1975) and the abundance of coprolites. From time to time under relatively high energy conditions ripplemarks, cross laminations (Pl. VI, Fig. 3) scours and intraclasts were formed.

At the close of the Lima striata Beds extinction of fauna took place. This is considered as marker point delimitating the boundary between the Lower and Middle Muschelkalk. Sedimentation in the restricted basin with high salinity continued into the Middle Muschelkalk.

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STRESZCZENIE

W pracy przedstawiono ogólnie wykształcenie litologiczne dolnego wapienia muszlowego i retu, których profile ilustrują fig. 2 i 3. Szczegółowo zostały omówione składniki ziarnowe skał węglanowych, wśród których wyróżniono: a) szczątki organiczne; b) peloidy i c) intraklasty.

Spośród szczątków organicznych najważniejsze to: małże, ślimaki, szkarłupnie, otwornice i małżoraczki. W drobnych ilościach występują ponadto: ramienionogi, rurki robaków, glony wapienne, spikule gąbek, mikroproblematyki oraz łuski, zęby ryb i inne elementy niewęglanowe.

Do peloidów zaliczono: koprolity (tabl. I, fig. 3, tabl. III, fig. 1, tabl. VI, fig. 3, 4), drobne grudki przypuszczalnie fekalnego pochodzenia, grudki mułowe, grudki groniaste (tabl. VI, fig. 1) oraz elementy zmikrytyzowane (tabl. VI, fig. 2).

Wśród intraklastów wyróżniono trzy typy elementów powstałych w wyniku erozji wcześniej deponowanych osadów o różnym stopniu konsolidacji. Należą do nich a) intraklasty „uzbrojone" wytworzone z osadów słabo skonsolidowanych; b) intraklasty powstałe z osadów o dość wysokim stopniu konsolidacji; c) intraklasty wytworzone z osadów zwięzłych. Czwarty typ intraklastów odpowiada elementom, które swe pochodzenie zawdzięczają procesom wczesnej cementacji (tabl. IV, fig. 4). Są to intraklasty biosparytowe.

Wyrazem zależności między środowiskiem sedymentacji, warunkami depozycji i rodzajem deponowanego osadu są trzy grupy skał.

Pierwsza grupa obejmuje utwory deponowane w spokojnym środowisku o niskiej energii, poniżej normalnej podstawy falowania. Należą tu głównie mikrosparyty i biomikrosparyty.

Utwory grupy drugiej powstawały na tej samej głębokości co utwory grupy pierwszej, lecz powyżej burzowej podstawy falowania i ich geneza związana jest z okresami silnych wiatrów i sztormów, powodujących erozję i przerabianie wcześniej złożonych osadów. Do grupy tej należą mikrosparyty i biomikrosparyty laminowane przekątnie (tabl. III, fig. 2), biomikrosparyty z intraklastami, biomikrosparyty uziarnione frakcjonalnie oraz zlepieńce śródformacyjne.

Depozycja utworów grupy III jest związana z obszarami ruchliwych płycizn (powyżej normalnej podstawy falowania). W grupie tej występują głównie biosparyty, biopelsparyty i pelsparyty, które w licznych przypadkach wykazują uwarstwienie przekątne (tabl. II, fig. 2). Utwory te reprezentują przypuszczalnie podwodne formy typu barier lub ławic piaszczystych.

Sedymentację morską środkowego triasu zapoczątkowała transgresja retu. Dolne ogniwa tego piętra tworzyły się w płytkowodnym środowisku litoralnym (pływowym), częściowo, być może, w lagunowym i su-

pralitoralnym, w warunkach podwyższonego zasolenia, czego wyrazem są wczesnodiagenetyczne dolomity i ich brekcje (tabl. II, fig. 1, tabl. I, fig. 2) oraz przekątnie laminowane utwory piaszczysto mułowcowe (tabl. I, fig. 1), oraz obecność rozproszonych kryształów gipsu.

Sedymentacja utworów wyższej części retu i dolnej części warstw wolickich przebiegała w płytkim i ruchliwym środowisku sublitoralnym (obecność wapieni oolitowych w recie oraz biosparytów w warstwach wolickich) z tendencją do stopniowego pogłębiania zbiornika. Pogłębianie zbiornika i oddalanie się strefy brzegowej znalazło odbicie w zaniku dopływu kwarcowego materiału terygenicznego oraz w depozycji mułów węglanowych (mikrosparyty), które stanowią dominujący typ osadów w kompleksie warstw falistych, częściowo także w warstwach łukowskich. Sedymentacja utworów węglanowych tych ogniw przebiegała poniżej normalnej podstawy falowania w warunkach płytkiego, otwartego morza epikontynentalnego. Czasowe obniżenie podstawy falowania, spowodowane burzami lub silnymi wiatrami, wywoływało erozję, przerabianie i redepozycję osadów. W rezultacie tworzyły się osady bioklasyczne z intraklastami, zlepieńce śródformacyjne, biomikrosparyty uziarnione frakcjonalnie lub przekątnie warstwowane mikrosparyty.

Stopniowe spłycenie zbiornika zaznaczyło się w środkowych ogniwach warstw łukowskich. Wskazują na to liczne poziomy z U-kształtnymi jamkami mieszkalnymi przypuszczalnie jelitodysznych oraz częste powierzchnie erozyjne, którym towarzyszą intraklasty.

