

# OYSTER BUILDUP WITHIN THE DISAEROBIC-FACIES MUDSTONES (MIDDLE JURASSIC, CENTRAL POLAND) – EXAMPLE OF BENTHIC ISLAND COLONIZATION

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Hoffmann, M. & Krobicki, M., 1989. Oyster buildup within the disaerobic-facies mudstone (Middle Jurassic, Central Poland) – example of benthic island colonization. *Ann. Soc. Geol. Polon.*, 59: 299-330.

**Abstract:** In the mudstone complex which is exposed in the lignite open-pit „Bełchatów” there occurs a small oyster buildup. The buildup developed on the lens of the coquina including numerous hiatus-concretions and is surrounded by mudstone. Sedimentation of mudstones took place in disaerobic conditions, where development of benthos was restricted due to low oxygen concentration. Development of oyster buildup was possible due to the presence of the stable benthic island built of coquina which originated as the redeposited, reworked horizon. The buildup formed during episodic cessation of mud deposition and increase in aeration of bottom water.

**Key words:** oyster buildup, hiatus-concretions, disaerobic sediment, Middle Jurassic, Central Poland.

*Manuscript received June 1988, accepted August 1988*

## INTRODUCTION

Among the numerous factors affecting growth of carbonate buildups, the basic are: physicochemical properties and fertility of water, energy of environment, clastic sedimentation rate and type of substratum (Dzik, 1982). The present paper aims at presenting the variability of these factors found within the complex of Middle Jurassic mudstones exposed in the lignite open-pit mine „Bełchatów”. The environmental changes have been interpreted in the present paper from analysis of growth of a small oyster buildup as well as from sedimentary structures and ecological features of fauna in the rocks surrounding the buildup.

Oysters, existing since Triassic, in Jurassic attain ability to form buildups and lumachelle. The notion of carbonate buildup refers primarily to the

geometry of the structure of a distinctly positive relief (Heckel, 1974). The term lumachelle is commonly applied to the biolithitic accumulations of organisms that formed due to the successive intergrowth of individuals (*cf.* Dzik, 1982). In literature lumachelles are also referred to as reefs. However, they usually form isolated shoals or discontinuous accumulations of an indistinct positive morphology.

Table 1

## Selected geological examples of the ancient oyster buildups

Age	Localization	Environment	Author(s)	Dominant species
Recent	USA	estuarine (brackish)	Hopkins, 1979	<i>Crassostrea virginica</i>
Recent	USA	bay (estuarine)	Wells, 1961	<i>C. virginica</i>
	Japan	brackish, lake	Chinzei, 1982	<i>C. gigas</i>
Recent— -Pleistocene	USA	brackish, lake and lagoon	Shepard & Moore, 1955	<i>C. virginica</i>
Pleistocene	Japan	brackish	Chinzei, 1982	<i>C. gigas</i> ,
Neogene (M)	Poland	normal marine	Bielecka, 1959; Pisera, 1985	<i>Neopychodonte navicularis</i>
Neogene (M)	Hungary	meso-to polyhaline	Bohn-Havas, 1985	<i>Crassostrea gryphoides</i>
Neogene (M)	Somaliland	brackish	Azzarolli, 1958	<i>Ostrea latimarginata</i> , <i>C. gryphoides</i>
Palaeogene (O1)	USA	brackish	Lawrence, 1968	<i>Crassostrea gigantissima</i>
Palaeogene (O1)	New Zealand	marine and brackish	Nelson <i>et al.</i> , 1983	indet. <i>Flemingostreines</i>
Cretaceous (Cr <sub>3</sub> )	Japan	tidal levels	Chinzei, 1982	<i>Crassostrea</i> sp.
Cretaceous (Cr <sub>1</sub> )	USA	marine and brackish	Laughbaum, 1960	<i>Ostrea (Lopha) quadriplicata</i>
Jurassic (J <sub>3</sub> )	Poland	marine	Pugaczewska, 1971	<i>Alectryonia gregarea</i>
Jurassic (J <sub>3</sub> )	Portugal	meso-to brachyhaline	Fürsich, 1981; Werner, 1986; Fürsich & Werner, 1986	<i>Praeexogyra pustulosa</i> , <i>Nanogyra nana</i> ass., <i>Liostrea</i> sp.
Jurassic (J <sub>2</sub> )	Poland	brackish	this paper	<i>Liostrea explanata</i>
Jurassic (J <sub>2</sub> )	England	brackish, lagoon	Richardson, 1933 <i>fide</i> Hudson & Palmer, 1976	<i>Praeexogyra hebridica</i>
Jurassic (F <sub>2</sub> )	England	brachyhaline	Hudson, 1963a, b	<i>P. hebridica</i>

Development of an oyster lumachelle was described in the paper by Dzik (1982). In Table 1 geological examples of oyster buildups are collected. The best known are "reefs" from the Bajocian through Bathonian Great Estuarine Series of Scotland (Hudson, 1963a, b) and from the Kimmeridgian of the Lusitanian Basin in Portugal (Werner, 1986). In Central Poland, small Middle Jurassic oyster lumachelles are known from the area of Bełchatów (Kopik, 1979) and Łęczyca (Pugaczewska, 1986).

### GEOLOGICAL SETTING

Lignite open-pit "Bełchatów" is situated in central Poland, in the southern part of the Laramian Łódź synclinorium. In this area, in the central part of the small anticline of Łękińsko, the Lower and Middle Jurassic strata directly underlie the Tertiary. The lignite deposit is located in the Miocene Kleszczów graben that intersects this anticline. In the southwestern flank of this graben, in the pit, the Middle Jurassic rocks are exposed (Fig. 1).

