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Depositional architecture of the Polish epicontinental Middle Jurassic basin

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A number of depositional systems and sub-systems have been distinguished within the Middle Jurassic deposits of the Polish Lowlands: fluvial, siliciclastic shelf (with shallower and deeper shelf — the latter includes anoxic shelf facies), carbonate-clastic shelf, carbonate ramp and starved shelf. On the basis of the analysis of their vertical succession and lateral changes as well as gaps recognized within the stratigraphical column, the Middle Jurassic deposits have been subdivided into six transgressive-regressive cycles. They have been compared with the eustatic curves of B. U. Haq *et al.* (1988) and A. Hallam (1988).

INTRODUCTION

The analysis of depositional systems has been performed on a basis of several tens of boreholes situated in the Mid-Polish Trough and along its margins (Fig. 1). Boreholes with the best geological material, i. e. entirely or almost entirely cored and having a legible wireline log record, are shown as both individual borehole sections and two correlations stretching across the Mid-Polish Trough:

1. Along the Pomeranian line (Fig. 2) boreholes: Choszczno IG 1 (Fig. 4), Lędyczek 2 (Fig. 5), Złotów 1, Charzykowy IG 1 and Bytów IG 1.

2. Along the central line (Fig. 3) boreholes: Koło IG 4, Koło IG 3, Poddębice PIG 2, Wojszyce IG 4 (Fig. 6) and Nidzica IG 1 (Fig. 7).

For purposes of the project the following data have been employed: (1) the author's own sedimentological studies (particularly in the central region), (2) lithological data from archival materials and published papers (R. Dadlez, J. Dembowska, 1965; K. Dayczak-Calikowska, 1977*a–e*, 1987, 1990; K. Dayczak-Calikowska, J. Kopik, 1973; A. Ryll, 1970, 1971, 1983; J. Znosko, 1957) and (3) maps constructed by geologists of the Polish Geological Institute during many years' studies.

It should be mentioned that the stratigraphy of Middle Jurassic deposits is well evidenced by fauna. A number of ammonites occurring in various parts of Poland allows a precise timing of initial and final stages within the cycles. No lithostratigraphic scheme has been proposed for the Middle Jurassic.

PALAEOTECTONIC AND PALAEOGEOGRAPHIC ELEMENTS OF THE MIDDLE JURASSIC BASIN

The most important palaeotectonic element of the Early Jurassic basin was the Mid-Polish Trough which was subjected to slow subsidence during the Middle Jurassic sedimentation.

In this area, the complete lithological-stratigraphical column reaching over 1000 m in thickness in the Kutno Depression is recorded. This trough was a path of successively developing transgressions reaching the Polish Basin from

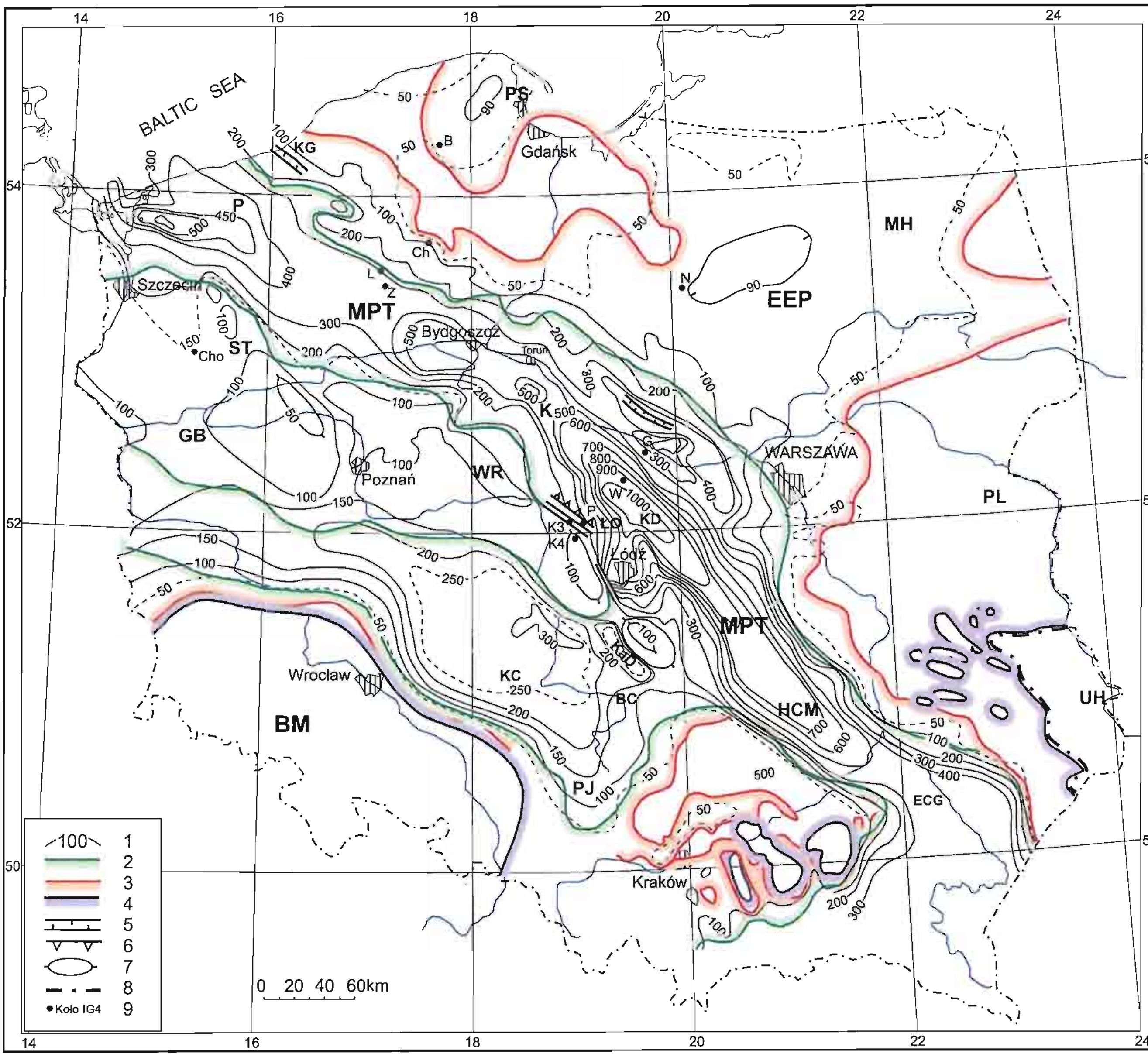


Fig. 1. The Middle Jurassic primary thickness map after K. Dayczak-Calikowska, Z. Deczkowski (*fide* K. Dayczak-Calikowska, W. Moryc, 1988) modified by A. Feldman-Olszewska

1 — restored isopachs; maximum extent of basin: 2 — Aalenian (J3-I), 3 — Late Kuiavian–Early Bathonian (J3-III), 4 — Callovian (J4-I); 5 — synsedimentary grabens; 6 — synsedimentary faults; 7 — elevations; 8 — extent of the Middle Jurassic basin; 9 — interpreted borehole sections: B — Bytów IG 1, Ch — Charzykowy IG 1, Cho — Choszczno IG 1, G — Gostynin IG 1/1a, K3 — Koło IG 3, K4 — Koło IG 4, L — Lędyczek 2, N — Nidzica IG 1, P — Poddębice PIG 2, W — Wojszyce IG 4, Z — Złotów 1; BC — Bełchatów–Częstochowa region, BM — Bohemian Massif, ECG — East Carpathian Gate, EEP — East European Platform, GB — Gorzów Block, HCM — Holy Cross Mts., K — Kujawy region, KaD — Kamieńsk Depression, KC — Kalisz–Częstochowa area, KD — Kutno Depression, KG — Koszalin Graben, MH — Mazury High, ŁO — Łęczyca-Ozorków area, MPT — Mid-Polish Trough, P — Pomeranian region, PJ — Polish Jura, PL — Podlasie–Lublin region, PS — Peribaltic Syneclise, ST — Szczecin Trough, UH — Ukrainian High, WR — Wielkopolska Ridge