W wyższej części warstw łukowskich i dolnej części warstw z Lima striata pospolicie występują laminowane przekątnie biosparyty, biopelsparyty i pelsparyty wskazujące na wzrost ruchliwości wód, uniemożliwiający depozycję mułów.

Sedymentacja wyższej części warstw z Lima striata przebiegała w warunkach spłycenia, postępującej izolacji zbiornika i wzrastającego zasolenia wód, czego wyrazem jest obecność wczesnodiagenetycznego gipsu (tabl. IV, fig. 3) w osadach tego kompleksu oraz zupełny zanik fauny na pograniczu dolnego i środkowego wapienia muszlowego.

EXPLANATION OF PLATES — OBJAŚNIENIA PLANSZ

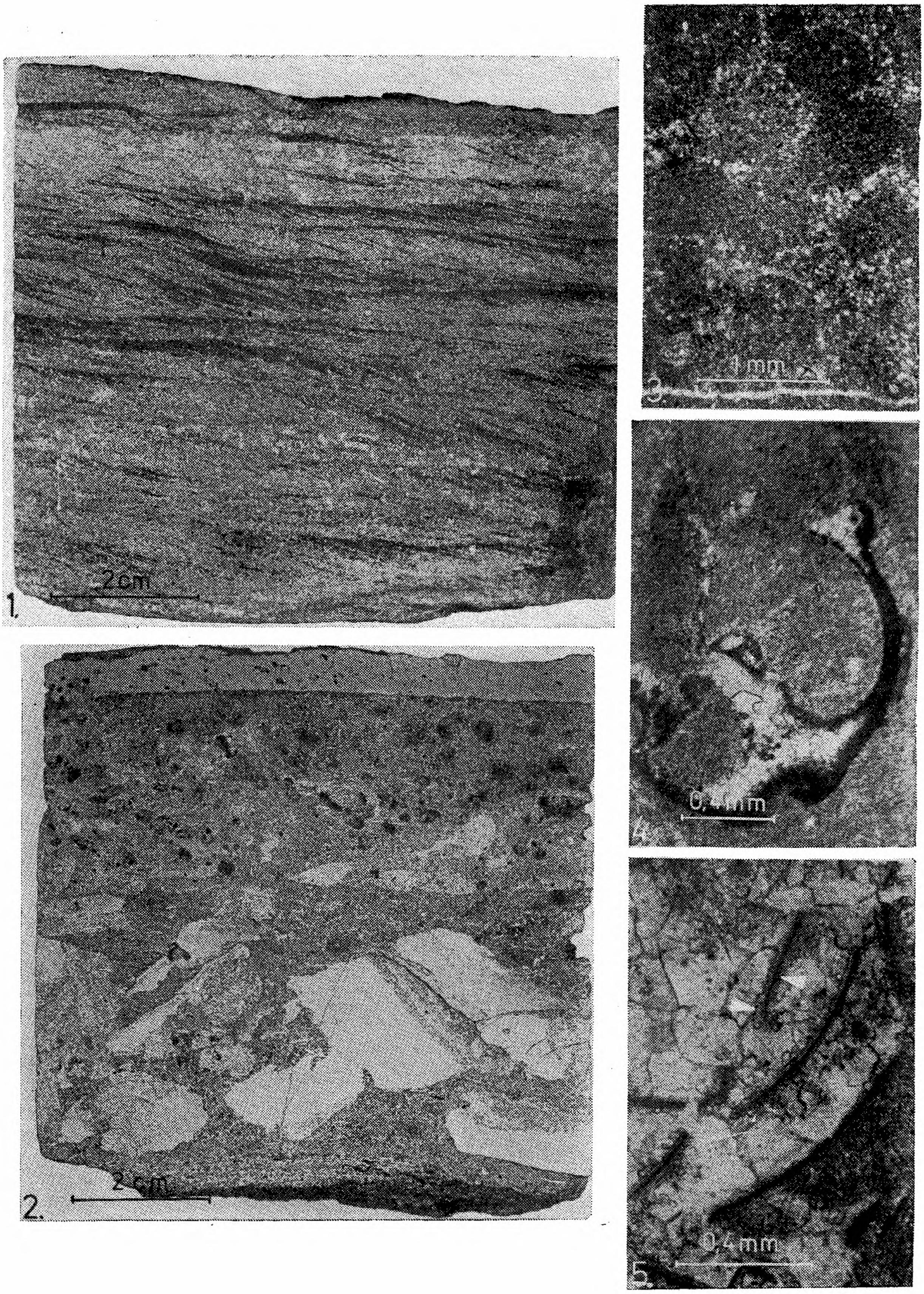
Plate — Plansza I

Fig. 1. Cross laminated muddy sandstone. Röth. Piekoszów IG — 1. Polished surface

Fig. 1. Skała piaszczysto-mułowcowa laminowana przekątnie. Ret. Piekoszów IG—1. Zgład

Fig. 2. Dolomite breccia in quartz sand. Early diagenetic dolomite weakly consolidated during erosion. Röth. Piekoszów IG—1. Polished surface