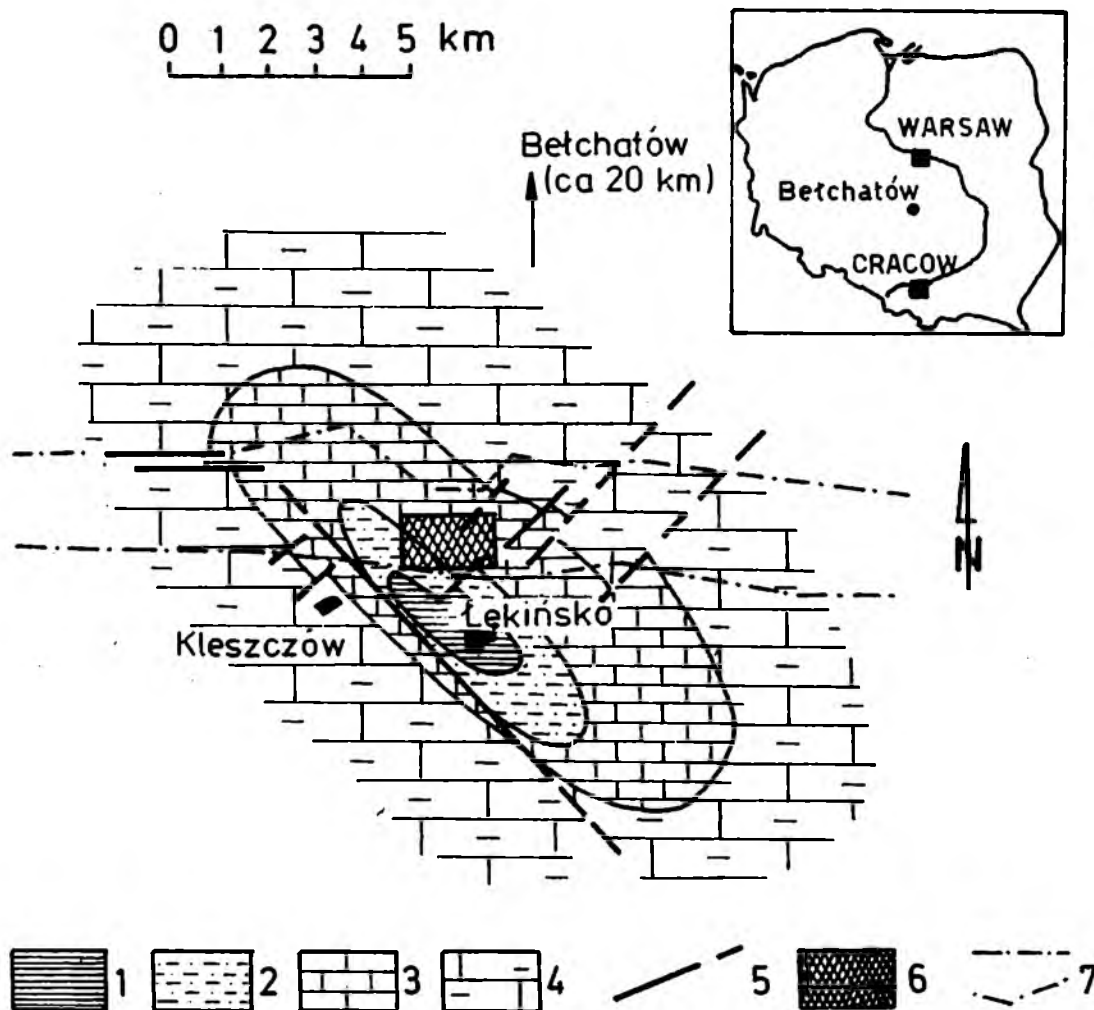


Fig. 1. Geological sketch of the Bełchatów Mine area without Cainozoic (according to Cieśliński & Dąbrowska, 1980). 1 – Lower Jurassic; 2 – Middle Jurassic; 3 – Upper Jurassic; 4 – Upper Cretaceous; 5 – faults; 6 – pit of the mine; 7 – inferred course of the Kleszczów graben

In the area of Bełchatów, the Middle Jurassic strata determined in bore-holes include Bajocian, Bathonian and Callovian. The Bajocian and Bathonian deposits are developed in the dark mudstone, claystone, and sandstone facies, subordinately iron oolite and bivalve-serpulid coquina (Kopik, 1979).

In Middle Jurassic time marine sedimentation over the area of the today Poland took place in the epicontinental basin of a variable size, whose axis was formed by the Danish-Polish trough (*cf.* Dayczak-Calikowska & Kopik, 1973). To the north and east the basin bounded on Fennoarmatian land, whereas its connection with the Tethys was restricted by the Bohemian and Beskid Massifs (Dadlez & Kopik, 1972; Ziegler, 1982) Such setting hindered water circulation and enhanced supply of the fine-derived organic matter. This is reflected by the occurrence of dark fine-grained clastic sediments in the central part of the basin during Bajocian and Bathonian. In the near-shore zone the coarse-clastic sedimentation prevailed (Dadlez & Kopik, 1972).

## DESCRIPTION OF THE SECTION

Middle Jurassic sediments that crop out in the pit occur in the marginal fault zone of the Kleszczów graben and are strongly deformed, what complicates reconstruction of a continuous section. In the bottom part of the exposure dark claystone occur with numerous horizons of large siderite and smaller calcareous concretions. Higher in the sections these sediments pass into dark mudstones within which the discussed oyster buildup occurs. The mudstones are overlain by a complex of fine-grained sandstones and sideritic bivalve-serpulid coquinas (Fig. 2A). A 6-m segment of the section surrounding the oyster buildup will be here described in more detail (Fig. 2B).

Foraminifers found in the mudstone surrounding the buildup suggest its Bathonian age (O. Styk, personal communication, 1987). Lithologic correlation with the bore-hole sections allows one to estimate the age of the studied segment of the succession at the Bajocian-Bathonian boundary.

