ANNALES SOCIETATIS GEOLOGORUM POLONIAE
ROCZNIK POLSKIEGO TOWARZYSTWA GEOLOGICZNEGO

v. 55 – 1/2: 127 – 138 Kraków 1985

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PALAEOECOLOGY AND SEDIMENTARY ENVIRONMENT OF THE TEREBRATULA BEDS (LOWER MUSCHELKALK) FROM UPPER SILESIA (SOUTH POLAND)

(Pl. I – II, 8 Figs.)

Paleoekologia i środowisko sedymentacji warstw terebratulowych Górnego Śląska (Polska południowa)

(Pl. I – II, 8 fig.)

am Bodzioch: Palaeoecology and sedimentary environment of the Terebratula Beds (Lower Muschelkalk) from Upper Silesia (South Poland). *Ann. Soc. Geol. Poloniae*, 55-1/2: 127 – 138, 1985 Kraków.

Abstract: The paper deals with accumulations of brachiopods shells from the Terebratula Beds, occurring in Upper Silesia. The autochthonous accumulations have been interpreted as biostromes, whereas the allochthonous ones as storm deposits. The sedimentary environment has generally been defined as a shallow-water one. Moreover, shallower and deeper zones have been distinguished. Environmental energy is considered to be the main factor controlling sedimentation and development of faunas. The change of the type of sedimentation found in the Upper Terebratula Beds section have been related to the shift of facies, associated with subsidence of the Vindelician Ridge.

Key words: shell beds, storm deposits, epicontinental Triassic, Upper Silesia, Poland.

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manuscript received: January, 1984 accepted: February, 1984

Treść: Praca traktuje o nagromadzeniach muszli ramienionogów z warstw terebratulowych. Nagromadzenia autochtoniczne zostały zinterpretowane jako biostromy, natomiast nagromadzenia allochtoniczne jako utwory sztormowe. Środowisko sedymentacji określone zostało ogólnie jako płytkowodne, z wyróżnieniem strefy płytszej i głębszej. Za główny czynnik kontrolujący sedymentację oraz rozwój fauny uznano energię środowiska. Zmiana typu sedymentacji, stwierdzona w profilu górnych warstw terebratulowych, odniesiona została do przesunięcia facji, związanego z obniżeniem wału windelickiego.

INTRODUCTION

The bipartite Terebratula Beds were distinguished by Eck (1863) and more precisely characterized in the western part of Upper Silesia by Assman (1944) and in its eastern part by Siedlecki (1949). The upper part of the profile, occurring above the so-called main crinoidal layer, is characterized by alternate arrangement of coquinas and marly limestones of crumpled structure. Dżułyński and Kubicz (1975) made an attempt at a closer defining of the origin of these deposits and postulated the following model of sedimentation (*op. cit.*, p. 169 – translated from Polish):

1. "In the authors' opinion, the coquinoid layers, relevant to single sudden acts of deposition, are storm deposits".
2. "A shallow sea with shoals was sedimentary environment of the Terebratula Beds. The shoals were most likely to be a seat of brachiopods and a source of clastic material which was carried by storm currents and settled in the depressions surrounding the shoals".
3. "Domination of brachiopods, their mass occurrence and mortality, were the effect of strong environmental instability, expressed in great changes of water temperature which, in turn, were leading to wide fluctuations of oxygen's content".

Detailed investigations carried out by the author in the Strzelce Opolskie and Dziewkowice quarries lead to new conclusions referring to sedimentary environment of the upper part of the Terebratula Beds.

DESCRIPTION OF THE COQUINAS

Two rocky complexes (A and B) have been distinguished in the upper part of the Terebratula Beds. They differ in the crumpled limestones/coquinas ratio (Fig. 1) and in the development, form of occurrence and the origin of coquinas.