Fig. 2. Brekcja dolomitowa w piasku kwarcowym. Dolomit wczesnodiagenetyczny, słabo skonsolidowany w czasie erozji. Ret. Piekoszów IG—1. Zgład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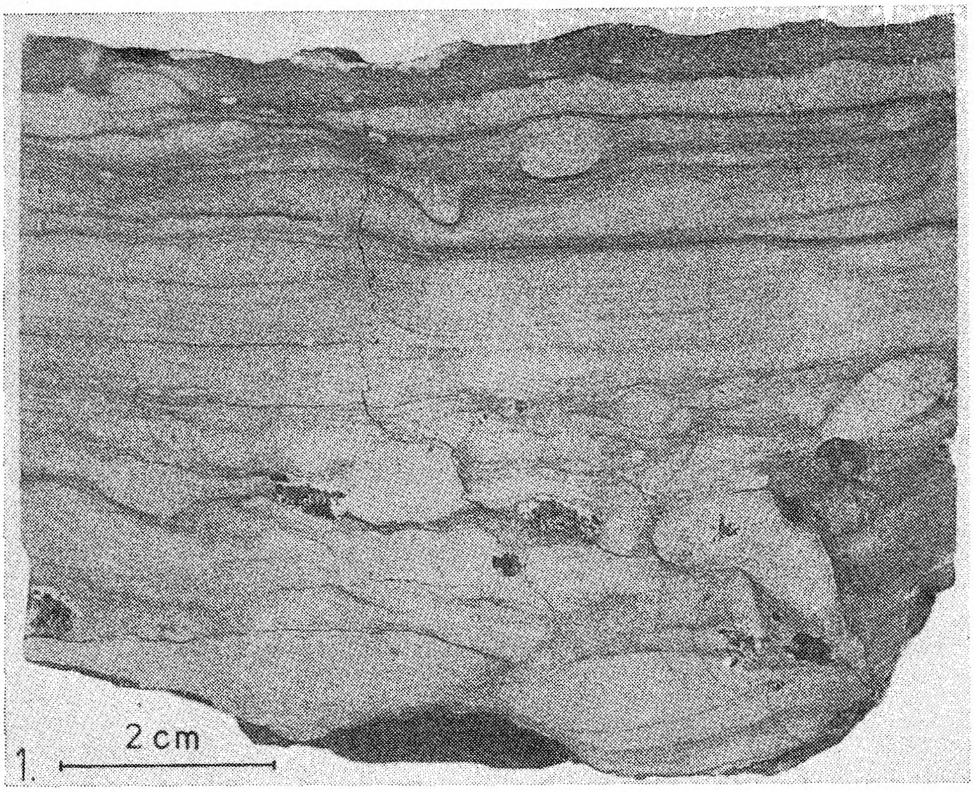

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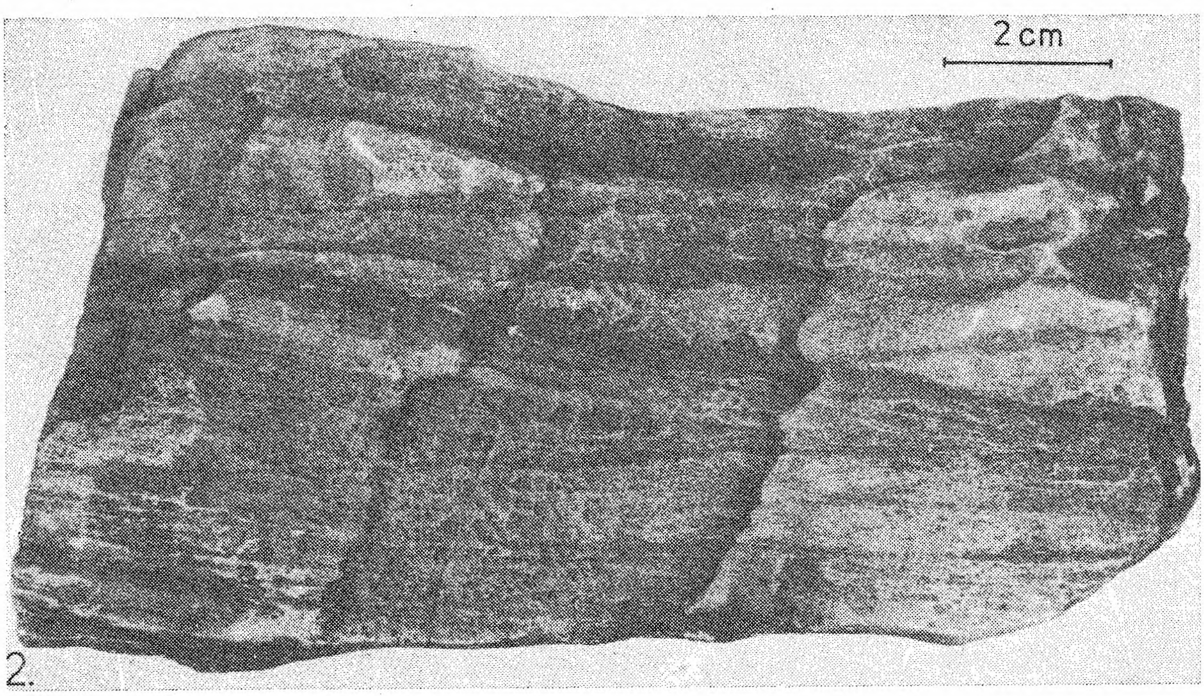

