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Program badań płytkich złóż węgla brunatnego pozwolił na dokładne poznanie budowy szeregu niewielkich, zazwyczaj wyraźnie wyodrębnionych basenów sedymentacyjnych neogeńskiej formacji brunatnowęglowej. Zgromadzone dane geologiczne umożliwiły dokonanie rekonstrukcji środowiska sedymentacji w wybranych basenach. Rekonstrukcję tę przeprowadzono dla trzech basenów o odmiennej genezie: basenu paralicznego o sedymentacji typu barierowo-lagunowego (Trzydnik), basenu typu niecki śródgórskiej (Siedlimowice) i basenu zdominowanego przez sedymentację fluwialną (Jastrzębia).

Dla każdego z opracowywanych basenów wykonano zestaw map strukturalnych i litofacjalnych (mapy morfologii podłoża, mapy miąższościowe, mapy sumarycznej miąższości osadów klastycznych i mapy stosunków miąższościowych). Na podstawie materiału wiertniczego przeanalizowano typy sekwencji sedymentacyjnych i częstotliwość ich występowania oraz wykonano analizę cykliczności sedymentacji metodą szeregów włożonych Markowa. Prace te posłużyły do opracowania modelu środowiska sedymentacji dla każdego z omawianych basenów.

Porównując wyniki prac z modelami opracowanymi wcześniej dla rozległych trzeciorzędowych basenów brunatnowęglowych stwierdzono, że oba typy modeli wykazują daleko sięgające podobieństwo w przypadku podobnej genezy basenów. Modele opracowywane dla małych basenów sedymentacyjnych mogą zatem mieć duże znaczenie jako materiał porównawczy i stanowić narzędzie bardziej uniwersalne, przydatne także do badań struktur o znacznie większej skali.

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LOWER PERMIAN FRESHWATER BIOCOENOSIS IN LASKOWICE OŁAWSKIE–LIPOWA TROUGH (SW POLAND)

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Traces of life are exceptionally found in continental deposits of "redbeds" type. For this reason the authors decided to describe the Lower Permian assemblage of fossils and trace fossils known from Laskowice–Lipowa trough.

Laskowice–Lipowa trough (Fig. 1) is filled with red, mainly macroclastic deposits (more than 1100 m of thickness). Two different lithofacies were distinguished there – the alluvial fans facies as the predominant and the subordinate one of lacustrine deposits. The lacustrine facies is represented by sediments of both ephemeral and perennial lakes as well as swamps. It consists mainly of sandy claystones and mudstones, sandstones and conglomerates. Subordinately there are small inserts of carbonates up to 1 m thick and thin intercalations of coals and carbonaceous mudstones (in the lower part of the profile).

After lithostratigraphic correlation these deposits have been encountered to Rotliegendes, to Odra and Warta groups (11, 22). The subdivision is specified by biostratigraphic correlation based on micro- and macroflora analysis. Microflora is represented by rich assemblage of palynomorphs with high content of gymnospermous pollen grains. According to S. Jachowicz (8) these deposits belong to the lowermost Autunian and probably Saxonian (as an equivalent of Warta group approximately). In lacustrine facies macroflora is rare, wind-blown or flown on and it is represented by several of the following genus: *Calamites, Pecopteris, Taeniopteris, Cordaites* (after A. Kotasowa, 13). This assemblage is scarce but similar to Autunian flora of Karniowice calcareous sinter described by I. Lipiarski (18). This paper concerns the part of infilling of Laskowice–Lipowa trough which is encountered to Autunian. Allochthonous micro- and macroflora found in the sediments was a part of entire lacustrine paleobiotope, it is conceived as the defined place (environment) where the paleobiocoenosis lived. The described paleobiocoenosis is composed of: 1) ichnocoenosis of muddy-sandy facies, 2) biocoenosis of carbonate facies.