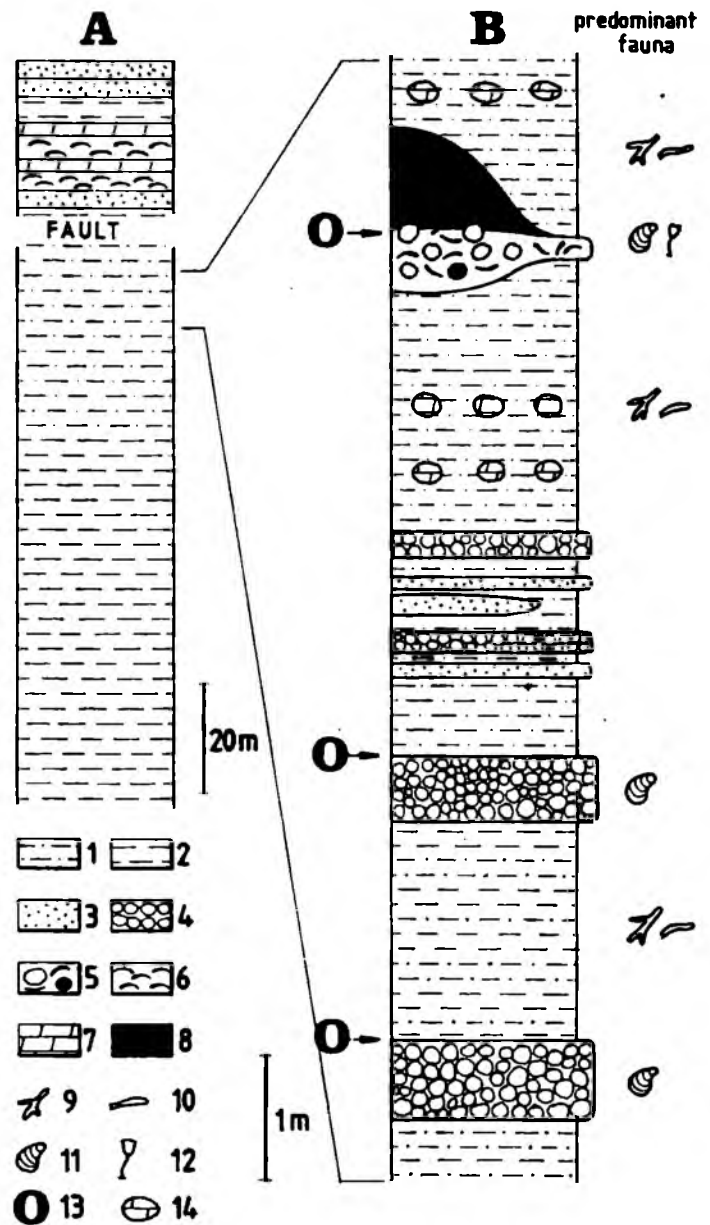
## MUDSTONES

### Lithology

The mudstones are a dark monotonous sequence intercalated with claystones and fine-grained sandstones, with numerous siderite nodule horizons. The nodules are up to 30 cm in diameter and do not show features suggesting their exposition on the sea bottom.

Primary sedimentary structures in the mudstones are nearly completely obscured by strong bioturbation (Pl. VIII). Sporadically only flaser bedding and parallel lamination are preserved. Lamination is manifested by alternation of clay and mud laminae or change in colour of the clay layers.

Fig. 2. Generalized section of the Middle Jurassic exposed in the mine (A) and the detailed section of the strata at the Bajocian/Bathonian boundary, where the oyster buildup occurs (B). 1 — mudstone; 2 — claystone; 3 — sandstone; 4 — conglomerate; 5 — coquina; 6 — bivalve-serpulid coquina; 7 — sideritic beds; 8 — oyster buildup; 9 — *Chondrites*; 10 — *Planolites*; 11 — oysters; 12 — echinoderm fragments; 13 — nondeposition surface; 14 — siderite nodule



### Fauna assemblage

Rare shelly fauna is represented by poorly preserved shells of cephalopods and thin-shelled bivalves (e.g. *Buchia* sp.). Ichnofauna assemblage consists of abundant *Chondrites*- and *Planolites*-type traces. The burrows are not evenly distributed within the rock, but in the distinct horizons: thicker, with densely packed *Chondrites* and *Planolites*, and thinner, revealing solely less dense *Chondrites* traces. Compared to the host rocks, the burrows are filled with coarser (silty) and lighter material.

### Interpretation

Poor preservation of the sedimentary structures precludes unambiguous determination of depositional mechanisms of the mudstones. In part they

presumably constitute deposits of episodic sedimentation — distal parts of clastic tempestites with bottom-current structures (*cf.* Bloos, 1982; Aigner, 1985). Clay layers distinguished by the alternation of light and dark colours might have formed due to suspension settling (Wetzel, 1982).

Environmental conditions may be described in more detail using ecological analysis of fauna. Ichnofauna is typified by its high density and low diversification. These are features typical of opportunistic assemblages living in environments, where they suffer from environmental stress (Ekdale, 1985). Such composition of ichnofauna and absence of shelly benthos point to the low oxygen level as the main stress factor. The ichnofauna assemblage is, thus, typical of disaerobic zone (Rhoads & Morse, 1971; Byers, 1977; Thompson *et al.*, 1985). Depletion in oxygen occurred both in the sediment and in near-bottom water. Presence of cephalopods in the sediment excludes dissolution as a cause for the lack of benthic organisms shells.

The variability of trace fossils density and their lack in some horizons probably reflect oxygen level fluctuations in the upper layer of the sediment (*cf.* Savrda & Bottjer, 1986). The horizons containing only *Chondrites* burrows formed by the minimum oxygen concentration. *Planolites* traces are present in the relatively well oxygenated sediment, typical of conditions transitional between disaerobic and aerobic zones (Bromley & Ekdale, 1984).

Deeper in the sediment, anaerobic conditions prevailed. This is evidenced by the presence in the mudstone of very fine dispersed pyrite grains (*cf.* Hudson, 1982) and diagenetic siderite concretions. The presence of authigenic carbonates is typical of numerous “black-shale” sequences (Tassé & Hesse, 1984). The concretions and laminae of authigenic carbonates are being related with the dissolution and reprecipitation processes occurring in anaerobic conditions (Brett & Baird, 1986 and references therein).

## SANDSTONES AND CONGLOMERATES

### Lithology

Fine-grained sandstones occur in continuous beds and lenses. Both, the lower and upper boundaries of the beds are sharp and well visible. The sandstone beds are massive and no sedimentary structures have been found, whereas in the lenses occasionally cross-lamination was seen.

Conglomerates consist of pebble-size grains with iron ooids, and of the less frequent siderite and calcareous hiatus concretions. Well rounded and sorted pebbles attain 3 cm in diameter. Conglomerates are grain-supported and their upper and lower contacts are sharp.

### Fauna assemblage

Sandstones and sandstone clasts do not include fauna. A part of pebbles are on their whole surface coated with oyster and serpulid incrustation (Pl. II : 1-6).

Oyster shells (*Nanogyra* sp., *Praeexogyra* sp.) are strongly xenomorphic, reflecting the substratum morphology. In the sandy matrix of conglomerates numerous crushed fragments of bivalves and echinoderms occur.