Mapa paleotektoniczna jury środkowej według K. Dayczak-Calikowskiej, Z. Deczkowskiego (*fide* K. Dayczak-Calikowska, W. Moryc, 1988) uzupełniona przez A. Feldman-Olszewską

1 — paleoizopachyty; maksymalne zasięgi basenów: 2 — aalenu (J3-I), 3 — górnego kujawu–dolnego batonu (J3-III), 4 — keloweju (J4-I); 5 — rowy synsedymentacyjne; 6 — uskoki synsedymentacyjne; 7 — elewacje; 8 — zasięg basenu środkowojurajskiego; 9 — interpretowane profile otworów wiertniczych patrz tekst angielski; BC — obszar bełchatowsko-częstochowski, BM — Masyw Czeski, ECG — brama wschodniokarpacka, EEP — platforma wschodnioeuropejska, GB — blok Gorzowa, HCM — Góry Świętokrzyskie, K — Kujawy, KaD — depresja Kamieńska, KC — obszar kalisko-częstochowski, KD — depresja Kutna, KG — rów Koszalina, MH — wyniesienie mazurskie, ŁO — obszar Łęczycy–Ozorkowa, MPT — bruzda śródpolska, P — Pomorze, PJ — Jura Polska, PL — obszar podlasko-lubelski, PS — synekliza perybałtycka, ST — niecka szczecińska, UH — ląd ukraiński, WR — garb wielkopolski

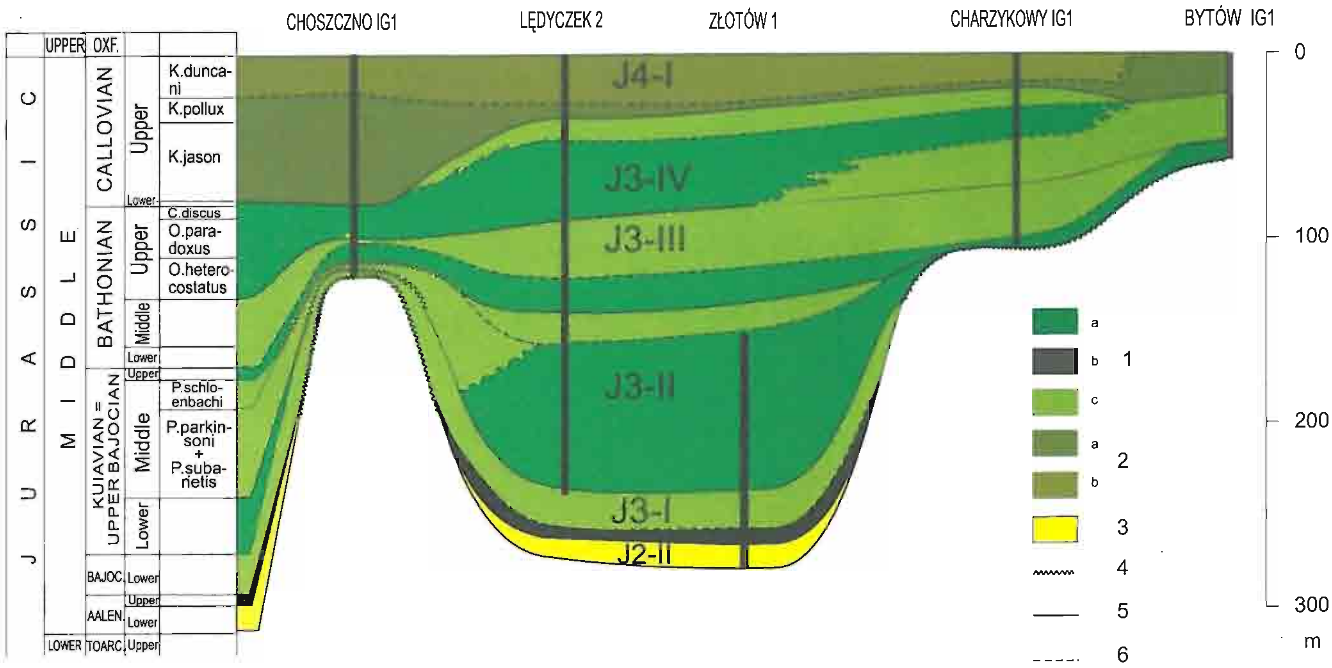


Fig. 2. Correlation of depositional systems and transgressive-regressive cycles between selected boreholes in the Middle Jurassic sequences of Pomeranian region

1 — siliciclastic shelf system (a — deeper siliciclastic shelf sub-system, b — anoxic shelf facies, c — shallower siliciclastic shelf sub-system); 2 — carbonate-clastic shelf system (a — deeper shelf, b — shallower shelf); 3 — fluvial system; 4 — erosional surfaces; 5 — boundaries between transgressive-regressive cycles; 6 — boundaries between depositional systems

Korelacja systemów depozycyjnych i cykli transgresywno-regresywnych jury środkowej w regionie pomorskim pomiędzy wybranymi otworami wiertniczymi

1 — system szelfu klastycznego (a — podsystem szelfu głębszego, b — facje szelfu anoksycznego, c — podsystem szelfu płytszego); 2 — system szelfu węglanowo-klastycznego (a — głębszego, b — płytszego); 3 — system fluwialny; 4 — powierzchnie erozyjne; 5 — granice cykli transgresywno-regresywnych; 6 — granice systemów depozycyjnych

both south-east (Aalenian–Bathonian) and north-west (Callovian) (K. Dayczak-Calikowska, W. Moryc, 1988).

In the Middle Jurassic, contrary to the Early Jurassic epoch, synsedimentary grabens bordering the Mid-Polish Trough are hardly marked in a palaeotectonic picture of the Polish Lowlands. They are only expressed as residual graben zones of slightly stronger subsidence. These are: the Koszalin Graben which is a continuation of the extreme north part of the earlier Koszalin–Chojnice Graben and the Kamieńsk Depression being a remainder of the southeastern part of the Kaleje–Kliczków Graben (K. Dayczak-Calikowska, W. Moryc, 1988). The lack of synsedimentary grabens did not preclude the tectonic activity in the marginal parts of the Mid-Polish Trough. It seems that its northeastern edge, beginning from the Aalenian through the end of the Middle Kuiavian, must have been active resulting in permanent subsidence of the trough in relation to the East European Platform. As a result of such a tectonic setting, the Aalenian to Middle Kuiavian sea did not transgressed over the East European Platform with contemporaneous deposition of a few hundreds of metres thick complex in the Mid-Polish Trough. Synsedimentary activity of faults was also marked south-west of the trough at that time. It is expressed particularly clear in the Kuiavian part where probably extensional half-graben systems separating the trough from the Wielkopolska Ridge and active earlier in the Jurassic, still strongly influenced the sedimentation within the basin. A transversal segmentation of the Mid-Polish Trough with the most subsiding Kutno segment (over 1000 m of the Middle Jurassic deposits) is also observed (R. Dadlez, 1994). The activity of the extensional half-graben system connected with a tectonic activity in the zone of the Early Jurassic Laska–Poznań and Kaleje–Kamieńsk Grabens caused the Wielkopolska Ridge to be uplifted. This resulted in a formation of probable land areas which were subjected to erosion during Aalenian–Middle Kuiavian times. Beginning with the Late Kuiavian, the activity of tectonic zones bordering the Wielkopolska Ridge disappeared or diminished — this is evidenced by the invading transgressions of the Late Kuiavian, Bathonian and Callovian, uniform thickness of Upper Kuiavian–Bathonian deposits in the Mid-Polish Trough and Wielkopolska Ridge. At the same time transgressions over the East European Platform took place.