Table – Tabela 1

Palaeoecology of the Terebratula Beds
Paleoekologia warstw terebratulowych

Lithology	Fauna	Mode of life	Trophic category	%
COQUINAS	*Coenothyris vulgaris*	epifauna	suspension-feeders	86
	Decurtella decurtata	epifauna	suspension-feeders	1
	Tetractinella trigonella	epifauna	suspension-feeders	1
	Enantiostreon difformae	epifauna	suspension-feeders	8
	Plagiostoma striatum	epifauna	suspension-feeders	1
	Placunopsis plana	epifauna	suspension-feeders	3
	*Crinoidea	epifauna	suspension-feeders	*
	*Pisces	nekton	predators	*
	*Reptilia	nekton	predators	*
CRUMPLED LIMESTONES	*Hoernesia socialis*	semi-infauna	deposit-feeders	5
	Annelida (traces)	infauna	deposit feeders	95
	Arthropoda (traces)	infauna	suspension-feeders	

*The fauna without the importance in the palaeoecological analysis
*Fauna nie brana pod uwagę w analizie paleoekologicznej

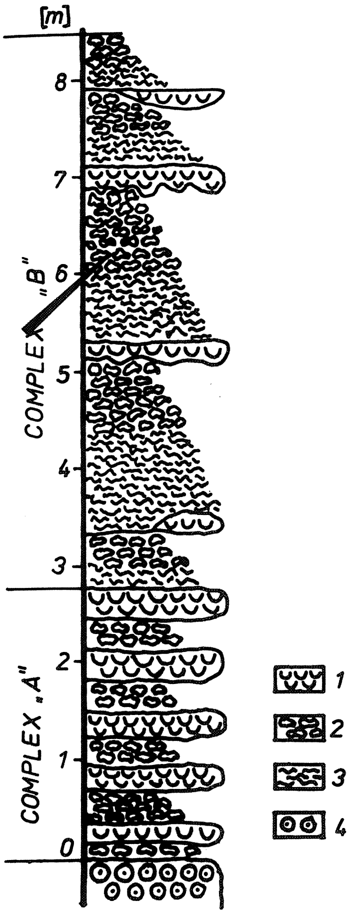

Fig. 1. Lithostratigraphic section of the upper Terebratula Beds. *1* – coquinas, *2* – crumpled limestones, *3* – wavy bedding limestones, *4* – main crinoidal bed

Fig. 1. Profil litostratygraficzny górnych warstw terebratulowych. *1* – muszlowce, *2* – wapienie gruzłowe, *3* – wapienie faliste, *4* – główna ławica krynoidowa

COMPLEX A

Coquinas layers occur in the lower part of the discussed section (Fig. 1). They are up to 30 cm thick and of wide lateral extent (about 6 km) and are separated by crumpled limestones. Poorly differentiated fauna, occurring in the coquinas, is dominated by brachiopods of *Coenothyris vulgaris*[1] species which compose about 86% of the ascertained fauna (Table 1).

Not closely identified ichnofauna dominates in the crumpled limestones. A pelycypod *Hoernesia socialis* occurs sporadically (Table 1). Limestone lumps represent fragments of sediment which was not burrowed by animals, and are preserved between the channels left by infauna. Moreover, there occur lumps infilling these channels (Pl. I). This fact proves that the crumpled structure of the investigated limestones is the effect of intensive activity of infauna.

Fossil preservation is differentiated and shows vertical and lateral variability. In vertical sections the following regularity, indicating redeposition of organic remains, is noticeable (Fig. 2):

1. Completely preserved specimens devoid of mechanical damage (crushing, abrasion), occur only at the bottom and are found in a mass of singular both uncrushed and fractionated shells.

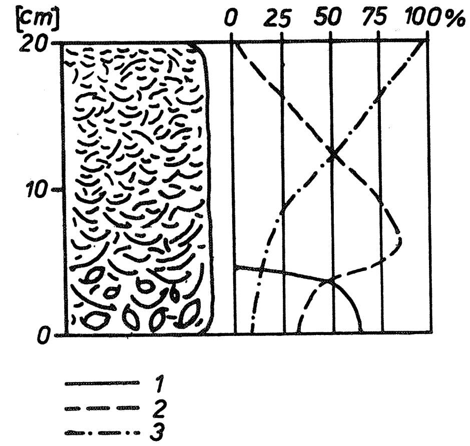

Fig. 2. Development of the coquina layers of the complex *A*. The picture shows variability in content of the organic remains of various preservation, in the vertical sections. *1* – complete preserved specimens, *2* – disarticulated, but not crushed shells, *3* – disarticulated and strongly crushed shells

Fig. 2. Zróżnicowanie zawartości szczątków organicznych o różnym stanie zachowania w profilach pionowych warstw muszlowców kompleksu *A*. *1* – kompletnie zachowane okazy, *2* – rozłączone, lecz nie pokruszone muszle, *3* – rozłączone i silnie pokruszone muszle

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[1] The name *Coenothyris vulgaris* has been used on the ground of macroscopic determination, based on works of Schmit (1928), Assman (1937) and Senkowiczowa (1979). Therefore, the problem of diversity of meaning of the species' qualification is omitted. Usnarska-Talerzak (1981) pays attention to this question on the basis of the brachidium structure.