### Interpretation

Continuous sandstone beds are interpreted as tempestites. These sediments are characterized by sharp upper and lower contacts (*cf.* Seilacher, 1982a). Lack of graded bedding may result from a good sorting of material prior to its redeposition (*cf.* Bloos, 1982). Sandstone lenses (large ripplemarks) formed due to bottom currents.

Conglomerate beds are episodic deposits. Sandstone pebbles were formed in the high-energy zone of sandstone erosion. In this environment shelly benthos were developing. This material was occasionally redeposited towards deeper portions of the basin building there tempestite conglomerate beds. Analogous conglomerates have been described from the Middle Jurassic of the South-German basin (*cf.* Bayer *et al.*, 1985).

## THE COQUINA

### Lithology

The coquina has a laterally diversified geometry and internal structure. It forms a 1-m long lens which attains thickness of 40 cm (Fig. 3; Pl. I:2). The lens passes into a bed of a constant thickness of 25 cm. Pebbly claystone occurs within the lenticular part of the coquina. Dominant clasts embedded in the clay matrix of this claystone are calcareous hiatus-concretions and shells. Majority of shells occur as thoroughly crushed bioclasts, and rarely one meets whole specimens. Less frequent are sandstone pebbles and sideritized wood fragments. The rock is matrix-supported and has a random texture (Pl. III). Organic hard parts reveal traces of corrosion and organogenic incrustation.

In the remaining part of the coquina the hiatus-concretions do not occur, and there are fewer and more crushed shells.

### Fauna assemblage

The fauna assemblage occurring in the coquina is pauspecific (*sensu* Kidwell *et al.*, 1986). Echinoderms (trochites and echinoid plates and spines) and oysters dominate. There occur also other bivalves (e.g. *Chlamys* sp., *Plagiostoma* sp.), brachiopods (*Rhynchonella* sp.) and serpulids (*Tetraserpula* sp., *Dorsoserpula* sp.) and foraminifers. Less frequent are cephalopods (Pl. III) and vertebrate bones. Flora is represented by araucaria fragments (*Araucarioxylon* sp., Pl. II:8).

### Hiatus-concretions

Nodules occurring in the coquina bed bear traces of exposure and reworking on the sea bottom. Such concretions are known as hiatus-concretions (*cf.* Voigt, 1968).

The nodules are oval or ellipsoidal shape, considerably changed by bioerosion (Pls. IV-VI). Their dimensions reach 10 cm but on an average they are smaller (about 4 cm or less). They are built of micrite with variable admixture of fine quartz grains. Their greyish-blue colour results from abundant dispersed pyrite. Only in the marginal parts and along borings yellow-tanned zones are visible (Pl. IV). They were formed by oxidation of pyrite during exposure of the nodules at the sea bottom under aerobic conditions (*cf.* Kennedy & Klinger, 1972; Baird & Fürsich, 1975). In the concretions which are found beyond the sideritized coquina, the oxidized zone is much broader and it occasionally extends over a whole nodule. This is presumably an effect of the recent weathering.

**Borings and epiliths.** Most concretions reveal traces of bioerosion and organogenic incrustation. Both usually occur over the whole nodule surface (Pl. IV; PL. V:2). The concentration of borings is variable. It fluctuates between single and densely packed, mutually interwoven channels (Pl. VI; Pl. VII:3). The most common among borings, the borings of bivalves, are represented by ichnospecies *Gastrochaenolites lapidicus* Kelly & Bromley and, less frequent, *G. dijugus* Kelly & Bromley (Pls. IV-V; Pl. VI: 1-3; Pl. VII:1).

Polychaeta borings are represented by several ichno-genera. The most frequent are winding, non-branched channels of circular cross-section 2 mm in diameter included in ichnospecies *Meandropolydora sulcans* Voigt (Pl. IV:4; Pl. VII:4-5). Occasionally in the concretions borings of *Potamilla*- and *Trypanites*-type occur.

Degree of preservation of the borings varies within the rock. Some are preserved unchanged, whereas the other are extensively abraded. Some empty borings have been occupied by the nestling bivalves.

Traces of organogenic incrustation are less frequent, what may result from abrasion. The most common are serpulids (PL. IV; PL. V:1). Moreover, the oysters (Pl. IV:3; Pl. VII:2) and foraminifers are also present.

The described concretions do not reveal several generations of inorganogenic coatings separated by traces of exposure at the sea bottom. This suggests a simple mechanism of their formation. During reworking they were not buried in the sediment where authigenic calcareous coatings could have precipitated. Similar hiatus-concretions are called "simple bored concretions" (Kennedy *et al.*, 1977).

Examples of hiatus-concretions have been described from numerous settings (review in the paper by Chudzikiewicz and Wieczorek, 1985) and among others from the Middle Jurassic strata of the epicontinental basin of Poland (*cf.* Znosko, 1957; Deczkowski, 1976; Kopik, 1979; Śnieżek, 1980).



### Interpretation

Both, degree of shell and hiatus-concretion preservation and fauna assemblage allow one to define environment of formation of the coquina. However, crucial is determination of the type of paraautochthonous or allochthonous fauna concentration. Allochthonous shell will not carry environmental signature.

Fauna assemblage of the coquina is characterized by domination of benthos with thick-shelled bivalves and numerous boring organisms. It is assemblage typical of shallow-marine, sublittoral, well aerated environment (Warne, 1975; Hallam, 1976; Fürsich, 1977). Presence of crinoids and cephalopods indicates normal salinity, whereas strong fragmentation and corrosion of bioclasts results from high energy of environment and low clastic flux or lack of clastic accumulation (*cf.* Brett & Baird, 1986). Bioclasts and hiatus-concretions either remained for a long time in the zone of high energy or were repeatedly reworked. Calcareous concretions after having been eroded from their parent clayey rocks rolled over the bottom and were colonized on all their sides. Repeated reworking may explain strong abrasion of bioclasts and hiatus-concretions and simultaneous presence of delicate foraminiferal incrustations.

The coquina by its structure strongly resembles reworked horizons. The reworked horizons — paraautochthonous concentrations of shells and hiatus-concretions of a pavement type (*sensu* Kidwell *et al.*, 1986) — are a sort of condensed beds (*cf.* Kidwell & Aigner, 1985). Their formation is related to energy increase in sedimentary basin, erosion and sediment winnowing, as well as with change in terrigenous material supply. These factors might have been connected with regressive cycles (*cf.* Einsele, 1985), change of bottom current circulation or other reasons (*cf.* Bloos, 1982).