The Middle Jurassic sedimentary basin was surrounded from the east by the Ukrainian High and from the north-east by the land of East European Platform. From the south-west, Bohemian Massif extended. There are some premises that the Bohemian Massif might have been transgressed by the sea during the Late Callovian (K. Dayczak-Calikowska, W. Moryc, 1988; R. Dadlez, 1989).

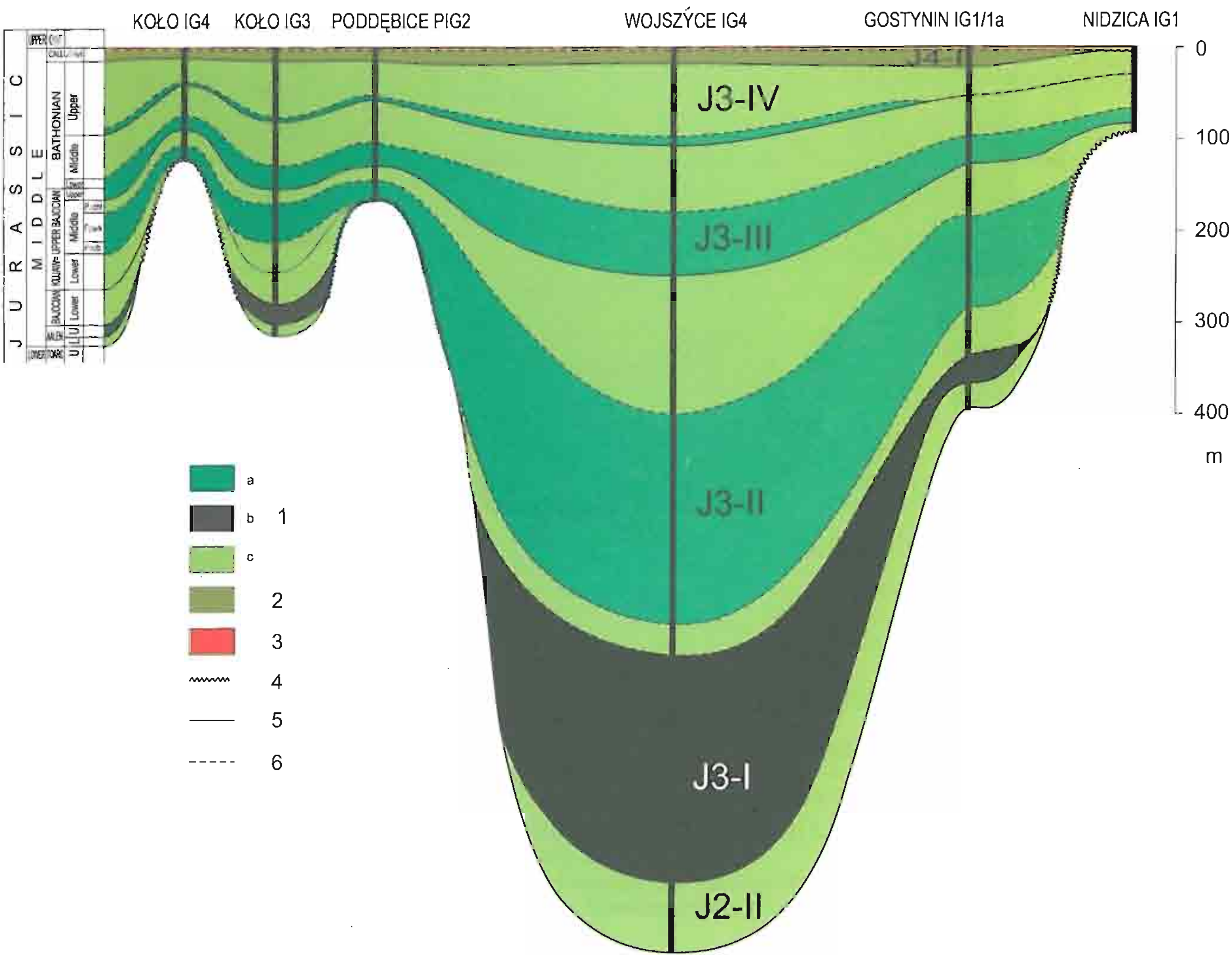


Fig. 3. Correlation of depositional systems and transgressive-regressive cycles between selected boreholes in the Middle Jurassic sequences of Central Poland

1 — siliciclastic shelf system (a — deeper siliciclastic shelf sub-system, b — anoxic shelf facies, c — shallower siliciclastic shelf sub-system); 2 — carbonate-clastic shelf system; 3 — starved shelf system; 4 — erosional surfaces; 5 — boundaries between transgressive-regressive cycles; 6 — boundaries between depositional systems

Korelacja systemów depozycyjnych i cykli transgresywno-regresywnych środkowej jury centralnej Polski pomiędzy wybranymi otworami wiertniczymi

1 — system szelfu klastycznego (a — podsystem szelfu głębszego, b — facje szelfu anoksycznego, c — podsystem szelfu płytszego); 2 — system szelfu węglanowo-klastycznego; 3 — system szelfu wygłodzonego; 4 — powierzchnie erozyjne; 5 — granice cykli transgresywno-regresywnych; 6 — granice systemów depozycyjnych

The Middle Jurassic epicontinental basin was connected with the Tethys, but transgression paths in Poland are still unclear. K. Dayczak-Calikowska and W. Moryc (1988) are of the opinion that the connection could exist via the East Carpathian Gate. J. Świdrowska (1994) considers that at least the Aalenian and Bajocian transgressions reached the Polish Lowlands via the Bełchatów–Częstochowa region.

Salt tectonics influenced the sedimentation and evolution of the Middle Jurassic basin. There were local elevations located south of the trough margin, which were formed as a result of salt movements (K. Dayczak-Calikowska, W. Moryc, 1988; R. Dadlez, 1989). Activity of salt masses was also quite strongly marked in the central part of the Kujawy Trough.