2. Towards the top, the number and size of uncrushed shells decreases, whilst the amount of crushed shells increases. Similarly, the degree of fractionation of bioclastic material increases, so that in the top of coquinas, there occurs almost exclusively fine organogenic detritus, up to 3 mm in diameter.

Graded bedding, expressed in this way, is the effect of gravitational selection of bioclastic material, easily settling from suspension. Similar examples are described by Brenner and Davis (1973), Specht and Brenner (1979) and Bodzioch (1984). Such an interpretation can be supported by concave-up arrangement of single shells (Fig. 3) which were probably not being turned by currents. This arrangement is considered to be primary, because there are no indications of shell reorientation. Toots (1965) and Clifton (1971) described reorientation of shells due to activity of infauna, while Clifton and Boggs (1970) described similar cases but owing to activity of currents.

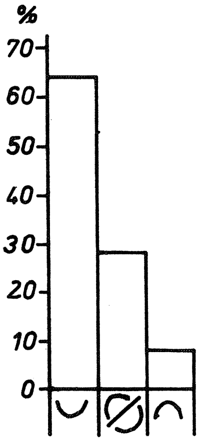

Fig. 3. Orientation convex-up/convex-down of disarticulated shells in the shell beds of complex *A*

Fig. 3. Ułożenie rozłączonych muszli w warstwach muszlowców kompleksu *A*

Within the described layers there occur small erosional channels, up to 1 m wide and several cm deep, displaying reversed arrangement of shells, while the graded bedding remains unchanged. These channels were connected with small, short-term flows, the origin of which will be described below.

The described sequence of arrangement of organic remains recurs in the majority of layers, that permits to call them composite layers (Aigner *et al.* 1978), originating in several stages (Fig. 4). The above features of coquina layers, as well as their sharply defined top and bottom, made it possible to relate their origin to storm accumulation (*cf.* Ager 1974, Aigner 1977, 1979).

Lateral changeability is manifested in the bottom of the coquinas. The major part of bottom surfaces of coquina layers is shaped as shown in Fig. 2. Such a bottom surface changes laterally into accumulations, composed of completely preserved

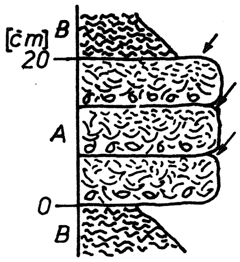

Fig. 4. Composite coquina layer (*A*) within marly limestones exhibiting wavy and crumpled bedding (*B*). The arrows shows the surfaces covered by *Thalassinoides* type of traces

Fig. 4. Złożona ławica muszlowca (*A*) w obrębie marglistych wapieni wykazujących strukturę falistą i gruzłową (*B*). Strzałki pokazują powierzchnie pokryte śladami typu *Thalassinoides*

specimens (Pl. II, Fig. 1). These specimens are considered as autochthonous on the basis of the following properties:

1) domination of specimens found in life position (Fig. 5),
2) size distribution of brachiopods (Fig. 6) indicative of the lack of redeposition (Fagerstrom, 1964; Craig, Hallam, 1963; Thayer, 1975),
3) the lack of abrasion and of disarticulation of shells (Boucot, 1981).

Ordinary crushings of shells comprise only those parts which are not filled with sediment. It permits to relate their origin to compaction.

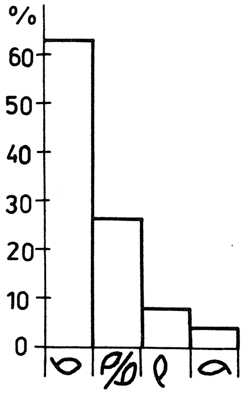

Fig. 5. Orientation of brachiopods in the autochthonous accumulations (biostromes), showing domination of specimens in growth position

Fig. 5. Ułożenie ramienionogów w nagromadzeniach autochtonicznych (biostromach) ukazujące dominację osobników w pozycji życiowej