The reworked horizons are common in clayey and muddy sediments (*cf.* Baird & Fürsich, 1975; Baird, 1981; Fürsich, 1982; Brandt, 1985). Coquina and conglomerate beds of similar structure have been described also from the area of Wieluń (Deczkowski, 1976) and Łęczyca (Znosko, 1957).

The described coquina is, however, not a paraautochthonous concentration of fauna. In the reworked horizons lateral displacement of sediment is small. In the studied case shelly fauna and calcareous nodules do not occur in the underlying mudstone. They constitute allochthonous material redeposited from the other part of the basin of a different environment (see above). This was a reworked horizon that had been redeposited. The situation is analogous to that observed in the so-called Klüpfel cycles (Aalen and Bajocian of the South-German basin), where reworked horizons correspond to tempestites in the deeper part of the basin (Bayer & McGhee, 1985).

Two mechanisms may be suggested for formation of the coquina. Matrix-supported texture and random orientation of bioclasts and hiatus-concretions are characteristic of cohesive gravity-flow deposits (Reineck & Singh,

1980) or proximal tempestites of a "one-event bed" type (Reif, 1982). Structure of such tempestites strongly resembles that of the reworked horizons (*cf.* Einsele, 1985). They might have been moved to the deeper part of the basin along the erosional channels formed by bottom currents (*cf.* Goldring & Aigner, 1982). The lenticular part of the coquina may be a fill of such a channel.

### DISCONTINUITY SURFACES

The surface of nondeposition are structures developing in the sediment due to temporary cessation of sedimentation (*cf.* Kennedy & Garrison, 1975). In carbonate sediments they are easy to identify (e.g. hard ground) but in fine-grained clastic sediments they are less conspicuous (*cf.* Baird, 1976). A good indicator of decreased clastic sediment supply or no sediment accumulation is presence of concentration of the cementing benthos. Development of these sessile organism not free to move or escape burial, is strictly limited by sediment accumulation rate (*cf.* Dzik, 1982). Occurrence of the cementing benthos is, however, restricted to the areas of stable substratum.

In the described section nondeposition surfaces have been identified only in the top parts of conglomerate and coquina (Fig. 2). The top parts of conglomerates are covered by oysters and serpulids which do not build thick crusts. Oysters are dispersed and only occasionally mutually incruusted. This limited development of benthos results probably from the short time of no clastic sediment deposition. The discussed oyster buildup indicates much longer lasting nondeposition conditions (see below).

It is difficult to establish whether the nondeposition periods occurred directly after formation of stable substratum. There is a feasible scenario which assumes that originally conglomerates were covered by mud and only later exhumed (*cf.* Seilacher, 1985).

### OYSTER BUILDUP

#### Description

The oyster buildup is of an irregular shape, 80 cm high and some 200 cm in diameter (Fig. 3; Pl. I). It is built of oysters *Liostrea explanata* Goldfus (Pl. II:7). The length of oyster shells attains 11 cm. They are attached to one another with their entire sinistral valves, which results in the compact and masive structure of the buildup. Small cavities within the buildup are filled with mud. Beside oysters, within the buildup only rare serpulids and bivalve borings are encountered (Pl. VIII). There is no significant bioerosion over the outer surface of the buildup, but its upper surface is densely covered by serpulids.

The buildup developed on the lenticular part of the coquina. Hiatus-concretions occurring in the upper part of the coquina are frequently incruusted by

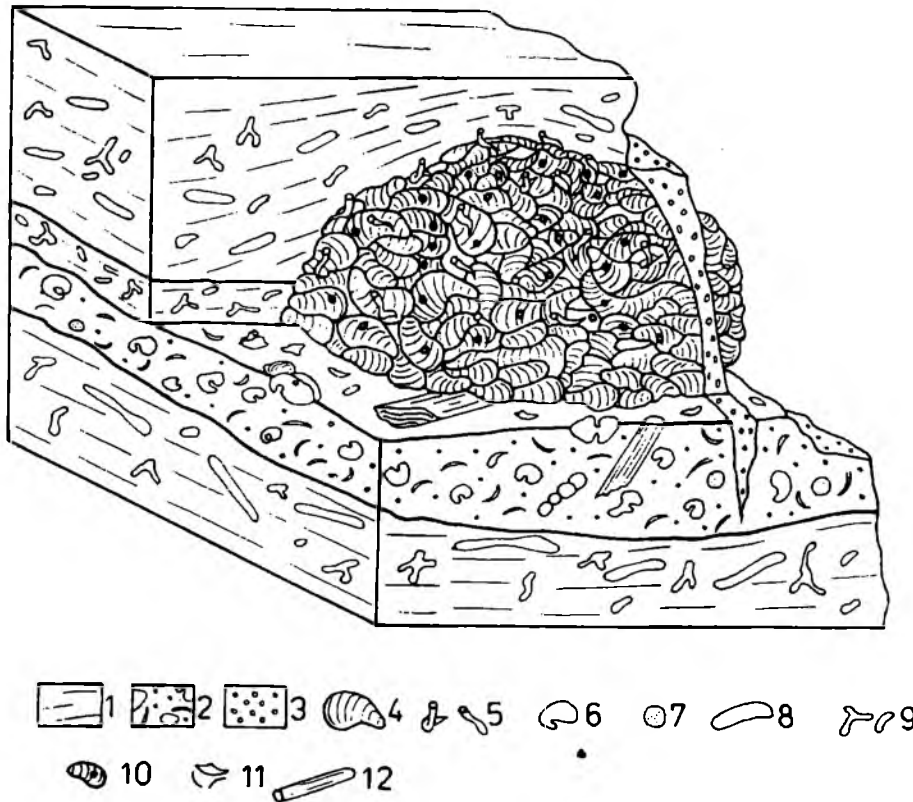


Fig. 3. Oyster buildup and surrounding sediments. 1 – mudstone; 2 – coquina; 3 – sandstone; 4 – oysters; 5 – serpulids; 6 – hiatus concretions; 7 – sandstone pebbles; 8 – *Planolites*; 9 – *Chondrites*; 10 – borings; 11 – bioclasts; 12 – wood fragments

the oysters forming the base of the buildup (Pl. IX:2). The size of these oysters exceeds that of the incrustated clasts. However, there are no traces of incrustation by oysters of the coalified wood fragments that occur between the buildup and the coquina. Similar phenomenon was observed in the Lower Jurassic sediments in Germany (cf. Seilacher, 1982b). Certain oyster species may attach to drift wood or mangrove roots (cf. Stenzel, 1971). However, wood does not constitute a good substratum for bivalves (Kauffman, 1978).