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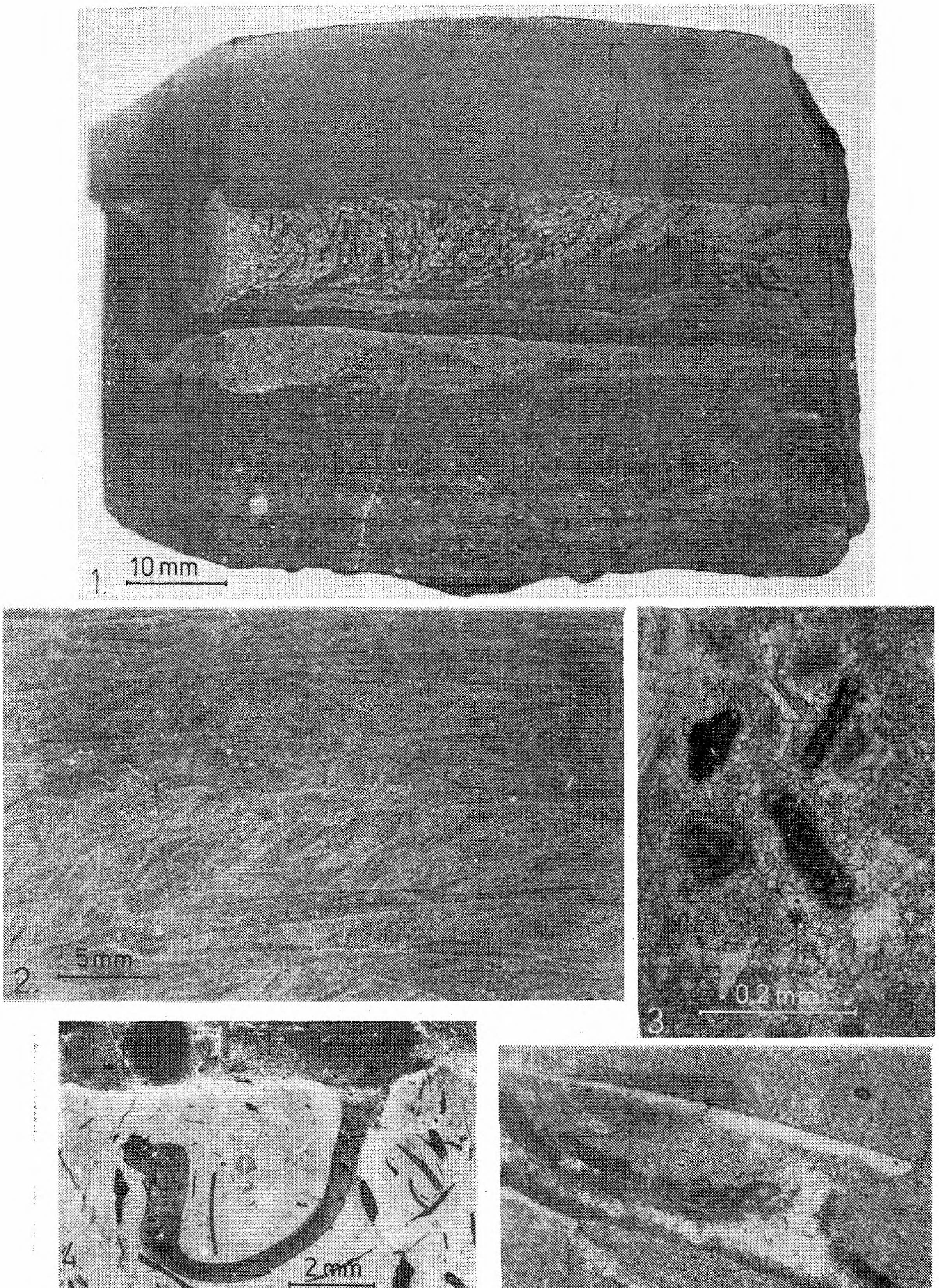
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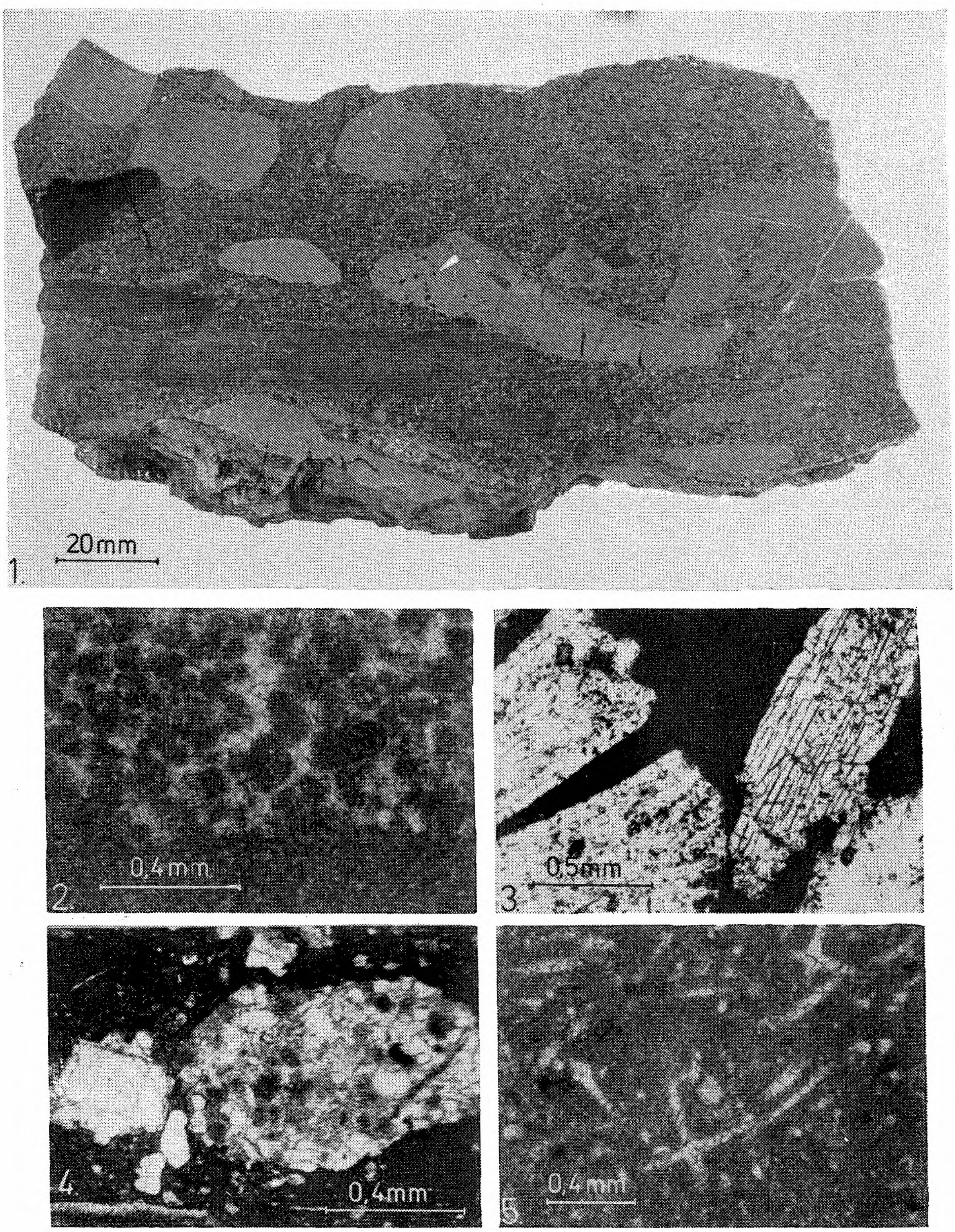
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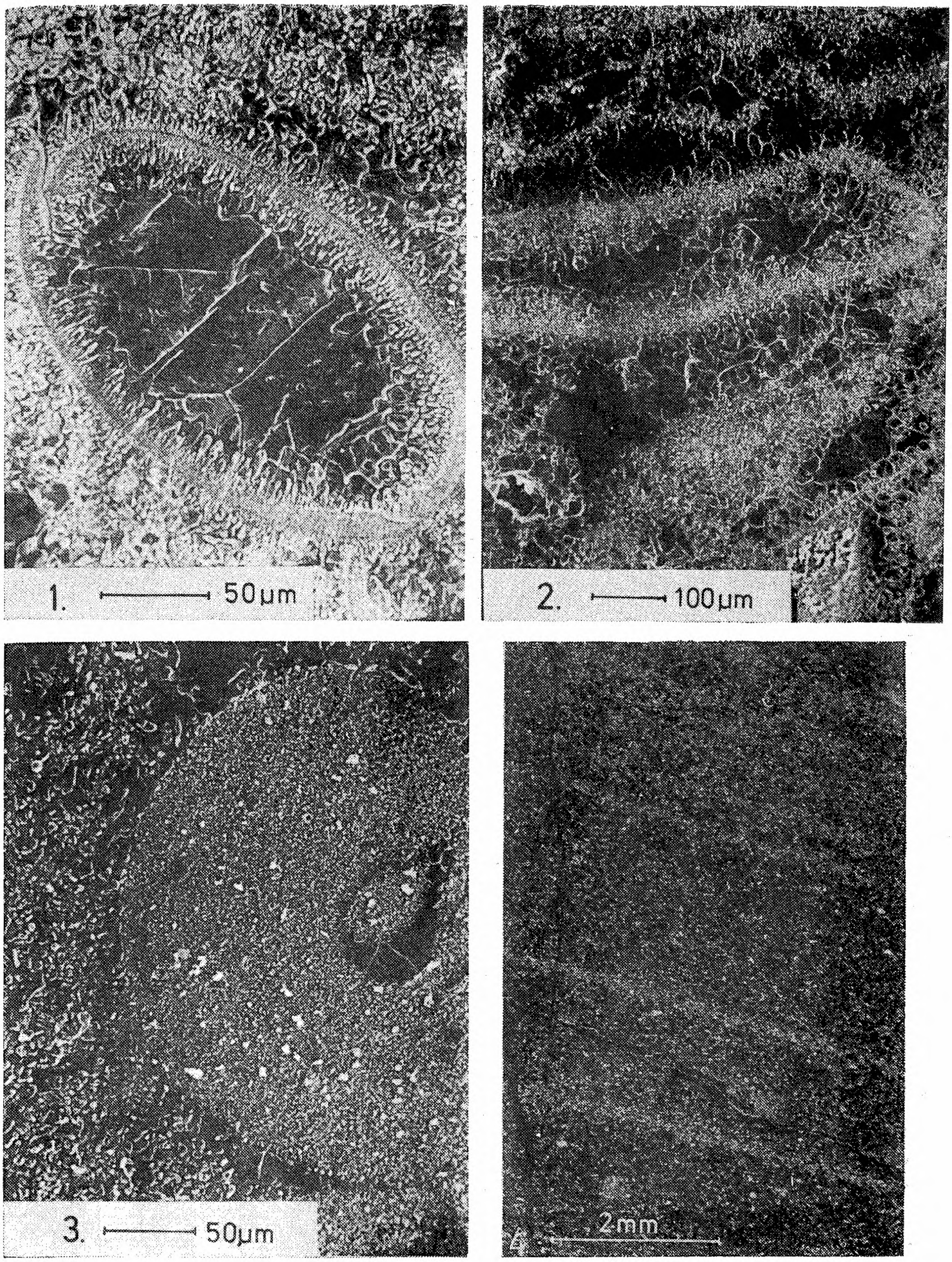