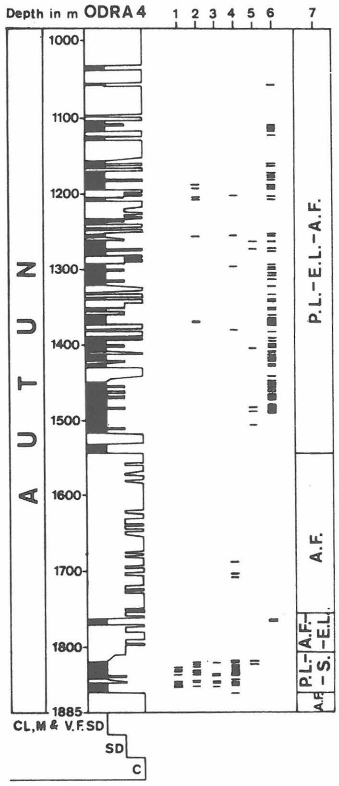
ICHNOCOENOSIS OF MUDDY-SANDY FACIES

Most abundant trace fossils have been encountered to Fodinichnia ethologic group. These structures are produced by mud feeders. Three kinds of trace fossils have been distinguished basing on the parameters like diameter, infilling, curvature and features of burrow walls (21). Most commonly found is *Planolites*, while *Palaeophycus* and cf. *Teichichnus* are rare. The following taxonomic subdivision of the ichnogenus of *Planolites* Nicholson, 1875 has been applied: *Planolites beverleyensis* (Billings, 1862) and *Planolites montanus* Richter, 1937 (Phot. 2–7 on the 3rd cover).

Description. Organisms reworked the sediment during their searching for food and left burrows from 1 to randomly 25–30 mm in diameter (on average 3 to 10 mm). Burrows are round in cross section (rarely ovate–then probably due to compaction), with smooth walls. Infillings (maximum length 30–40 cm observed in drilling core) are usually structureless and slightly differ from surrounding sediment. These differences are most distinct at the boundaries between layers of other grains

Fig. 1. Location of the study.

1 – main faults, 2 – probable maximum extent of lacustrine lithofacies, 3 – boreholes with recorded Rotliegendes.



Ryc. 1. Rów Laskowic Oławskich–Lipowej (miejsce badań).

1 – główne uskoki, 2 – prawdopodobny maksymalny zasięg litofacji jeziornej, 3 – wiercenia, w których stwierdzono czerwony spągowiec.

Fig. 2. Fragment of profile of Rotliegendes from Odra 4 borehole at Laskowice Oławskie–Lipowa trough (generalized).

cl – claystone, m – mudstone, v.f. sd – very fine sandstone, sd – sandstone (medium and coarse), c – conglomerate. 1 – coal seams and carbonaceous mudstones, 2 – detritus and macroflora imprints, 3 – occurrence of spores, 4 – occurrence of sporonites, 5 – limestones in regular interbeds, 6 – occurrence of bioturbations, 7 – interpretation of paleoenvironment. A.F. – alluvial fans, P.L. – perenial lakes, S. – swamps, E.L. – ephemeral lakes.

Ryc. 2. Fragment profilu czerwonego spągowca z otworu Odra 4 w rowie Laskowic Oławskich–Lipowej (zgeneralizowany).

cl – iłowiec, m – mułowiec, v.f.sd. – piaskowiec bardzo drobnoziarnisty, sd – piaskowiec średnio i gruboziarnisty, c – zlepieniec. 1 – pokład węgla i mułowce węgliste, 2 – detrytus i odciski makroflory, 3 – występowanie spor, 4 – występowanie zarodników grzybów, 5 – wapienie w formie regularnych przewarstwień, 6 – występowanie bioturbacji, 7 – interpretacja paleośrodowiska. A.F. – stożki aluwialne, P.L. – długotrwałe jeziora, S. – bagna, E.L. – efemeryczne jeziora.

size distribution. Locally the bioturbations completely obliterated the boundaries between layers and thus several meters thick series of structureless sediments are observed. The burrows are irregularely meandering (sometimes to small extent) and often get almost vertical position.

The ichnogenus of *Palaeophycus* Hall, 1847 is represented by *Palaeophycus tubularis* Hall, 1847 (?) (Phot. 1).

Description. Irregular, curved burrows, from 3 to 10 mm diameter with smooth walls. According to macroscopic observations their infillings do not differ from surrounding sediment. Sometimes the burrows are very close patterned and then cause the homogenization of the sediment.

Besides mentioned above the ichnogenus of cf. *Teichichnus* Seilacher 1955 has been distinguished (very rare).

Description. Horizontal tube 18–30 mm in diameter. Inside the spreite structure occurs. It is composed of fine grained sand and clay laminae which slightly differ each from other in colours. The surrounding sediment is homogenous.