The oyster buildup does not reveal traces of mechanical erosion and in the surrounding sediment there are no crushed fragments of the buildup. The mudstones mantle the buildup. The faint lamination is not interrupted and only individual mudstone layers bend and thin above the structure. In its central part the buildup is cut by a crevice filled with fine sand (Pl. IX). The preserved fill of the crevice (its part on the side of the pit is not preserved) is in form of a thin wedge disappearing in the underlying coquina. The crevice results presumably from a different response to compaction by the mudstone and the rigid buildup.

### Interpretation

The environment of mudstone deposition did not favour development of the cementing benthos. This was due to soft, unstable bottom and low oxygen

level in bottom waters. Episodically, these conditions changed and certain parts of the bottom could be colonized. Formation of the oyster buildup was controlled by the coincidence of three factors: (1) presence of stable substratum on the bottom, (2) good aeration of bottom waters, and (3) considerable decrease of clastic-sediment accumulation rate.

The cementing benthos living in the environment dominated by soft bottom employs strategy of colonization of benthic islands. This strategy consists in attachment of the organisms to the hard objects on the bottom (e.g. larger shells, drowned wood fragments, exhumed nodules, etc.) (Carter, 1972; Dzik, 1982). Such strategy allows for colonization of certain types of disaerobic environments, where the thickness of oxygen-deficient zone does not exceed the elevation of the "island" (Kauffman, 1978, 1982).

The lenticular part of the coquina constituted the island at which oyster buildup was initiated. The exposed bioclasts and hiatus-concretions occurring there were a suitable substratum for the incrusting oysters. They colonized the whole area of occurrence of hard objects on the bottom but did not settle beyond it. Dome-like, the so-called "regressive" outline of the buildup, as well as the mode of the oyster attachment, both laterally and vertically, indicates that the period of buildup growth took place during the break in clastic sedimentation. The height of this structure above the coquina is its original elevation above the bottom. The period of nondeposition should not be associated with incidental growth in environment energy in sedimentary basin. The phenomenon is rather due to a prolonged action of bottom current, or lowering of the wave base. The energy enhancement did not cause destruction of the buildup itself but resulted in better aeration of the deeper part of the basin.

The oyster buildup grew in relatively shallow water. Oyster lumachelles and buildups develop at depths not exceeding several tens of metres. Also occurrence of the boring bivalves is characteristic of moderate shelf depths (*cf.* Radwański, 1970; Warne, 1975).

Little diversification of the structure-building organisms may suggest that the development of the buildup took place under ecological stress. Oysters belong to the euryhaline animals (Stenzel, 1971; Hudson & Palmer, 1976). Their intensive development occurs when abnormal salinity or its strong fluctuations eliminate organisms that may be feeding competitors or destroy the buildup (Heckel, 1974; Hallam, 1976; Fürsich, 1981). Oyster buildups are most common in environments of lowered salinity (Table 1). Particularly species *Liostrea explanata*, as well as the related (not only taxonomically but also ecologically) species *Nanogyra nana* and *Praeexogura acuminata* prefer brackish waters (Pugaczewska, 1971; Fürsich & Werner, 1986). Serpulids are more tolerant against salinity than oysters (*cf.* Heckel, 1974), and occurrence of gastrochens in the brackish environments was also noted (*cf.* Werner, 1986). The presence in the surrounding sediment of stenohaline organisms may indicate strong salinity fluctuations. Such fluctuations are recorded in sediment

by succession of normal-marine and brackish faunas (Fürsich, 1981; Werner, 1986). Such phenomenon is typical of littoral parts of epicontinental basins and may be connected with climatic change (*cf.* Francis, 1984). Summarizing, one may suggest that the buildup grew by the abnormal salinity level.

Termination of growth might have been caused by numerous factors (e.g. by rapid burial, biological reasons, change of physico-chemical conditions of sedimentation). After the termination of oyster growth the upper part of the buildup was intensively incrustated by serpulids. Thus, this part of the buildup was still exposed on the bottom. The final cessation of the buildup development was probably related to the diminishing of near-bottom turbulence. This brought about revival of clastic accumulation, gradual burial, and simultaneously decrease in bottom water oxygenation. Lower oxygen level stopped oyster growth but for some time yet supported existence of serpulids over the upper part of the buildup.

### COMMENTS ON THE SEDIMENTARY BASIN

There exist numerous analogies between the morphology and sediments of the Middle Jurassic epicontinental basin in Poland and the Lower and Middle Jurassic basin in south Germany. This allowed for application of sedimentary models elaborated for the South-German basin to the interpretation of sedimentation in the epicontinental basin in Poland.

The sediments described in this paper were formed during the episodes of sandstone and conglomerate sedimentation and periods of nondeposition and erosion within the dominating background sedimentation of mudstones. Such sedimentary successions are typical of the relatively deeper and distant from the shore part of the basin of regressive tendencies (*cf.* Bayer *et al.*, 1985; Bayer & McGhee, 1985; Einsele, 1985). Both, the depth and distance from the shore may be approximated using the above data. The bottom was below the normal wave base but still in the zone where oyster buildup development was possible. The moderate distance from the shore is indicated by the presence of proximal tempestites, fluctuations of salinity, and presence of numerous wood fragments. The present-day Bełchatów area in the discussed time might have correspond with the zone of the "offshore shales" sedimentation distinguished in the Hettangian of the South-German basin (Bloos, 1982, fig. 2).

The coarser material was delivered to this part of the basin from its shallower zone. No direction of transport could be established. However, using composition of the described beds formed during episodic sedimentation, an approximate section of the source sediments could be reconstructed. These were clayey sediments with calcareous concretions and sandstones with iron-bearing ooids. The presence of shelly benthos speaks for, at least episodically, well oxygenated environment. Such sedimentary sequence may be referred to the outer part of the sandy shelf in the Bloos's model (1982, fig. 2). These sediments were eroded and redeposited in the deeper zone of the basin.