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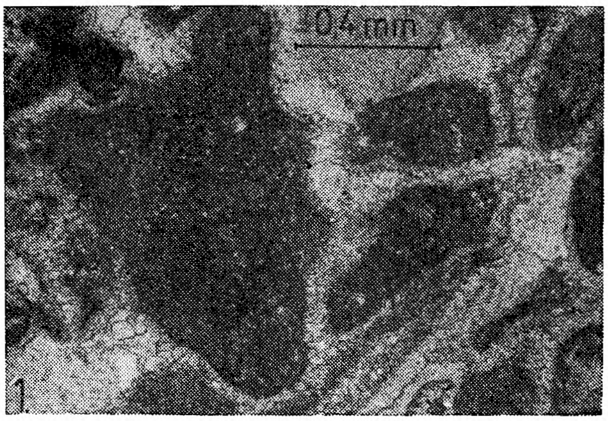
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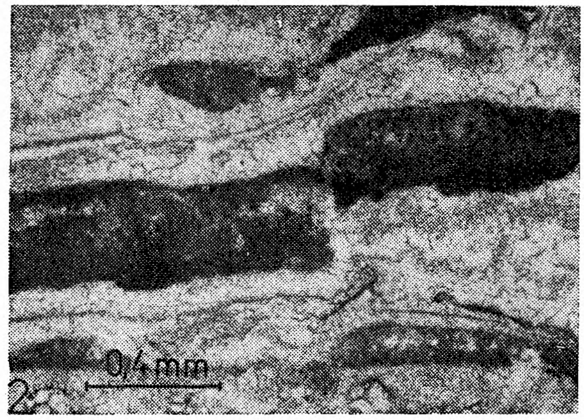
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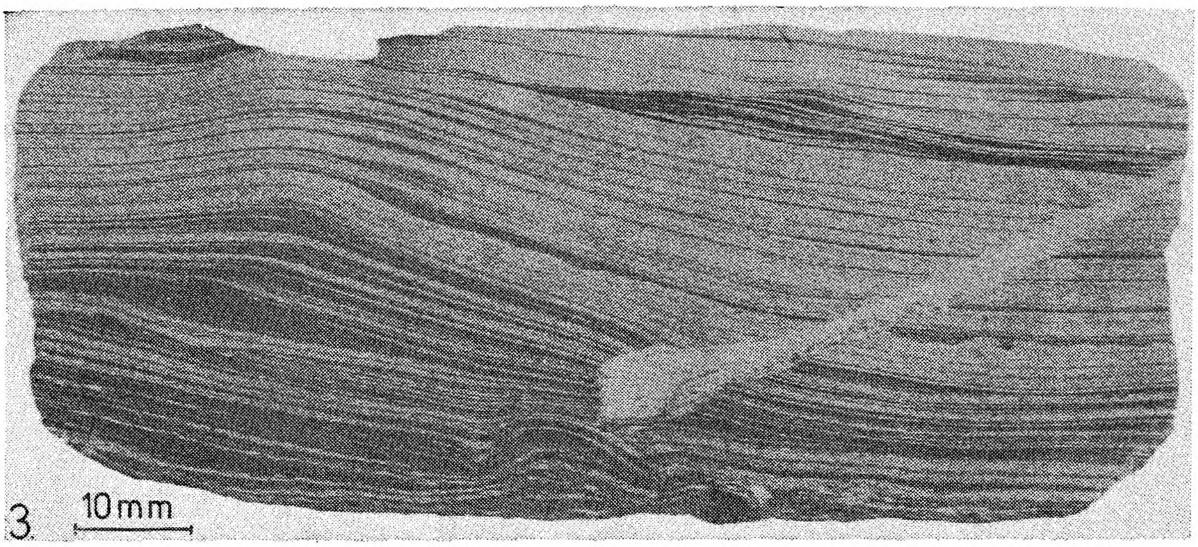