DEPOSITIONAL SYSTEMS

The following depositional systems have been recognized within the Middle Jurassic sequence in the Polish Lowlands:

(1) fluvial system;

(2) siliciclastic shelf system:

— shallower siliciclastic shelf sub-system,

— deeper siliciclastic shelf sub-system,

Table 1

Subdivision of the Middle Jurassic and sedimentary cyclicity in Polish Lowlands (stratigraphy after K. Dayczak-Calikowska *et al.*, 1997)

CYCLES	DEPOSITIONAL SYSTEMS					STAGE	SUB-STAGE	ZONES
J4-I		shallower carbonate-clastic shelf	starved shelf	carbonate-clastic shelf	carbonate ramp	Callovian	Upper	*duncani*
	deeper carbonate-clastic shelf							*pollux*
								jason
		shallower carbonate-clastic shelf					Lower	*calloviense*
J3-IV				carbonate ramp				*typicus*
	deeper siliciclastic shelf		shallower siliciclastic shelf		carbonate-clastic shelf	Bathonian	Upper	*discus*
								paradoxus
					carbonate ramp			*heterocostatus*
J3-III	shallower siliciclastic shelf				fluvial		Middle	*bremeri* *morrisi*
							Lower	*Procerites* sp.
	deeper siliciclastic shelf				shallower siliciclastic shelf	Kuiavian	Upper	*wuerttembergica* *ferruginea*
J3-II	shallower siliciclastic shelf						Middle	*schloenbachi*
	deeper siliciclastic shelf		shallower siliciclastic shelf		fluvial			*parkinsoni*
								subarietis
							Lower	*tetragona* *garantiana* *subfurcatum*
J3-I	shallower siliciclastic shelf					Bajocian	Lower	*blagdeni* *humphriesianum* *sauzei* *sowerbyi*
	anoxic shelf facies					Aalenian	Upper	*murchisonae*
J2-II	shallower siliciclastic shelf						Lower	*opalinum*

— anoxic shelf facies;
(3) carbonate-clastic shelf system;
(4) carbonate ramp system;
(5) starved shelf system.

Spacial relationships between the depositional sub-systems and systems within each cycle are shown in Tab. 1 and Figs. 8 and 9.

FLUVIAL SYSTEM

This system is composed of light grey fine-grained sandstones with kaolinite in matrix, showing large-scale cross bedding and intercalated by coals and coaly claystones rich in plant detritus.

These deposits have been recognized in the Lower Aalenian (transgressive-regressive cycle J2-II) in the Pomeranian part of the Mid-Polish Trough and in a continental series representing the Middle Kuiavian of the East European Platform.

SILICICLASTIC SHELF SYSTEM

Shallower siliciclastic shelf sub-system — sandstone complexes, several tens of metres thick deposited above storm wave level. The sandstones are fine-, medium- or coarse-grained with siliceous or argillaceous, locally calcareous matrix. Parallel, tabular, wave-ripple, flaser and low-angle cross bedding are observed. Heteroliths and flaser- or lenticular-bedded siltstones intercalated with conglomerates, pebbly horizons and mud clasts, are less common here. Limonite and chamosite oolites, chlorite, bivalves, foraminifers, ammonites, belemnites, crinoids, plant detritus and trace fossils (*Planolites* ichnosp., *Paleophycos* ichnosp., *Lockeia* ichnosp., *Isopodichnus* ichnosp., *Teichichnus* ichnosp. and *Diplocraterion* ichnosp. — only in the Lower Aalenian of the Kutno Depression) have been found.

This sub-system constitutes the transgressive-regressive cycle J1-II (Lower Aalenian) in the central and southeastern region of the Mid-Polish Trough, appears in the regressive phases of cycles J3-III and J3-IV in the East European Platform as well as corresponds to the transgressive phase of cycle J3-I in the Gorzów Block and Szczecin Trough.

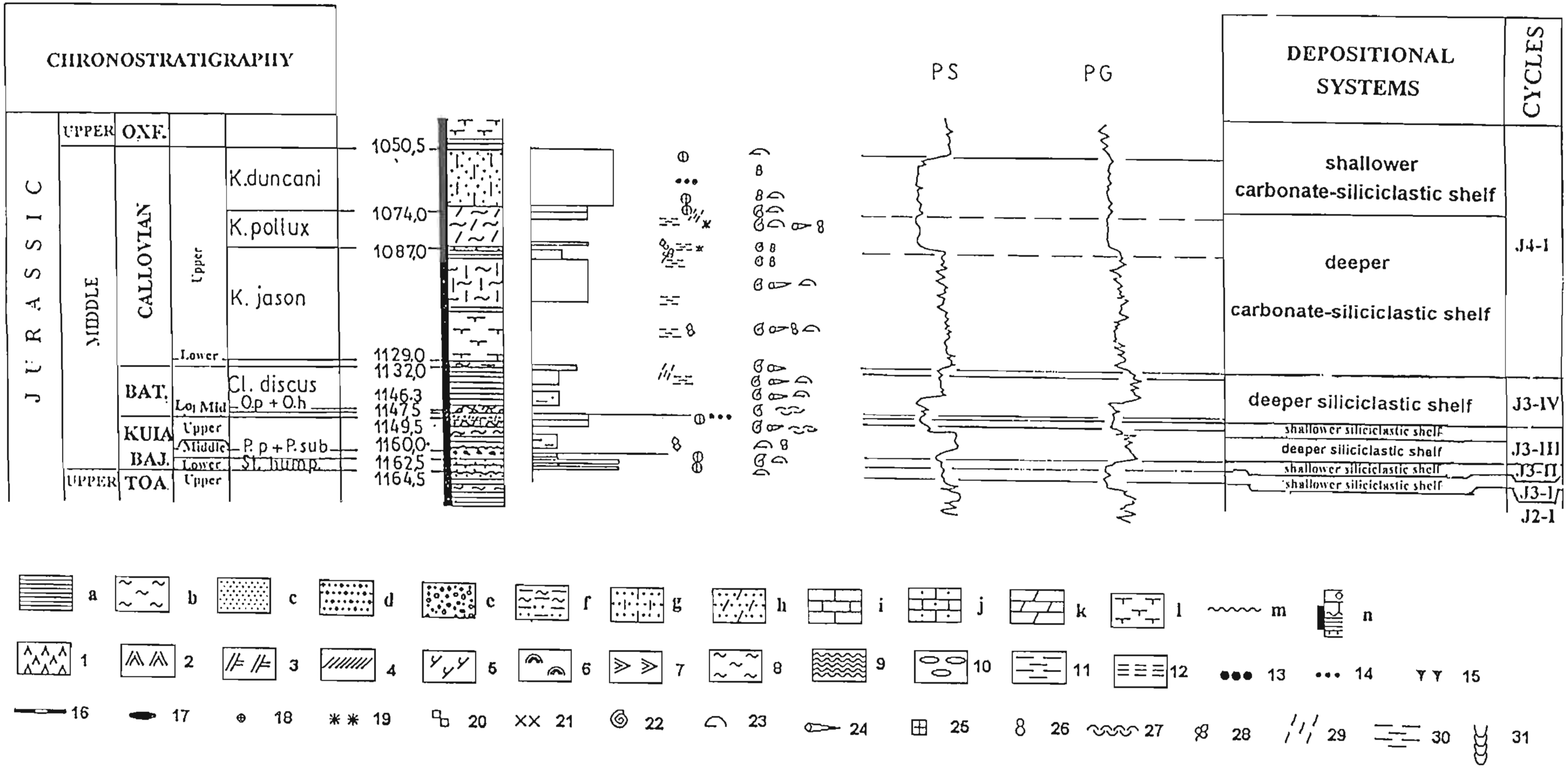


Fig. 4. Middle Jurassic depositional systems and cyclicity in the Choszczno IG 1 borehole section

L i t h o l o g y : a — shales and claystones, b — siltstones, c — very fine-grained and fine-grained sandstones, d — medium-, coarse-grained sandstones, e — gravel, conglomerates, f — argillaceous siltstones and sandstones, g — calcareous sandstones, h — dolomitic silstones, i — limestones, j — sandy limestones, k — dolomites, l — marls, m — erosional surfaces, n — cores; s e d i m e n t a r y   s t r u c t u r e s : 1 — flaser bedding, 2 — ripple bedding, 3 — low-angle cross bedding, 4 — tabular cross bedding, 5 — trough cross bedding, 6 — hummocky cross stratification, 7 — herring-bone bedding, 8 — clay laminae, 9 — wavy bedding, 10 — lenticular bedding, 11 — lenticular lamination, 12 — planar bedding, 13 — pebbles, 14 — quartz gravels, 15 — clay clast, 16 — sideritic horizons, 17 — sideritic concretions, 18 — ferruginous oolites, 19 — glauconite, 20 — mica, 21 — pyrite, 22 — ammonites, 23 — bivalves, 24 — belemnites, 25 — crinoids, 26 — foraminifera, 27 — coquina, 28 — flora remains, 29 — coalified flora detritus, 30 — pyritized flora detritus, 31 — *Diplocraterion* ichnosp.