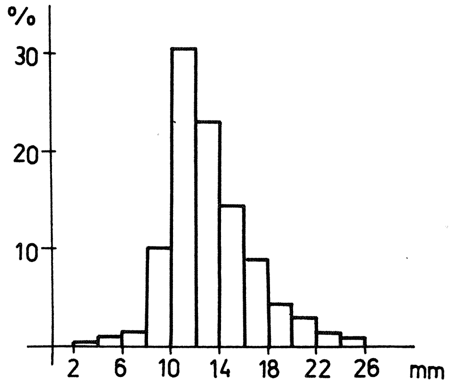

Fig. 6. Size-frequency of *Coenothyris vulgaris* in the biostromes. The histogram denotes lack of redeposition of dead brachiopods (displacement in the direction of small-size specimens)

Fig. 6. Zróżnicowanie wielkości osobników *Coenothyris vulgaris* w biostromach. Histogram wskazuje na brak redepozycji ramienionogów (przesunięcie w kierunku osobników mniejszych)

The presence of epibionts (*Placunopsis plana*) and of attachment scars of brachiopod pedicles (*Polichnus silesiacus* – Małkowski, 1975), occurring abundantly on specimens of *Coenothyris vulgaris*, leads to the conclusion that the accumulations represent biostromes analogous to those, known from SW Germany (Hagdorn, Mundlos, 1982).

Although the observed biostromes are just fragments of larger accumulations, it is easy to notice features indicative of opportunistic character of *Coenothyris vulgaris*:

1) decisive domination of this species, attaining 86%,
2) the species appears suddenly in great quantities and on a vast area; it enables to accept its appearance as isochronous,
3) a marked horizontal differentiation of the size of specimens,
4) similar number of specimens of different ranks occurs at the same level,
5) a tendency to form assemblages of the same size.

The presence of opportunistic species testify to highly variable physico-chemical environmental conditions (Levinton, 1970; Alexander, 1977). A physical parameter controlling sedimentation was, most probably, environmental energy. It could be confirmed by exceptionally numerous storm episodes, by the composition of fauna, represented almost exclusively by species displaying massive, resistant to mechanical damage, skeleton; and by the distribution of biostromes pointing to the presence of current circulation zones.

A decrease in oxygen content, owing to abnormal rise in water temperature (Dżułyński, Kubicz, 1975), should have caused mass mortality not only of benthos but also of nekton. Such mortality has not, however, been proved; the amount of nekton remains in the coquinas and in crumpled limestones, does not show wide differences (on the basis of dissolution of samples in acetic acid).

Salinity changes should be excluded for the lack of data. Mass mortality of biostrome builders in such an environment, characterized by stabilized salinity and water temperatures, might have been caused by a marked increase in environmental energy, due to the "choking" with sediment. This process is one of main causes of mass mortality of suspension-feeders in contemporary shallow-water environments (Schafer, 1962). Larves, surviving thanks to planktonic mode of life, were giving rise to new biostromes.

The top of the coquina layers is covered by traces of the *Thalassinoides* type, built up of marly pelite which corresponds to crumpled limestones, intercalating coquinas (Pl. II, Fig. 2). Fragmentarily, it is also possible to observe these traces on upper surfaces of thin layers that compose composite beds (Fig. 4). The traces of *Thalassinoides*, together with the total lack of *Rhizocorallium* and *Glossofungites* traces, indicate a weak consolidation of sediment, penetrated by infauna (*cf.* Seilacher, 1964; Rhoads, 1975; Kennedy, 1975). This is relevant to slender environmental energy. The lack of suspension-feeders is though to be responsible for that (Walker, Bambach, 1974; Fürsich, 1976).

COMPLEX B

A thick complex of crumpled limestones (Fig. 1) occurs in the upper part of the Terebratula Beds. Numerous erosional channels, tens of metres wide and about 1 m deep, are visible within this complex. The channels are filled with coquinas of two types:

1) coquinas composed of small organogenic detritus, less than 3 mm in diameter,

2) coquinas built up of poorly sorted mixtures of shells, shell fragments, crinoids and intraclasts; completely preserved specimens, less than 8 mm in length, occur sporadically.

Poorly expressed graded bedding can be observed in some layers. Moreover, the coquinas occur in the shape of pseudonodules, drop structures, etc., sticking in crumpled limestones. The fauna of crumpled limestones is exceptionally scanty. It is possible to find traces of deposit-feeders and, sporadically, of a pelecypod *Hoernesia socialis*.