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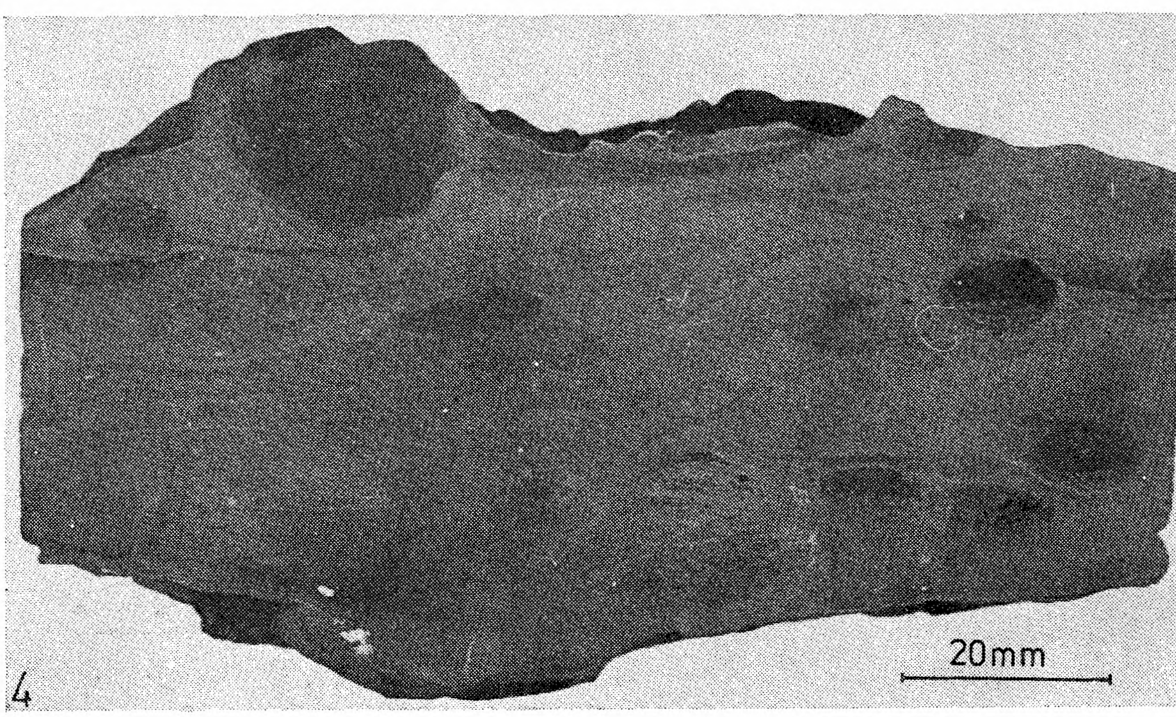
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Fig. 3. Noncompacted coprolites built of microspar. Wolica Beds. Wolica. Thin section