Systemy depozycyjne i cykliczność w jurze środkowej w otworze Choszczno IG 1

L i t o l o g i a : a — łupki ilaste i iłowce, b — mułowce, c — piaskowce bardzo drobno- i drobnoziarniste, d — piaskowce średnio- i gruboziarniste, e — żwiry i zlepieńce, f — piaskowce i mułowce ilaste, g — piaskowce wapniste, h — mułowce dolomityczne, i — wapienie, j — wapienie piaszczyste, k — dolomity, l — margle, m — powierzchnie erozyjne, n — zakres rdzeniowania; s t r u k t u r y   s e d y m e n t a c y j n e : 1 — warstwowanie smużyste, 2 — warstwowanie ripplemarkowe, 3 — warstwowanie przekątne niskokątne, 4 — warstwowanie przekątne tabularne, 5 — warstwowanie przekątne rynnowe, 6 — warstwowanie kopułowe, 7 — warstwowanie jodełkowe, 8 — pojedyncze przesmużenia ilaste, 9 — warstwowanie faliste, 10 — warstwowanie soczewkowe, 11 — laminacja soczewkowa, 12 — warstwowanie poziome, 13 — otoczaki, 14 — żwirek kwarcowy, 15 — klasty ilaste, 16 — poziomy syderytyczne, 17 — konkrecje syderytyczne, 18 — oolity żelaziste, 19 — glauconit, 20 — muskowit, 21 — piryt, 22 — amonity, 23 — małże, 24 — belemnity, 25 — krynoidy, 26 — otwornice, 27 — muszlowce, 28 — fragmenty flory, 29 — uwęglona sieczka roślinna, 30 — spirytyzowana sieczka roślinna, 31 — *Diplocraterion* ichnosp.

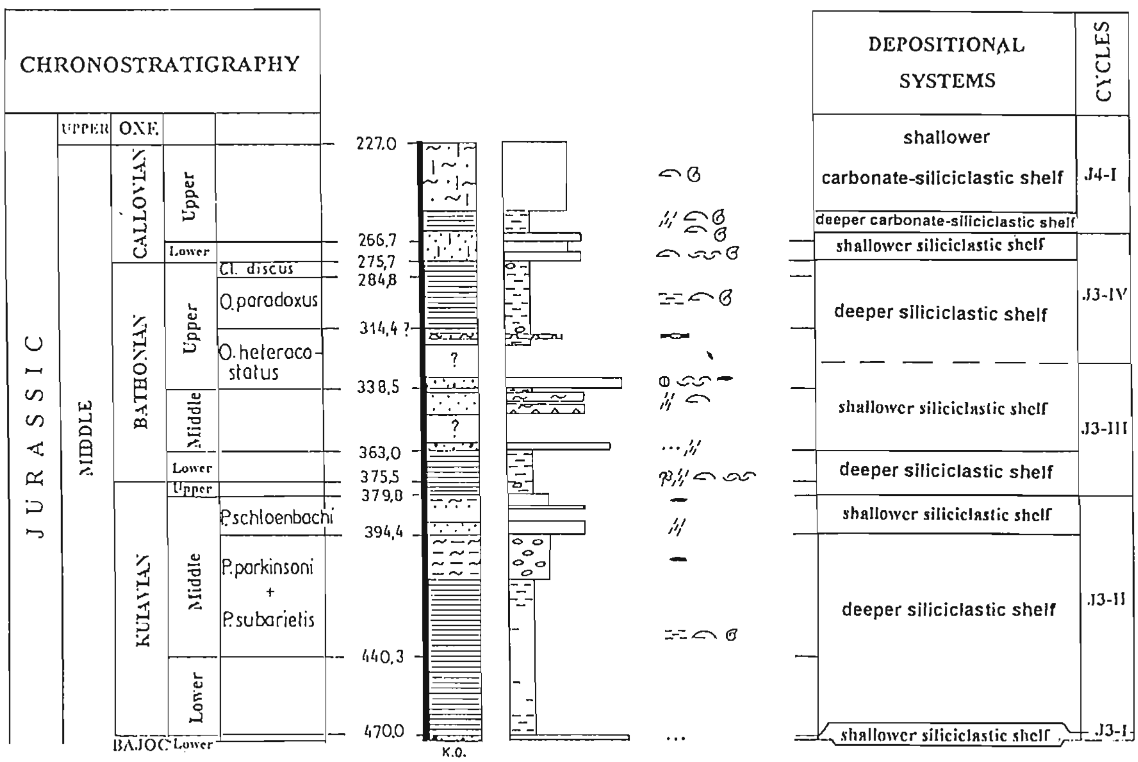


Fig. 5. Middle Jurassic depositional systems and cyclicity in the Lędyczek 2 borehole section
For explanations see Fig. 4

Systemy depozycyjne i cykliczność w jurze środkowej w otworze Lędyczek 2
Objaśnienia jak na fig. 4

In the lithologic column these deposits always reflect the progradation of shallower siliciclastic shelf — the transition from the offshore through shoreface into foreshore zone (J. Dadlez, 1996).

The deepest part of the sedimentary basin was located in the Kujawy region and in the northwestern margin of the Holy Cross Mts. Towards the north-west and north-east (into the East European Platform area) the basin was gradually shallowing. It is evidenced among others by the occurrence of abundant Fe-oolites in shallow shelf deposits of many cycles, e.g. in borehole sections of Nidzica IG 1, Choszczno IG 1 and Bytów IG 1. According to the recent views (G. Einsele, 1992), ferruginous oolites are deposited in shallow-marine, high-energy zones, above wave base (facilitating the formation of oolites), near estuaries of rivers transporting into marine basins iron compounds washed out from soil horizons of land areas. It seems, however, that the southwestern boundary of the central Mid-Polish Trough was of a different character. No evidence for the presence of foreshore zone (barrier or beach) has been recorded here. Bearing in mind the huge stratigraphic gap spanning Aalenian to Middle Kuiavian times, it is likely that the sea coast was steep from that side.

Deeper siliciclastic shelf sub-system — few tens of metres thick complex of dark grey structureless or lenticular-bedded and laminated mudstones with frequent sideritic horizons and concretions deposited below storm wave level. They yield a variety of fossils: ammonites, bivalves, foraminifers, belemnites, brachiopods, bryozoans, serpulids and locally very numerous feeding structures. Bivalve fauna very often occurs as coquina horizons, frequently sideritized. This sub-system includes ore-bearing deposits in the Łęczyca area (J. Znosko, 1957) and Polish Jura (K. Dayczak-Calikowska, J. Kopik, 1973; Z. Deczkowski, 1977).