Considering the origin of these deposits, the author upholds the opinion of Dżułyński and Kubicz (1974, 1975) who stated that:

– the crumpled structure of limestones originated as a result of postsedimentary disturbances, related to unstable density stratification (for detailes see Bogacz *et al.*, 1968),

— coquinas were deposited on a soft, unconsolidated substratum, as indicated by the presence of numerous pseudonodules, drop structures and load folds,

— heavy crushing of shells, the lack of selection of bioclastic material, the lack of graded bedding and the appearance of coquinas as channel-fill deposits, indicate sudden deposition from high energy currents, interpreted as storm ones (*cf.* coquinas of item 2, complex *B*).

Good sorting of coquinas (item 1) might have been caused by longer transportation and/or by lower energy of currents.

INTERPRETATION

The lack of unequivocal data which could have proved the existence of bottom height changes during sedimentation of the Upper Terebratula Beds, leads to a conclusion that the bottom of sedimentary basin was flat. Deposition of various deposits must then have been assigned to hydrodynamics and to the basin depth. A model of such sedimentation is shown in Fig. 7.

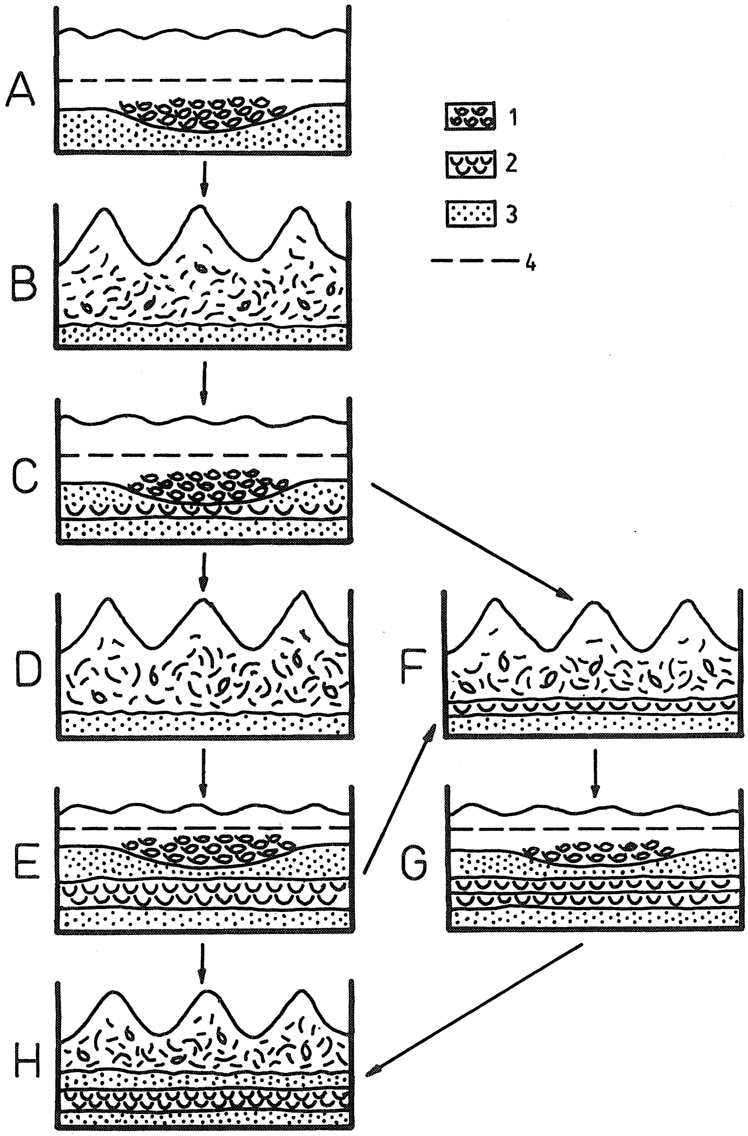

Fig. 7. The model of sedimentation of complex *A* (explanations in text). *1* — biostromes, *2* — shell beds, *3* — lime sediment, *4* — mean level of wave basis

Fig. 7. Model sedymentacji kompleksu *A* (objaśnienia w tekście). *1* — biostromy, *2* — warstwy muszlowców, *3* — osad pelityczny, *4* — średni poziom podstawy falowania

In the crumpled limestones there occurs, almost exclusively, infauna, mainly of the deposit-feeding type. It points to poor consolidation of sediments and to small turbulency near the bottom. Thus, the basin bottom must have been situated somewhat below the middle level of wave basis. The presence of biostromes, composed of suspension-feeding epifauna, indicates the existence of a certain system of bottom currents, causing turbulency and hardening of the bottom, within the zones of current flows (Fig. 7A).