Remarks. Though the taxonomic subdivision is based on morphologic features (21) the traces described above seem to reflect the activity of the same type of ichnofauna (besides cf. *Teichichnus*). Organisms searching for rich in organic matter clayey-muddy horizons, penetrated the sediment in all the directions. Sometimes they crossed the layers of coarse grained sandstones which are few to about a dozen centimeters thick (Phot. 2). It seems that the high activity of animals resulted from scarcity of food which was caused by periodic changes of lake trophism and frequently repeated modifications of its bottom morphology. Food consisted of decaying organic matter (probably also small algae and bacteria colonies) and the remains of macroflora. According to A. Kotasowa, numerous perforations observed in highly disintegrated detritus (fragments of stems and leaves) are produced by organisms.

In some cases they also exploited other previously formed traces. According to Frey and Seilacher (4), the former traces could facilitate motion within the sediment and could contain nutritive plant remains (Phot. 7). A sudden appearance of numerous bioturbations and their gradual disappearance repeats periodically. The number of bioturbations decreases in particular cycles that reflects the deterioration of living conditions for mud feeders in the entire basin (Fig. 2). Periodicity of bioturbations is associated with slightly expressed sedimentary cycles observed in lithologic profiles (coarsening upward cycles).

BIOCOENOSIS OF CARBONATE FACIES

Carbonate lacustrine facies occur as:
1) irregular, locally nodular horizons of calcification which appear in mudstones, sandstones and conglomerates;
2) horizons of calcareous concretions of different size;
3) carbonate layers.

Only fine bioclasts are found within the calcificated horizons Carbonaceous concretions which sparitic matrix is development to different degree, locally contain numerous small bushing microorganisms. Carbonate layers reveal relatively high microfacial differentiation and contain most diversified assemblage of fossils.

Generally two microfacies have been separated within the carbonate layers (Fig. 3) – bioclastic-peloid wackestones and packstones, which are developed to different degree and underlie (locally also overlie) the laminated deposits.

Bioclastic-peloid wackestones and packstones generally reveal traces of transportation thus the organic remnants are bad preserved and represent the assemblage of redeposited fossils. Only some organisms could exist *in situ* there (e.g. ostracods, gastropods). The others were probably removed from nearby parts of the lake bottom, because the assemblage of fossils slightly differs from this one which was recorded in laminated deposits (frag-

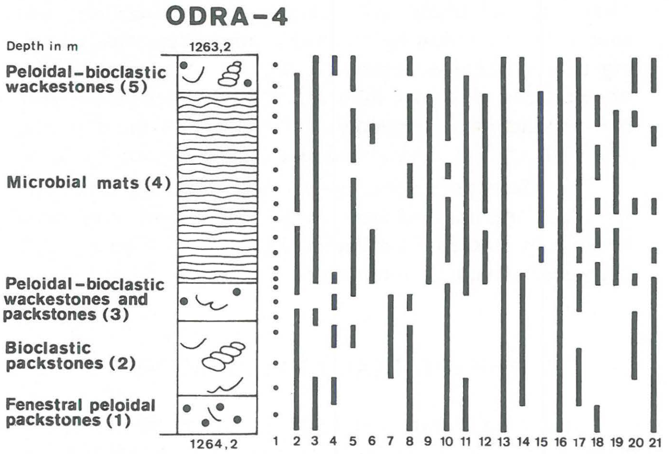


Fig. 3. Litofacies of carbonate bedlayer. Composition and processes.

1 – thin section, 2 – gastropods, 3 – ostracods, 4 – bivalves, 5 – simple serpulids, 6 – incrustation of serpulids, 7 – intraclasts, 8 – microoncoids, 9 – micrograins *sensu* K. Dahanayake et al. (2), 10 – peloids *sensu stricto*, 11 – fenestrae, 12 – bioturbation, 13 – micritization of skeletal elements, 14 – transportation, 15 – fragmentation of mat, 16 – micrite, 17 – microsparite, 18 – sparite, 19 – dolomite, 20 – sulphate, 21 – quartz.

Ryc. 3. Litofacje warstwy węglanowej.

Facje: 1 – fenestralne pakstony peleoidowe, 2 – bioklastyczne pakstony, 3 – peleoidowo-bioklastyczne wakstony i pakstony, 4 – maty mikrobiologiczne, 5 – peleoidowo-bioklastyczne wakstony. Skład ziarnisty i procesy sedymentacyjne: 1 – lokalizacja płytek cienkich, 2 – ślimaki, 3 – małżoraczki, 4 – małże, 5 – pojedyncze serpule, 6 – inkrustacje serpulowe, 7 – intraklasty, 8 – mikroonkoidy, 9 – pojedyncze lub skupienia mikroziarn *sensu* K. Dahanayake et al. (2), 10 – peloidy *sensu stricto*, 11 – struktury fenestralne, 12 – bioturbacje, 13 – mikrytyzacja elementów szkieletowych, 14 – transport materiału, 15 – fragmentacja maty, 16 – mikryt, 17 – mikrosparyt, 18 – sparyt, 19 – dolomit, 20 – siarczan, 21 – kwarc.