Deeper siliciclastic shelf sub-system can be observed in the Middle Jurassic basin within the transgressive systems tract of cycles J3-I, J3-II and J3-III in the Mid-Polish Trough and Polish Jura as well as within the transgressive systems tract of cycle J4-I in Pomerania.

A n o x i c s h e l f f a c i e s — black structureless or lenticular-laminated shales and siltstones with spherical marly-sideritic concretions, pyritized plant debris, very scarce ammonites and also rare bivalve fauna concentrated in thin layers.

These facies occur within the transgressive systems tract of cycle J3-I.

CARBONATE-CLASTIC SHELF SYSTEM

This system is represented by highly calcareous or dolomitic sandstones, sandy limestones, dolomites and gaizes with flaser laminae, glauconite, flints and cherts. They yield

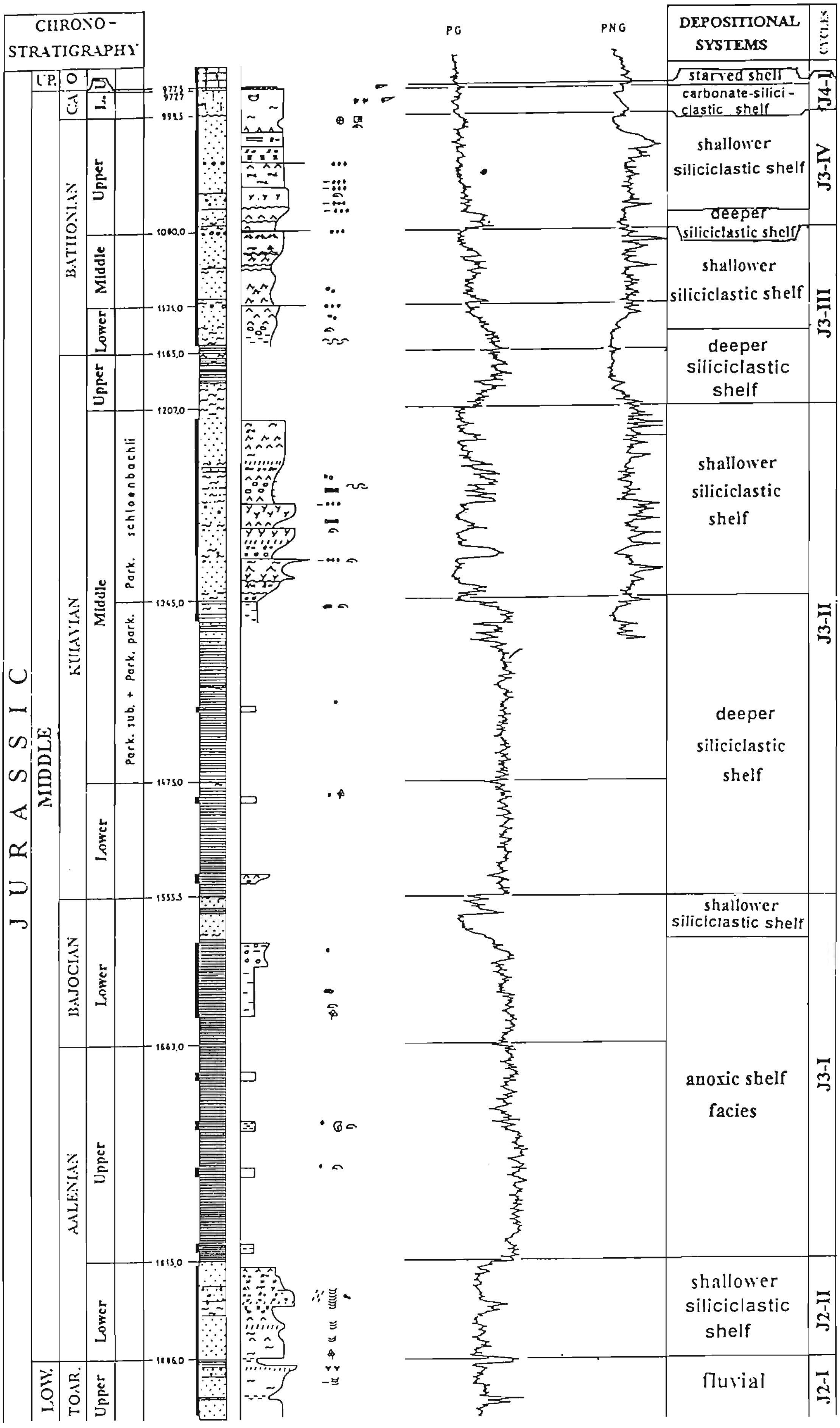


Fig. 6. Middle Jurassic depositional systems and cyclicity in the Wojszyce IG 4 borehole section
For explanations see Fig. 4

Systemy depozycyjne i cykliczność w jurze środkowej w otworze Wojszyce IG 4
Objaśnienia jak na fig. 4

many fossils: belemnites, ammonites, thin-shelled bivalves and few foraminifers.

Carbonate-clastic shelf deposits have been recorded from the transgressive systems tract of cycle J4-I in the central and Holy Cross part of the Mid-Polish Trough.

CARBONATE RAMP SYSTEM

This system comprises crinoid limestones composed of crinoid, bivalve and brachiopod detritus with admixture of dispersed limonite, oolites or iron crusts with scarce ammonites and foraminifers. The limestones are locally dolomitized.

This system appears in the transgressive stage of cycle VI in the Podlasie–Lublin area.

STARVED SHELF SYSTEM

This system is represented by a condensed layer, the so-called "nodular bed" composed of nodular limestones, slightly sandy or marly with glauconite or chamosite, as well as with sandstone, limestone and siderite pebbles, quartz gravel and abundant ammonite and belemnite fauna.

Such deposits occur in the regressive phase of transgressive-regressive cycle J4-I in the Polish Jura, central and Holy Cross part of the Mid-Polish Trough and in the Podlasie area.

TRANSGRESSIVE-REGRESSIVE CYCLES

Six 3rd-order transgressive-regressive cycles (1–10 Ma long each) can be recognized in the Middle Jurassic (Tab. 1, Figs. 8 and 9).

J2-II. This cycle corresponds to the Early Aalenian. It occurs only in the Mid-Polish Trough in a sedimentary continuity with the Lower Jurassic deposits (Upper Toarcian). In the central and southern regions this cycle is composed of shallower siliciclastic shelf sandstones, whereas in Pomerania it is represented by fluvial system. Transgressive and regressive parts can easily be distinguished in the central region. The transgressive part is characterized by the increasing upwards quantity of larger and larger trace fossils of *Diplocraterion* ichnosp. occurring in shallow shoreface zones, frequently of tidal flat character (as in the Hardeberg Formation in Scania). They are indicative of normal salinity basin. Within the regressive part these trace fossils dissapear and sandstones with dispersed coal dust, more and more coaly upwards, appear (Wojszyce IG 1, IG 3, IG 4 — Fig. 6).

The Early Aalenian transgressive-regressive cycle is poorly documented by fossils. Only borehole Kro**ś**niewice IG 1 has yielded foraminifers characteristic of the Aalenian (A. Ryll, 1970) (Tab. 2). The deposits containing foraminifers are believed to be Early Aalenian in age (*opalinum* Zone) since they underlie the documented Late Aalenian ones (*murchisonae* Zone).

This sedimentary cycle corresponds to the Early Aalenian cycle of the B. U. Haq *et al.* curve (1988), but it does not correspond to the A. Hallam curve (1988) in which a sea-level drop is drawn in the Early Aalenian (Fig. 10).