A lowering of wave basis during heavy gales, down to the sediment surface, was causing mass mortality of benthos and disarticulation and crushing of shells, building biostromes. It was also producing suspended matter composed of fine-grained lime mud, mixed with bioclastic material. The suspended matter was being spread over the bottom of the sedimentary basin by waves (Fig. 7B).

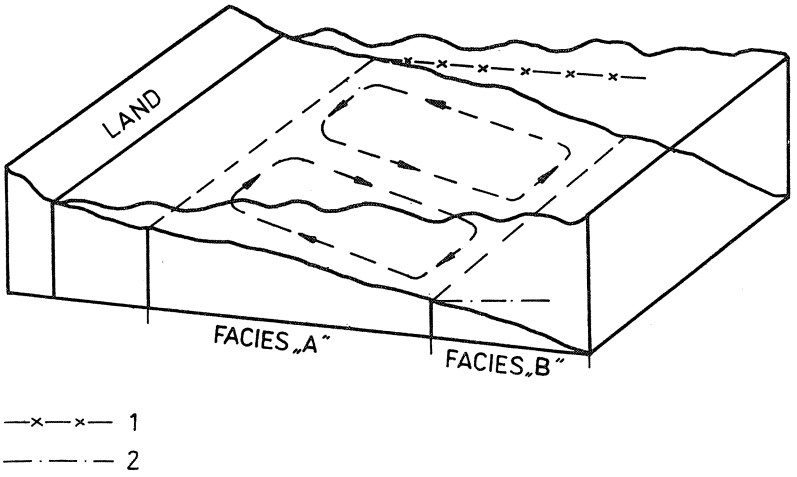

Fig. 8. Distribution of facies during sedimentation of the upper Terebratula Beds. The facies A and B corresponds to the complex *A* and *B*. *1* – mean level of wave basis, *2* – storm level of wave basis. The arrows shows hypothetical circulation of bottom currents

Fig. 8. Rozmieszczenie facji podczas sedymentacji górnych warstw terebratulowych. Facje A i B odpowiadają kompleksom *A* i *B*. *1* – średni poziom podstawy falowania, *2* – sztormowy poziom podstawy falowania; strzałki pokazują przypuszczalny układ prądów dennych

A decrease in energy caused by storm decay, was leading to deposition of shells and shell fragments, which were being gravitationally selected in respect to their size. These shells formed a thin coquina layer, displaying graded bedding. Local storm currents eroded small channels in which material transported by traction was deposited. Lime muds covering a thin layer of coquinas were being removed in the zones of bottom current circulation. Biostromes developed on the hard ground which had been formed in that way (Fig. 7C). The next storm episode was leading to increase in thickness of the shell bed (if the sediment had not been lithificated and the wave basis had reached the bottom of the previously formed lamina D – E) or to the formation of a composite bed (if the wave basis reached only the top of the previously formed coquina layer, F – G).

Owing to prograding lithifacation and the subsidence, bottom currents did not wash away completely the sediment, covering shell beds. Hence, biostromes were developing on the hardened lime mud, and the storm wave basis did not reach the top of the previously formed coquina layer (E – H, G – H). Eventually, this process lead to the formation of subsequent coquina layers.

Sediments composing the complex *B* were deposited in a zone devoid of turbulency near the bottom (the lack of autochthonous suspension-feeders). This zone was only being reached by storm currents which were depositing bioclastic material within erosional channels. In the author's opinion, the complex *B* represents a somewhat deeper facies, formed below the maximum level of wave basis, and occurring within bottom areas that were devoid of permanent circulation. The change of the type of sedimentation was a result of landward shoreline translocation (Fig. 8) caused, most probably, by subsidence of the Vindelic Ridge.

ACKNOWLEDGEMENTS

The author thanks Dr. J. Wieczorek for cristical remarks, Prof. Dr. S. Dżułyński for reading the manuscript and E. Świdnicka and P. Nowakowski for their help in preparation of this paper.