The regressive tendencies recorded both, in the deeper and shallower parts of the basin do not necessarily reflect eustatic sea-level changes. They might have been caused by local tectonic uplift e.g. in the area of Wielkopolska ridge (*cf.* Dadlez & Franczyk, 1976; Kopik, 1979).

## CONCLUSIONS

1. The Bajocian/Bathonian sediments were formed in the outer parts of the epicontinental basin of regressive tendencies. The basin was dominated by fine-clastic sedimentation interrupted by episodes of proximal tempestite deposition.

2. The coquina bed constituting substratum for the oyster buildup is a redeposited reworked horizon.

3. Mudstone sedimentation occurred under disaerobic conditions. Periods of erosion, nondeposition and good oxygenation are marked in the section by oyster-serpulid incrustation and presence of oyster buildup.

4. The oyster buildup developed on benthic island formed by lens of the coquina including numerous hiatus-concretions.

5. Figure 4 presents the inferred succession of events during the growth of the oyster buildup:

A — mud deposition in disaerobic conditions; the sediment was colonized exclusively by soft-bodied infauna;

B — sedimentation of the coquina by redeposition of the reworked horizon;

C — burial of the coquina by mud; sedimentary conditions as in A (it is possible that the period of nondeposition occurred directly after the coquina deposition and the latter had not been buried);

D — erosion and cessation of clastic sedimentation accompanied by increased oxygen level in bottom water enabled colonization by oysters of hard objects in the top of the coquina;

E — development of oyster buildup over the whole area of occurrence of hard bottom;

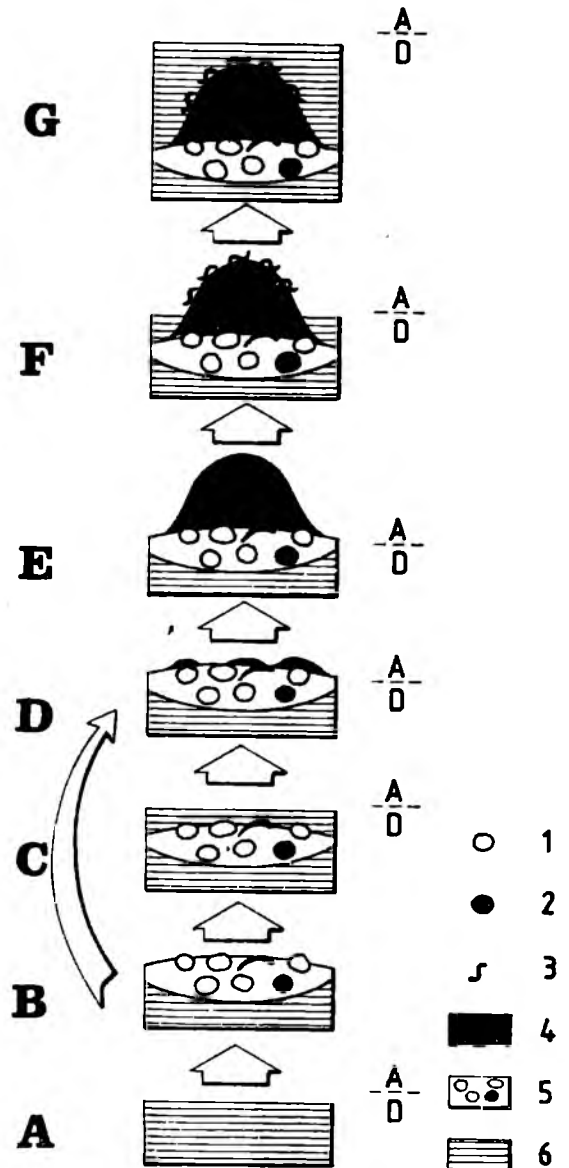
F — decrease of turbulence resulted in renewal of fine-clastic sedimentation and lowered oxygen level in water; the oyster growth stops — the lower part of the buildup was buried and its upper part incrustated by serpulids;

G — the buildup is totally buried — the environmental conditions as in A.

## ACKNOWLEDGEMENTS

The authors thank Dr Ewa Szewczyk for her help in field work and Prof. S. W. Alexandrowicz, Dr L. Chudzikiewicz, Dr. A. Hoffman, Dr J. Wiczorek, and M. Paszkowski M. Sc. for their critical reading of the draft of the manuscript. The thanks are also due to Dr H. Pugaczewska for advise in determination of oysters.

Fig. 4. Sequence of events during formation of the oyster buildup. Full explanation in the text. A/D – boundary of the aerobic and disaerobic zones. 1 – hiatus concretions; 2 – sandstone pebbles; 3 – serpulids; 4 – oyster buildup; 5 – coquina; 6 – mudstone



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## Streszczenie

**BUDOWLA OSTRYGOWA WŚRÓD MUŁOWCÓW  
FACJI DYSAEROBOWEJ  
(ŚRODKOWA JURA, BĘLCHATÓW, POLSKA CENTRALNA) –  
PRZYKŁAD KOLONIZACJI WYSPI BENTONICZNEJ****Mariusz Hoffmann & Michał Krobicki**

W Kopalni Węgla Brunatnego „Bełchatów” odsłonięte zostały osady środkowej jury. W mułowcach z pogranicza bajosu i batonu występuje niewielka budowla ostrygowa. Przeprowadzone badania miały na celu określenie warunków powstania tej budowli i osadów ją otaczających.

Kopalnia „Bełchatów” usytuowana jest w południowej części niecki łódzkiej w obrębie antykliny Łękińska (Fig. 1). Utwory jury środkowej wykształcone są w facjach iłowców, mułowców, drobnoziarnistych piaskowców i muszłowców małżowo-serpulowych (Fig. 2A). Budowla ostrygowa występuje w obrębie kompleksu mułowców przeławiconych warstwami piaskowców, zlepieńców i muszłowca (Fig. 2B; Pl. I). Mułowce są pozbawione prawie całkowicie struktur sedymentacyjnych w efekcie silnego zbioturbowania osadu. Nie występuje w nich bentos skorupowy. Występowanie wyłącznie penetracji *Chondrites* i *Planolites* wskazuje, że sedymentacja mułowców miała miejsce w warunkach dysaerobowych.