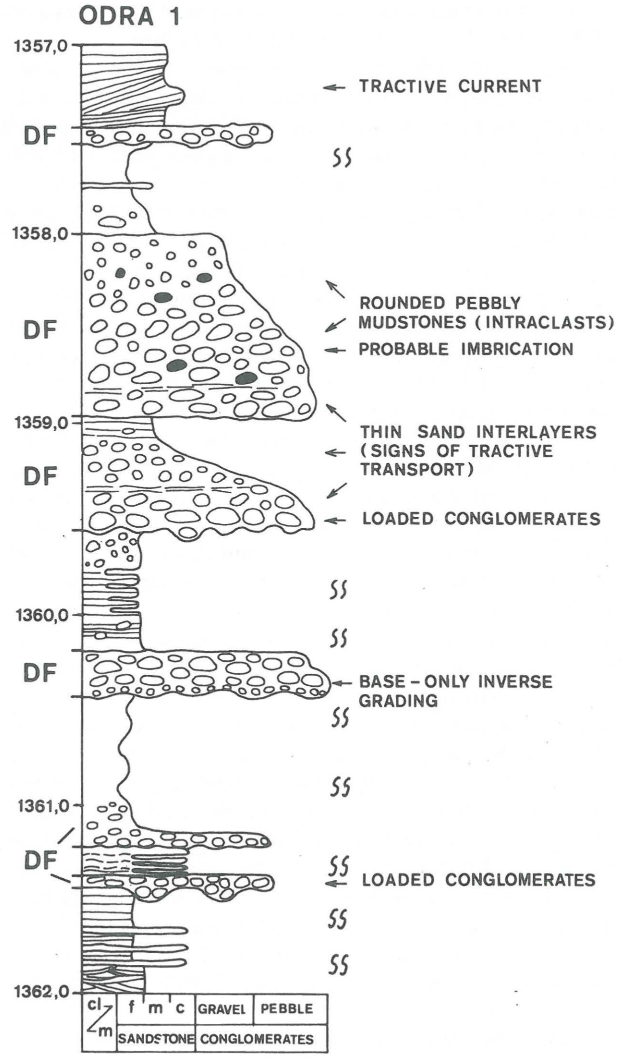


Fig. 4. Subaqueous debris flow deposits (Odra 1 borehole), interpretation after W. Nemec and R.J. Steel (20).

DF – debris flow, SS – bioturbations.

Ryc. 4. Podwodne spływy rumoszu (wiercenie Odra 1), interpretacja wg W. Nemeca i R.J. Steela (20).

DF – spływ rumoszu, SS – bioturbacje.

ments of bivalve shells are relatively more frequent – Fig. 3). All these organisms are benthic.

Small gastropods (up to 1 cm) are found most frequently. Their shells are predominantly smooth, fusiform, conical or spiral, rarely with side appendages. In wackestones and packstones they are often crushed and relatively less frequent but in mats on the contrary, shells are generally intact and much more frequent, because gastropods took part in the mat forming. Their activity resulted in numerous bioturbations which caused in turn the high homogenization of the lower mat horizons and obliteration of its primary laminated structure. The mat surface, fresh and relatively loose, was the food source for several grazing, scraping and ingesting organisms. Bioturbations also affected chemism of the sediment and caused its litification (see 9).

Besides gastropods, excellent preserved serpulid tubes were found pretty often. Their cross section size and the thickness of walls are different. They appear most frequently within the mats, though in detritic carbonate microfacies they occur as incomplete incrustations on the surface of the bigger bioclasts. The tubes of these worms are most often horizontally patterned, parallel either to lamination or to the primary sediment surface. Locally, in small hollows within the mat, serpulid tubes appear upward stratified, but their lateral extent is short then. In places serpulides overgrew the uppermost skeletal fragments but generally they occur in the lower parts of the mats. Vertical funnels with distinctly visible walls were found very rarely and almost entirely within the mats. They were produced by ingesting and penetrating organisms.

Scarcity of bioturbating and incrusting animals in described deposits could result from: 1) their character – being the mud feeders they had to be at least in permanent contact with the sediment surface. Moreover, these animals could specialize in feeding on the mat, by scraping food from its surface; 2) big amount of biomass in the mats, that caused the changes of chemism within the deposit and were detrimental to animals because of high consumption of oxygen and raising of H_2S concentration.