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STRESZCZENIE

W górnych warstwach terebratulowych wydzielono dwa kompleksy skał różniące się proporcją wapieni gruzłowych do muszlowców (fig. 1) oraz wykształceniem muszlowców (tab. 1), złożonych głównie ze skorupek ramienionoga *Coenothyris vulgaris*. W kompleksie dolnym (*A*) dominują allochtoniczne nagromadzenia szczątków ramienionogów występujące w formie ławic i wykazujące frakcjonalne uziarnienie muszli (fig. 2, 4), ułożonych wklęsłą stroną ku górze (fig. 3). Uznano, że nagromadzenia te powstały na skutek swobodnego opadania materiału

bioklastycznego z zawiesiny (selekcja grawitacyjna) bez współudziału prądów (ułożenie muszli). W obrębie tych ławic występują niewielkie rynny erozyjne wypełnione muszlowcem uziarnionym frakcjonalnie, w którym ułożenie muszli jest odwrotne. Tego typu osady utworzyły się w warunkach krótkotrwałych, lokalnych przepływów.

W spągu ławic muszlowcowych spotyka się autochtoniczne nagromadzenia ramienionogów, uznane przez autora za biostromy (fig. 5, 6, pl. 2, fig. 1).

Strop ławic muszlowców pokryty jest śladami typu *Thalassinoides* (pl. 2, fig. 2) świadczącymi o niewielkiej konsolidacji osadu przykrywającego muszlowce.

Wapienie gruzłowe rozdzielające warstwy muszlowców są zbudowane głównie z fragmentów osadu zachowanego pomiędzy kanałami pozostawionymi przez infaunę (pl. 1), która dominuje w tych utworach. Powyższe fakty wskazują, że struktura gruzłowa powstała w wyniku intensywnej działalności infauny.

W kompleksie wyższym (B) dominują wapienie gruzłowe, których geneza jest związana z zaburzeniami niestatecznego warstwowania gęstościowego. Muszlowce tego kompleksu występują w formie wypełnień rozległych, płaskich rynien erozyjnych oraz pogrązów i składają się albo z bardzo drobnego detrytusu organogenicznego, albo z bezładnie wymieszanych fragmentów muszli ramienionogów i małżów, którym podrzędnie towarzyszą szczątki liliowców. Uziarnienie frakcjonalne występuje bardzo rzadko i jest słabo wyrażone. Muszlowce te były osadzane na miękkim podłożu wskutek gwałtownej depozycji z prądów o wysokiej energii.

Środowisko sedymentacji zostało ogólnie określone jako płytkomorskie. Dno basenu sedymentacyjnego było płaskie i znajdowało się poniżej średniego poziomu podstawy falowania.

Mechanizm sedymentacji kompleksu *A* został przedstawiony na figurze 7. W strefie sedymentacji tego kompleksu istniała stała cyrkulacja wód dennych, co umożliwiało rozwój zawiesinożernej epifauny na utwardzonym podłożu (A). Niszczenie biostrom było zapewne związane z epizodami sztormowymi, które prowadziły ponadto do tworzenia zawiesiny składającej się z bezładnie wymieszanych szczątków organicznych i mułu wapiennego (B). Opadające swobodnie szczątki fauny tworzyły cienkie warstewki muszlowca uziarnionego frakcjonalnie, w których muszle ułożone są wklęsłą stroną ku górze (C). Kolejne epizody sztormowe przyczyniły się do wzrostu miąższości warstw muszlowców (D – E) lub powstawania ławic złożonych (F – G, fig. 4). Wskutek postępującej lityfikacji osadu oraz subsydencji, prądy denne nie rozmywały osadu przykrywającego muszlowce, a podstawa falowania w czasie sztormów nie osiągała ich stropu, co prowadziło do powstawania nowych ławic muszlowców (E – H, G – H).

Obszar sedymentacji kompleksu *B* znajdował się w strefie bardzo słabej turbulencji wód przydennych, do której sporadycznie docierały silne prądy deponujące muszlowce. Zdaniem autora, kompleks ten reprezentuje nieco głębszą fację, nie objętą stałą cyrkulacją wód dennych (fig. 8).

W związku z powyższym, zmiana typu sedymentacji w profilu górnych warstw terebratulowych byłaby nastepstwem przesunięcia facji, wywołanego obniżeniem wału windelickiego.