J3-I. This cycle comprises the Late Aalenian and Early Bajocian. In the Mid-Polish Trough it occurs in a stratigraphical continuity with the Lower Aalenian deposits, whereas in the Szczecin Trough, Gorzów Block and Kalisz–Częstochowa area it overlies the Lower Jurassic rocks.

The transgressive systems tract is composed of anoxic shelf facies (Fig. 6) (in the Kalisz–Częstochowa area only, it consists of shallower siliciclastic shelf deposits of the "Kościelisko Beds"). Shallower siliciclastic shelf deposits occur in the regressive part.

The age of the transgressive part is evidenced by the presence of index ammonites in the central region (J. Znosko, 1957; A. Ryll, 1970), Holy Cross Mts. margin (A. Ryll, 1970) and Kalisz–Częstochowa area (Z. Deczkowski, 1977) (Tab. 2).

The regressive part is dated by the latest Early Bajocian (*humphriesianum* Zone) index ammonites only in the Kalisz–Częstochowa area (Z. Deczkowski, 1977). In the central and southern Mid-Polish Trough, no index fossils have been found in sandstones referred to as Early Bajocian on the basis of its position in a lithologic-stratigraphic column.

In Pomerania (Szczecin Trough and Gorzów Block), the shallower siliciclastic shelf deposits (Choszczno IG 1 — Fig. 4) transgressing over the older basement with a basal conglomerate (Gorzów Wlkp. IG 1) are documented by Early Bajocian micro- and macrofossils (K. Dayczak-Calikowska, 1965). In borehole Gorzów Wlkp. IG 1, the ammonites of *Dorsetensia* sp. and *Witchellia* sp. indicative of the Early Bajocian, have been found in both the basal conglomerate and overlying sandstones. K. Dayczak-Calikowska and J. Znosko (1966) suggested that a great accumulation of ammonite fragments of the above-mentioned genera points to the *humphriesianum* Zone, as in the Częstochowa region. However, it seems possible that lower zones of the Early Bajocian are present here, and a gap corresponding to regressive sandy deposits of the central region will fall into the *humphriesianum* Zone. It will also correspond with the eustatic curve of B. U. Haq *et al.* (1988) in which the maximum regression is drawn within this ammonite zone.

Cycle J3-I corresponds to the curve of B. U. Haq *et al.* (1988), but it does not correspond to the A. Hallam curve (1988) in which, after the regressive Aalenian, a transgression is recorded as late as during the earliest Bajocian (*discites* Zone) (Fig. 10).

Occurrence of key taxa documenting ouset and termination of the Middle Jurassic transgressive-regressive cycles

STAGE	SUB-STAGE	ZONES	SZCZECIN TROUGH GORZÓW BLOCK	POMERANIAN SWELL	KUJAVIAN SWELL	POLISH JURA	MARGINS OF THE HOLY CROSS MTS.	EAST- EUROPEAN PLATFORM	CYCLES
OXF.	Lower								
CALLOVIAN	Upper								
	Lower	*calloviense*	(R) *Proplanulites teisseyeri* Tornquist *Cadoceras* cf. *elatmae* Nikitin (J) *Kepplerites (Gowericeras) gowerianus* (Sowerby)	(14) *Proplanulites* cf. *koenigi* Sowerby *Proplanulites teisseyrei* Tornquist *Cadoc ·as* cf. *elatme* Nikitin *Kepplerites (Gowericeras) gowerianus* (Sowerby) *Sigaloceras (S.)calloviense* (Sowerby)	*Macrocephalites macrocephalus* var. *compı ·ssus* Qu. *Macrocephalites (Pleurocephalites) tumidus* Rein. (2)(B)	(19) *Kepplerites (Koricellites)* cf. *lahuseni* (Parona et Bonarelli) (17) *Macrocephalites subsubtrapezinus* (Waag.) (9) *Hecticoceras hectı.um* (Rein.) *Kepplerites (Gowericeras) gowerianus* (Sow.) *Macrocephalites macrocephalus* (Schloth.) *Hecticoceras (H.) hecticum* (Rein.) *Sigalocer.:s (S.)calloviense* (Sow.)	(18) *Macrocephalites (M.) compressus* (Qu.) *M.(Indocephalites) chrysolithus* (Waag.) *M.(I.) diadematus* (Waag.) *M.(Pleurocephalites) pila* Nikitin *M.(Dolikephalites) uhligi* (Lemoine) *M.(Kamptokephalites) lamellosus* (Sow.) *M.(K.) herveyi* (Sow.) *Sigaloceras calloviense* (Sow.) *Indosphinctes* cf. *patina* (Neum.)	(16) (T) *Proplanulites koenigi* Sow. *Oppelii?* cf. *calloviensis* Par. et Bon. (S) *Oxycerites subcostarius* (Opp.) *Macrocephalites* sp. (cf. *pila* Nikitin) *Proplanulites teisseyrei* Tornq.	J4-I T
		typicus		(14) *Propranulites* cf.*koenigi* (Sowerby) *Spiroceras bispinatum* Bang.et Sanzl *Macrocephalit.. ; (Tmetokephalites)* cf. *franconicus* (Rollier) *Macrocephalites macrocephalus* (Schloth.) *Macrocaր.ıalites* sp. ex gr. *typicus* (Blake)	(2)(B) *Macrocephalites* sp. *Hibolites call. ·viense* Opp.	(19) *Keppleriters (Kr)* cf. *keppleri* Opp. (9) *Oxycerites subcostarius* (Opp.) *Macrocephalites macrocephalus* (Schloth.) *Macrocephalit. ɜ typicus* (Blake)			
BATHONIAN	Upper	*discus*							
		paradoxus	(15) *Paroecotraustes (P.) paradoxus* (Roemer)		(9) (12)				
		heterocostatus		(14) *Eohecticoceras notabile* (Roem.) *Oxycerites aspidoidı* (Opp.) *Oxycerites fuscoides* Westerm. (14)(O) *Paroecotraustes (P.)* cf. *heterocostatus* (Rehbinder)	*Paroecotraustes (P.) heterocostatus* (Rehbinder) *Paroecotraustes ser.igerus* var. *heterocostata* (Rehb.) *Paroecotraustes serrigerus* var. *densecostata* Liss. *Paralicidia* cf. *flexiradiata* Liss. *Paroecotraustes (P.) serrigerus* (Waagen)(9) *Prohecticoceras retrocostarium* Qu. *Oxycerites* cf. *aspidoides* Opp. (9)			(P) *Epistomina ex. gr parastelligera* (Hofk.) *Miliolina częstochov.:ensis* Pazdro *Ophthalmidium carinatum agglutinans* Pazdro *Thurmanella alemanica* Roll. (13)(N)	J3-IV T
	Middle								
	Lower								
KUJAVIAN	Upper	*compressa*	(8)(J) *O·ycerites yeovilensis* (Rollier)	(7)(I)	*Glyptocythere hieroglyphica tuberosa* Br. (1)(A) *Parkinsonia compre·sa* Qu. *Parkinsonia ferruginea* Opp. *Parkinsonia (Oranicera.) cf. valide* Wetz. (10)(K)		(10)(M) *Oxycerites* sp. cf. *sublillobatus* (Wetzel)		J3-III
		ferruginea (=*valida*)	(F) *Parkinsonia* sp. ex gr. *ferruginea - compressa* (5)(G) *Belemnopsis beyrichi* (Oppel) *Belemnopsis canaliculatus* (Schloth.)	(2)(B)	*Parkinsonia* cf. *eimensis* Wetz. *Parkinsonia* cf. *neuffensis* Opp. cf. *compressa* Qu. *Parkinsonia* cf. *ferruginea* Opp. *Parkinsonie* sp. (ex gr. *ferruginea - compressa*) *Oxycerites* cf. *bomfordi* Ark. *Oxycerites* cf. *asp·Joides* Opp	(3) *Morphoceras* cf. *polymorphum* (d'Orbigny) *Parkinsonia compressa*(Qu.) *Parkinsonia ferruginea* (Opp.)	*Glyptocythere tuberosa angularis* Blaszczyk *Oligocythereis fullonica* (Jones et Sherborn) *Zigzagiceras* sp. *Paroecotraustes (Paroecotraustes)* sp.	(11)(L)	T
	Middle	*schloenbachi*			*Parkinsonia* cf. *planulata* Qu. *Parkinsonia* sp. (cf.*neuffensis* Opp.)(7)(I)	*Parkinsonia schloenbachi* Schippe (9)			
		parkinsoni							
		subari.:tis	*Parkinsonia* sp. (5)(G) (ex gr. *radieta - subarietis*) *Subgarantiana* cf. *pompeckji* Wetzel *Parkinsonia* sp. *and* (8)(J) *Garantiana (Subgarantiana)* sp.						J3-II
	Lower	*tetragona*		(7)(I)	*Strenoceras subfurcatum* (Ziet.) *Strenoceras niortense* d'Orb. *Garantiana* cf. *bifurcata* (Ziet.) *Garantiana densicostata* Qu.				
		garantiene			*Orthogarantiana* sp. (1)(A) (6)(H)	*Garantiana* sp. (3)			
		subfurcatum		(2)(B)	*Strenoceras* sp. *Garantiane* sp. *Garantiene baculata* Qu.				T
BAJOCIAN		*blagdeni*				(3) *Toeloceras blagdeni* (Sowerby)			
		humphriesianum				*Stephanoceras humphriesianum* (Sowerby)			
	Lower	*sauzei sowerbyi?*	*Witchellia* sp. (5)(G) *Dorsetensia* sp. *Haplophragmoides concavus* (Chapm.) *Haplophragmoides canariensis* (d'Orb.) *Ammobaculites fontinensis* (Terq.) *Ammodiscus orbis* Lalick *Verneuilinoidı · liasina* Terq.et Berth. *Proteoina ar pullacea* (Brady)	(4)(F)		(3)			J3-I
AALENIAN	Upper	*murchı :ɔnae*			*Ludᐟ·.igia* sp. (B)(C)(D) (1)(2) *Reinholdella dreheri* (Bart.) (1)(A)	*Tmeloce·a·* sp. *Ludwigia murchisonae*(Sow.) *Graphoceras* sp. *Variamussium pumilum* (Lamarck)	(1)(E) *Co:tileioceras opalinoides* Mayer		T
	Lower	*opalinum*			(1)(A) *Reinholdella dreheri* (Bart.) *Ammodiscus glumaceus* Gerke et. Soss.. *Verneuilinoides mauritii* (Terq.)				J2-II T