Such conditions delimit the development of both penetrating and incrusting organisms which live in biologic mats (14). Erosion and rapid sedimentation which restrict the populations of bioturbating animals, were lacking in described environment and bioturbations could easy advance.

Biologic annihilation of mats was sometimes associated with other destructive physical factors like short time exposure and dissicating of the mats, their fragmentation and erosion. Erosion restrained the growth of mats. Drifting particles of sediment eroded the mat and then were physically deposited on its surface that suddenly interrupted growth of organisms. The development of mat could be stopped also by high rate sedimentation of carbonates (as shown in Fig. 3) but most often by deposition of clastics. On the other hand this kind of sedimentation protected the mat from waving and current effects.

The other organisms i.e. bivalves and ostracods played rather subordinate part in the sediment forming. Microorganisms took remarkable part in accretion of the carbonaceous intercalations within clastics.

Mats are changeable in character – from laminites to laminoids (sensu 19) of simple to complex lamination. Laminae are dense, locally distinctly visible, usually of flaser texture, void of not carbonaceous grains, with bioclasts patterned parallel to lamination. The analysis allowed to distinguish two kinds of laminae (Phot. 8) which differ each from other in the following: kind of organisms which formed them, their arrangement, thickness kind of matrix, kind of carbonaceous grains and bioclasts content.

Each laminae was the living space of cyanobacteria. Diversity and alteration of laminae corresponds to the type of these microorganisms – filamentous cyanobacteria (Phot. 9) prevailed alternatively with the coccoid ones (Phot. 10). This microbiocoenotic changeability is responsible for the character of the mats. The domination of given cyanobacteria type and the arrangement of filaments allowed to distinguish several types of laminae as proved by K. Dahanayake et al. (2) according to the results of their studies upon fossiled and recent microbiologic mats and lab experiments.

Basing on this classification two kinds of lamination have been discerned within examined mats – L_h type (horizontal arrangement of filamentous cyanobacteria and their domination in a lamina (and L_{dv} type) oblique to vertical arrangement and domination of coccoid forms). These cyanobacteria mats grew in the upper parts of the lake littoral (epilimnion). Their rate of acretion depended upon the depth of the lake bottom and the year lacustrine cycle i.e. temperature, insolation, oxidation and H_2S content changes (17, 15, 16). Filamentous cyanobacteria grew better during cool periods while coccoid ones during warm periods. Seasonal physical and chemical changes affected the increase of particular population and resulted in periodic development of the mat.

The main factor which controlled the mat's growth was the cementation with calcium carbonate because both trapping and binding of sediment by microorganisms was insignificant and periodically ceased. In the lakes, calcium ions derive mainly from river water inflows while CO_3^{2-} originate mostly from the respiration of entire biomass and bacterial reduction of organic matter (14, 6, 10), whereas ion exchange with atmosphere proceeds very slowly (J. Verduin 1975, S. Emerson 1975, in: 10).

In described mats the character of observed laminae revealed their origin – they were formed not by trapping and binding but due to microbiological control of cementation.

Besides accretion of carbonates, microorganisms also decomposed the carbonate substrate. Biological abrasion was associated with biological corrosion (terminology after J.B. Schneider, 23). This type of bioerosion was caused by the following endolithic microorganisms: fungi, algae, bacteria and lichens (7, 23, 12). According to the observations (16), less than 2% (on average) of the year mat production is preserved as a mat within the deposits. The rest of it is degradated due to activity of bacteria.

The effects of chemical dissolving of calcium carbonate by organisms is distinctly visible on skeletal fragments because in studied microfacies they generally reveal high degree of structural alteration.

DEPOSITIONAL ENVIRONMENT

Rates of accumulation and the nature of lacustrine deposits in Laskowice Oławskie – Lipowa trough depended mainly upon the subsidention rate. The sedimentation started with conglomeratic deposits. Subsequently the clayey-sandy deposits appeared. Rare traces of animals activity have been observed there (borehole Odra 1). Declining of environment energy enabled the development of swamp deposits. Numerous thin coal seams and carbonaceous siltstones with imprints of flora were found there (Fig. 2). The petrographic composition of coals (see I. Grotek and A. Szymkowiak, this volume) indicates that they originated in periodically dessicating peat-bogs under oxidizing conditions. A reincrease of environmental energy produced the conglomeratic-sandy deposits with interbeds of claystones, mudstones and rarely with thin beds of limestones. Numerous horizons of bioturbations have been observed within them.