EXPLANATIONS OF PLATES – OBJAŚNIENIA PLANSZ

Plate – Plansza I

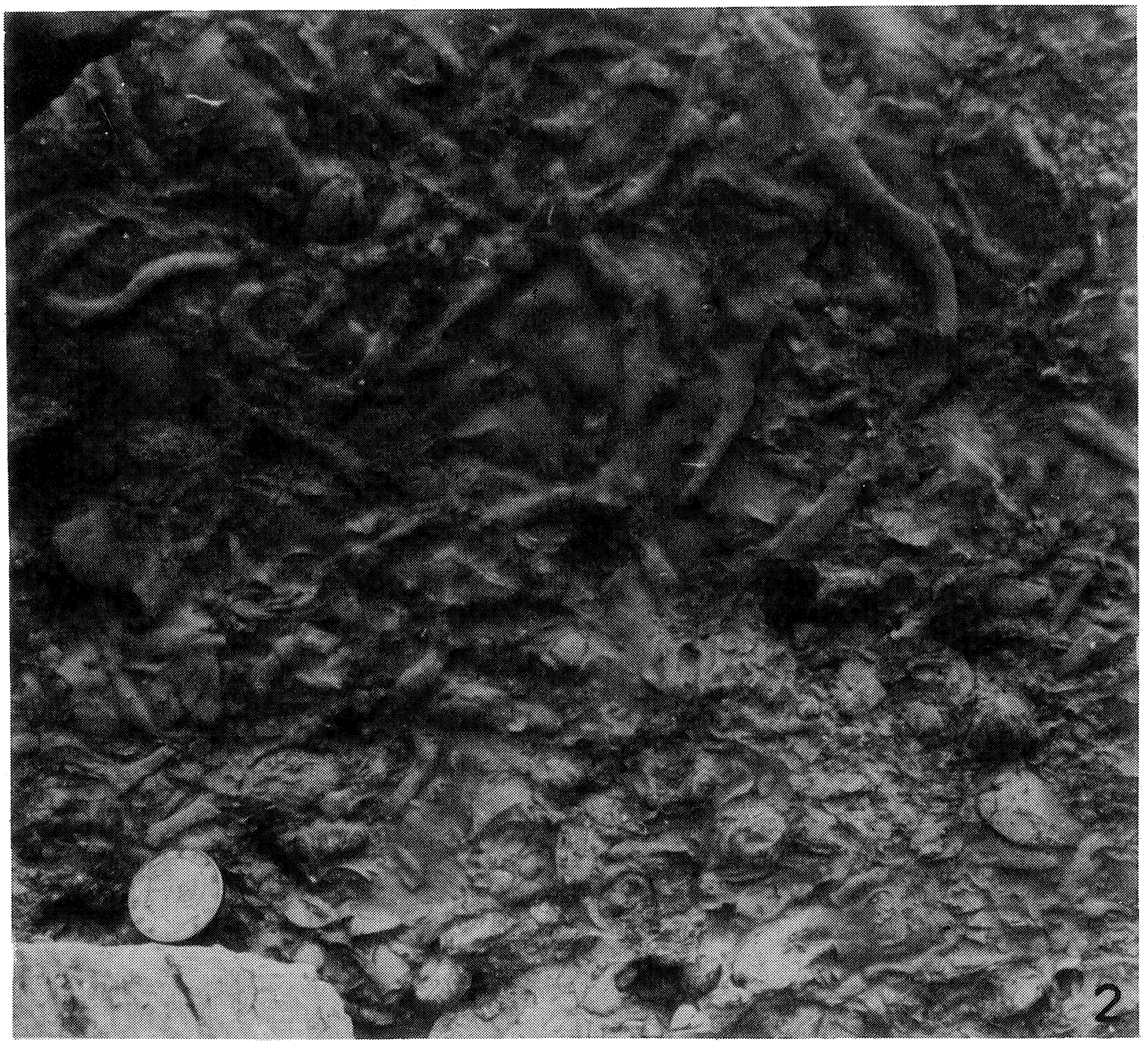
The upper surface of the crumpled bedding layer. Biogenic structures indicates that crumpled bedding was created by infaunal activity. Dziewkowice.

Górna powierzchnia ławicy wapieni gruzłowych. Struktury biogeniczne wskazują, że struktura gruzłowa powstała w wyniku intensywnej działalności infauny. Dziewkowice.

Plate – Plansza II

Fig. 1. The upper surface of the biostrome of complex *A*. Dziewkowice.
Fig. 1. Górna powierzchnia biostromy z kompleksu *A*. Dziewkowice.
Fig. 2. The upper surface of the shell bed covered by traces of *Thalassinoides*.
Fig. 2. Górna powierzchnia ławicy muszlowca pokryta śladami typu *Thalassinoides*.


1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