Warstwy piaskowców i zlepieńców, stanowiące wkładki w mułowcach, są osadami depozycji epizodycznej. Otoczaki piaskowców w zlepieńcach inkrustowane są przez ostrygi (Pl. II: 1-6).

Muszłowce w miejscu, nad którym rozwinięta jest budowla ostrygowa, ma kształt soczewy (Fig. 3; Pl. I). Zbudowany jest on z osadu typu żwirowca ilastego o rozproszonym szkielecie ziarnowym (Pl. III). Bioklasty reprezentują silnie pokruszone szczątki ostryg i szkarłupni. Mniej liczne są szczątki innych małży, ramienionogów, serpul, głowonogów i otwornic. W soczewkowatej części muszłowca występuje znaczna liczba wapiennych hiatus-konkrecji (Pl. III-V) i zsyderytyzowane fragmenty drewna (Pl. II: 8). Na całych powierzchniach hiatus-konkrecji występują dążenia gastrochen i wieloszczeta *Meandropolydora sulcans* (Pls. IV, VI, VII) oraz inkrustacje serpul (Pl. IV, VII: 2) i ostryg (Pl. IV: 3).

Budowa muszłowca bardzo przypomina budowę przerobionych horyzontów. Jednak zarówno muszle, jak i hiatus-konkrecje stanowią w miejscu obecnego występowania materiał allochtoniczny. Muszłowiec jest osadem spływu kohezyjnego lub proksymalnym tempestytem. Redepozycji ulegał prawdopodobnie przerobiony horyzont.

Przerwy w sedymentacji klastycznej zaznaczają się występowaniem inkrustacji serpulowo-ostrygowych na warstwach zlepieńców oraz obecnością budowli ostrygowej (Fig. 2B). Budowla ostrygowa rozwinięta jest na warstwie

zlepieńca i ma kształt nieregularnej kopuły o wysokości 80 cm i średnicy około 2 m (Fig. 3; Pl. I: 2). Zbudowana jest ona przez ostrygi z gatunku *Liostrea explanata* (Pl. II: 7; Pls. VIII, IX: 1). W obrębie budowli występują wydrążenia gastrochen (Pl. VIII). Górna powierzchnia budowli jest gęsto inkrustowana przez serpule. W środkowej części budowla przecięta jest szczeliną wypełnioną drobnoziarnistym piaskowcem (Pl. IX).

Możliwość wzrostu budowli ostrygowej w środowisku sedymentacji mułowców uzależniona była od koincydencji następujących czynników: 1) obecności twardego podłoża, 2) zaniku lub znacznego zwolnienia tempa sedymentacji klastycznej, 3) okresowego podniesienia się poziomu natlenienia wód przydennych. „Wyspę”, na której mogła rozwijać się budowla, stanowiła soczewa zawierająca znaczną ilość twardych obiektów. Poprawa natlenienia i zanik sedymentacji klastycznej były rezultatem okresowego wzrostu turbulencji. Budowla ostrygowa powstała w stosunkowo płytkim środowisku, jednak poniżej normalnej podstawy falowania. Poziom energii w okresie wzrostu budowli nie wystarczał do destrukcji mechanicznej jej struktury, a jednocześnie uniemożliwiał depozycję mułowców. W historii geologicznej budowli i zlepy ostrygowe rozwijały się głównie w zbiornikach o obniżonym zasoleniu (Tabela 1). Prawdopodobnie wzrost opisywanej budowli miał miejsce w środowisku, którego zasolenie okresowo różniło się od normalnego. Zakończenie wzrostu budowli związane było ze spadkiem turbulencji. Spadek poziomu natlenienia uniemożliwił rozwój ostryg, a przez pewien okres pozwalał na istnienie serpul na górnej części budowli. Schemat powstawania budowli przedstawiono na Fig. 4.

Basen sedymentacyjny w rejonie Bełchatowa na przelomie bajosu i batonu charakteryzował się zróżnicowaniem batymetrycznym. W części głębszej (odsłoniętej w kopalni) dominowała sedymentacja mułowców. Do tej części basenu epizodycznie dostarczany był materiał gruboziarnisty ze strefy płytszej. W tym czasie w całym basenie zaznaczyły się tendencje regresywne.

## EXPLANATION OF PLATES

### Plate I

- 1 — Exposed mudstone with oyster buildup. a — conglomerate bed
- 2 — Oyster buildup and coquina lense. The hammer is 40 cm long

### Plate II

- 1—6 Sandstone pebbles incrustated with oysters. Conglomerate beds
- 7— *Liostrea explanata* shell. Oyster buildup
- 8— Sideritized wood fragment (*Araucarioxylon* sp.). Coquina

### Plate III

The fragment of the lenticular part of the coquina with hiatus-concretions. a — *Nautilus* shell, b — sandstone pebbles, c — oyster shell. Polished section. Scale 5 cm

## Plate IV

- 1-3 - Hiatus-concretions with bivalve borings and incrustations by serpulids and oysters (b); weathered crust on the surface of concretions and borings (a). Details from Pl. III

## Plate V

- 1- Fragment of hiatus-concretion (a), bivalve boring (b), incrustation by serpulids (c). Coquina. Thin section  
 2- Hiatus-concretion with bivalve borings from all its sides. Coquina. Thin section

## Plate VI

- 1-3 - Hiatus-concretions with bivalve borings. Coquina  
 4- *Meandropolydora sulcans* borings. Coquina

## Plate VII

- 1- Moulds of *Gastrochaenolites lapidicus* borings. Coquina  
 2- Hiatus-concretion with incrustation by serpulids. Coquina  
 3- Moulds of the intersecting bivalve borings. Coquina  
 4-5 - *Meandropolydora sulcans* borings. Coquina

## Plate VIII

Upper part of the oyster buildup overlain by bioturbated mudstone. a - bivalve borings. Polished section. Scale 5 cm

## Plate IX

- 1- Contact of the oyster buildup with an intersecting fissure filled with fine-grained sandstone. Polished section  
 2- Bottom part of the buildup intersected by fissure (upper right-hand side of the photograph). a - oysters, b - calcareous concretions, c - sandy mudstone filling growth voids. Thin section