The above described freshwater biocoenosis was composed of benthic organisms which strongly depended on all environmental conditions, like the depth of the basin, water temperature, oxidation of the bottom layer, supply of the organic matter and catastrophic events which totaly annihilated sedentary organisms in some areas. It seems that just catastrophic events limited the development of biocoenosis in the described basin. Rapid debris flows or mud flows entered the lake, eroded its bottom and often covered it with layers of few meters thick conglomerates (11, 20). In subaqueous conditions the flows were deposited as typical density currents (1, 3). As a result, new sediments became differentiated from many meters thick conglomerates to thin silty-sandy layers (Fig. 4). Often repeated flows did not allow to complete development of fine clastic lacustrine facies which are in turn destined to be settled by organisms. At the same time other bottom areas remained not devastated, thus the new sediment became quickly colonized. Longer periods of calm conditions caused the development of micritic limestone horizons. To some extent they are similar to freshwater limestones (laminated algal mats reaching 2 m in thickness) from Lower Permian Saara-Nahe Basin (24).

The comparison confirmed that carbonate horizons from Laskowice Oławskie – Lipowa trough were formed in shallow water, photic environment of low rate sedimentation and low mobility of water. From time to time the algal mats partly emerged probably because of the oscillations of water level.

The annihilation of biocoenosis was gradual. Living conditions became worse and worse because of the gradual burying of the basin which was vanishing until it entirely disappeared.

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STRESZCZENIE

Dolnopermski rów tektoniczny Laskowic Oławskich–Lipowej wypełniają gruboklastyczne osady (ponad 1100 m miąższości) typu "red beds". Wyróżniono dwie podstawowe litofacje. Są to: facja stożków napływowych i facja osadów jeziornych. W osadach jeziornych stwierdzono istnienie słodkowodnej paleobiocenozy, w skład której wchodzą: ichnocenoza facji mułowcowo-piaskowcowej oraz biocenoza facji węglanowych. Ichnocenozę tworzą skamieniałości śladowe zaliczone do grupy etologicznej Fodinichnia. Są to ichnorodzaje: *Planolites* (najbardziej rozpowszechniony) oraz występujące rzadko *Palaeophycus* i cf. *Teichichnus*. Organizmy pozostawiające tego typu ślady charakteryzowały się dużą ruchliwością, wynikającą z niewielkiej ilości pożywienia w osadzie oraz koniecznością częstych zmian obszaru zasiedlenia. Zmiany te były wywołane przez subakwalne spływy rumoszu. Te wydarzenia o charakterze katastroficznym powodowały zagładę bentosu na pewnych obszarach oraz ponowną kolonizację przez organizmy świeżo złożonego osadu.

Nagłe liczne występowanie bioturbacji i ich stopniowy zanik powtarza się z wyraźną cyklicznością. Frekwencja występowania bioturbacji odzwierciedla w skali całego zbiornika stopniowe pogarszanie się warunków egzystencji organizmów mułożernych. Facje węglanowe stanowią nikły procent w profilu litologicznym zbiornika. Pojedyncze przewarstwienia węglanów osiągają maksymalnie do 1,1 m miąższości.

Szczegółowo omówiono zróżnicowanie mikrofacjalne i zespoły kopalne węglanowych warstw kopalnego jeziora. Utwory te zaczynają i kończą się sedymentacją detrytycznych osadów wypiennych, wykazujących cechy redepozycji i złożonych z przetransportowanego zespołu kopalnego. Utwory detrytyczne są przedzielone względnie grubszymi pakietami biogenicznych osadów wykształconych jako maty mikrobiologiczne. Wśród makrobentosu wybitnie aktywną rolę odegrały ślimaki, które doprowadziły do intensywnej bioturbacji biogenicznych węglanów. Pozostałe organizmy: serpule, małże, małżoraczki jedynie zasiedliły dostępne obszary dna jeziora. Osady te charakteryzują się także niewielkim udziałem organizmów penetrujących w osadzie. Maty mikrobiologiczne zbudowane są z filamentowych i kokoidowych cyjanobakterii i powstały w warunkach płytkowodnych, w okresach zwolnionej i spokojnej sedymentacji węglanowej. Głównym czynnikiem warunkującym ich rozwój była kontrolowana biologicznie cementacja węglanem wapnia. Mikroorganizmy jednocześnie dekomponowały węglanowy substrat.