Fig. 3. Koprolity zbudowane z mikrosparu. Brak przejawów kompakcji. Warstwy wolickie. Wolica. Płytka cienka

Fig. 4. Gastropod shell cast with micrite envelope of type I. Wolica Beds. Wolica. Thin section

Fig. 4. Cementowy odlew muszli ślimaka z powłoką mikrytową typu I. Warstwy wolickie. Wolica. Płytka cienka

Fig. 5. Crushed micrite envelope of type II with initial cement of the first generation. Fracture surfaces are free of the first generation cement. Wolica Beds. Wolica. Thin section

Fig. 5. Spękana osłona mikrytowa typu II ze słabo rozwiniętym cementem I generacji. Warstwy wolickie. Wolica. Płytka cienka

Plate — Plansza II

Fig. 1. Bioturbations in laminated dolomicrite. Röth. Piekoszów IG—1. Polished surface

Fig. 1. Struktury bioturbacyjne w laminowanych dolomikrytach. Ret. Piekoszów IG—1. Zgład

Fig. 2. Cross laminated fine-grained biopelsparite. Łukowa Beds. Łukowa. Weathered surface

Fig. 2. Drobnoziarnisty biopelsparyt przekątnie laminowany. Warstwy łukowskie. Nadwietrzała powierzchnia

Plate — Plansza III

Fig. 1. Bioturbation in microsparite. Spiral alignment of noncompacted coprolites. Erosional top surface of layer with bioturbation. Wellenkalk. Wolica. Polished and etched surface

Fig. 1. Struktura bioturbacyjna w wapieniu mikrosparytowym. Ślady ruchu organizmu utrwalone w ułożeniu koprolitów. Górna powierzchnia warstwy z bioturbacjami ścięta erozyjnie. Brak śladów kompakcji. Warstwy faliste. Wolica. Powierzchnia zgładu wytrawiona

Fig. 2. Cross laminated microsparite. Wellenkalk. Wolica. Thin section, negative print

Fig. 2. Przekątnie laminowany mikrosparyt. Warstwy faliste. Wolica. Płytka cienka, odbitka negatywowa

Fig. 3. Dwarf foraminifers. Lima striata Beds. Wolica. Thin section.

Fig. 3. „Skarlałe" otwornice. Warstwy z Lima striata. Wolica. Płytka cienka

Fig. 4. Klastyczny odlew skorupy małża na kontakcie z powierzchnią erozyjną. Pró- filled with material of overlaying bed. Lima striata Beds. Piekoszów IG—1. Thin section, negative print

Fig. 4. Klastyczny odlew skorupy małża na kontakcie z powierzchnią erozyjną. Próżnia po rozpuszczonej skorupie wypełniona materiałem warstwy nadległej. Warstwy z Lima striata. Piekoszów IG—1. Płytka cienka, odbitka negatywowa

Fig. 5. Pelecypod shell cast with micrite envelope and encrusting foraminifers. Wolica Beds. Wolica. Thin section

Fig. 5. Cementowy odlew skorupy małża z powłoką mikrytową i otwornicami obrastającymi. Warstwy wolickie. Wolica. Płytka cienka

Plate — Plansza IV

Fig. 1. Intraformational conglomerate. Intraclasts in biosparite matrix. Some of them with borings of Trypanites (arrow). Wellenkalk. Wincentów. Polished and etched surface.

Fig. 1. Zlepieniec śródformacyjny. Intraklasty w biosparytowym tle skalnym. W niektórych intraklastach wydrążenia typu Trypanites (strzałka). Warstwy faliste. Wincentów. Powierzchnia zgładu wytrawiona

Fig. 2. Biomicrosparite, structure grumeleuse. Wolica Beds. Brzeziny. Thin section

Fig. 2. Biomikrosparyt, struktura gruzełkowa. Warstwy wolickie. Brzeziny. Płytka cienka

Fig. 3. Authigenic gypsum crystals in muddy matrix. Lima striata Beds. Piekoszów IG—1. Thin section

Fig. 3. Kryształy autigenicznego gipsu w mułowcowym tle skalnym. Warstwy z Lima striata. Piekoszów IG—1. Płytka cienka

Fig. 4. Biosparite intraclast in muddy matrix. To left fragment of prismatic, thick-shelled pelecypod. Lima striata Beds. Piekoszów IG—1. Thin section

Fig. 4. Intraklast biosparytowy w mułowcowym tle skalnym. Obok fragment grubopryzmatycznej skorupy małża. Warstwy z Lima striata Piekoszów IG—1. Płytka cienka

Fig. 5. Biomiscrosparite, calcified sponge spiculs. Lima striata Beds. Wolica. Thin section

Fig. 5. Biomikrosparyt, skalcyfikowane igły gąbek. Warstwy z Lima stiata. Wolica. Płytka cienka

Plate — Plansza V

Fig. 1. Biomicrosparite, ostracod carapace. The first generation cement growing on external and internal surfaces of shell wall. The central part of the shell interior filled with the second generation cement. Wellenkalk. Wolica. Polished and etched surface of thin section, SEM

Fig. 1. Biomikrosparyt, pancerzyk małżoraczka. Cement I generacji rozwinięty na zewnętrznej i wewnętrznej powierzchni ściany pancerzyka. Wnętrze wypełnia cement II generacji. Warstwy faliste. Wolica. Płytka cienka, mikrofotografia skaningowa

Fig. 2. Biosparite, calcite shell cast with micrite envelope. Within the envelope the second generation cement. On the external surface of micrite envelope-first generation cement. Wolica Beds. Wolica. Polished and etched surface of thin section, SEM

Fig. 2. Biosparyt, kalcytowe odlewy skorup z powłokami mikrytowymi. Wewnątrz odlewów cement II generacji. Na zewnętrznych powierzchniach powłok cement I generacji. Warstwy wolickie. Wolica. Płytka cienka, mikrofotografia skaningowa

Fig. 3. Micrite-filled chamber of gastropod shell in microsparite matrix. Wolica Beds. Brzeziny. Polished and etched surface of thin section, SEM

Fig. 3. Mikrytowa ośródka ślimaka w mikrosparytowym tle skalnym. Warstwy wolickie. Brzeziny. Płytka cienka, mikrofotografia skaningowa.

Fig. 4. Cross laminated pelsparite. Lima striata Beds. Piekoszów IG—1. Thin section, negative print.

Fig. 4. Pelsparyt laminowany przekątnie. Warstwy z Lima striata. Piekoszów IG—1. Płytka cienka, odbitka negatywowa.

Plate — Plansza VI

Fig. 1. Biopelsparyt, grapestones with early calcite cement in pressure — solution contact. Łukowa Beds. Wolica. Thin section

Fig. 1. Biopelsparyt, grudki groniaste ze śladami rozpuszczania pod ciśnieniem. Warstwy łukowskie. Wolica. Płytka cienka

Fig. 2. Peloid as a result of micritization of skeletal grain, on its bottom surface micrite encrustation, biosparite. Wolica Beds. Brzeziny. Thin section

Fig. 2. Peloid powstały w wyniku mikrytyzacji szczątka szkieletowego, na jego dolnej powierzchni narośla mikrytowe, biosparyt. Warstwy wolickie. Brzeziny. Płytka cienka

Fig. 3. Pelsparite laminae (dark) alternated with muddy laminae (bright), at top part ripplemarks. Trace of organism escape (?) with some coprolites. Lima striata Beds. Piekoszów IG—1. Polished and etched surface

Fig. 3. Naprzemianległe laminy pelsparytowe (ciemne) i mułowcowe (jasne), w stropie ripplemarki. Ślad ucieczki (?) organizmu, w tunelu widoczne koprolity. Warstwy z Lima striata. Piekoszów IG—1. Zgład.

Fig. 4. Marly mudstone with bioturbations. Within burrows squashed coprolites. Lima striata Beds. Piekoszów IG—1. Polished and etched surface

Fig. 4. Mułowce margliste ze strukturami bioturbacyjnymi, wewnątrz tuneli sprasowane koprolity. Warstwy z Lima striata. Piekoszów IG—1. Zgład

PL. I Fig. 1, 2; PL. II Fig. 1, 2; PL. III Fig. 1; PL. IV Fig. 1; PL. VI Fig. 3, 4 — fot. K. Fedorowicz

PL. V Fig. 1, 2 — made in Electron — Microscopy Lab. of Inst. of Metallurgy, Pol. Ac. Sci.