J3-II. This cycle spans Early to Middle Kuiavian[1] times. In the Mid-Polish Trough it occurs in a sedimentary continuity with the Lower Bajocian deposits, whereas in the Szczecin Trough, Gorzów Block and Kalisz–Częstochowa area, there is a gap between cycles J3-I and J3-II embracing in Pomerania the upper part of the Lower Bajocian (*humphriesianum* Zone? and *blagdeni* Zone) and in the Kalisz–Częstochowa area the lowermost part of the Lower Kuiavian (*subfurcatum* Zone). In the areas of sedimentary continuity, the transgressive phase is marked by deeper shelf mudstones (e.g. Wojszyce IG 4 — Fig. 6; Gostynin IG 1/1a, Lędyczek 2 — Fig. 5). In the areas where the sea transgressed the earlier eroded land (Szczecin–Gorzów region — Choszczno IG 1 and Gorzów Wlkp. IG 1), shallower siliciclastic shelf deposits occur. In the regressive phase, deeper shelf mudstones pass up into shallower shelf heteroliths and sandstones. In the marginal zones, after a progradation of shallower siliciclastic shelf deposits during the Middle Kuiavian, the sea retreated and a land area was subjected to erosion.

The Early Kuiavian transgression is well dated over the whole area by the appearance of index ammonites pointing to the *subfurcatum* Zone (A. Ryll, 1970; K. Dayczak-Calikowska, 1990; J. Znosko, 1957; A. Ryll, 1971; Z. Deczkowski, 1977) (Tab. 2). In some areas, e.g. the Łęczyca–Ozorków and Rawa (Justynów Anticline) regions, all the ammonite zones have been recorded.

The transgression of the third cycle was delayed only in the Szczecin–Gorzów region. The coexistence of the ammonites of *Garantiana* (*Subgarantiana*) sp. and *Parkinsonia* sp. recognized in borehole Choszczno IG 1 in a medium-grained sandstone with gravel and chamosite oolites overlying a distinct erosional surface, univocally points to the *subarietis* Zone (K. Dayczak-Calikowska, 1977*e*). In borehole Gorzów Wlkp. IG 1, ammonite fauna indicative of the *subarietis* Zone has also been found in a transgressive conglomeratic vari-grained sandstone with clay balls and clasts (K. Dayczak-Calikowska, J. Znosko, 1966). In the Szczecin–Pomeranian region, J3-II deposits are merely a few metres thick and they comprise only the *subarietis* Zone and perhaps the lower part of the *parkinsoni* Zone. In the *schloenbachi* Zone, and maybe even somewhat earlier, the sea retreated from this area, surviving only along the whole Mid-Polish Trough.

The regressive phase of cycle J3-II is poorly documented. Ammonite fauna is present only in the Cracow–Częstochowa (S. Z. Różycki, 1953), Rawa (A. Ryll, 1971) and Łęczyca–Ozorków regions (J. Znosko, 1957) (Tab. 2).

The onset of the transgression of the Middle Jurassic cycle J3-II in the Mid-Polish Trough corresponds with the beginning of cycle LZA-2.1 of B. U. Haq *et al.* (1988). In the marginal parts, as it was shown above, this transgression begins later (upper zones of the Lower Kuiavian or even beginning of the Middle Kuiavian). The Early Kuiavian transgression generally corresponds with a sea-level rise shown in the eustatic curve of B. U. Haq *et al.* (1988), whereas the Middle Kuiavian one (Szczecin–Gorzów region) falls into a regressive section of that curve. A similar case occurred in the whole Mid-Polish Trough where a thick complex of dark grey mudstones was deposited during the *subarietis* and *parkinsoni* Zones and a distinct regression was marked as late as in the *schloenbachi* Zone. This cycle in the Polish Lowlands is not comparative with the A. Hallam's curve (1988), either (Fig. 10).

It seems that the run of this cycle was influenced by local tectonism in the Mid-Polish Trough. Probably strong subsidence in the *subarietis* and *parkinsoni* Zones resulted in the maintenance of deep shelf conditions during the worldwide regression. It also seems that the transgression in the Szczecin–Gorzów area probably took place at the very beginning of the *subarietis* Zone which is equivalent to the German *acris* Subzone. The maximum high stand of sea-level in cycle LZA-2.1 occurred at that time, as seen in the B. U. Haq *et al.* curve (1988) (Fig. 10).

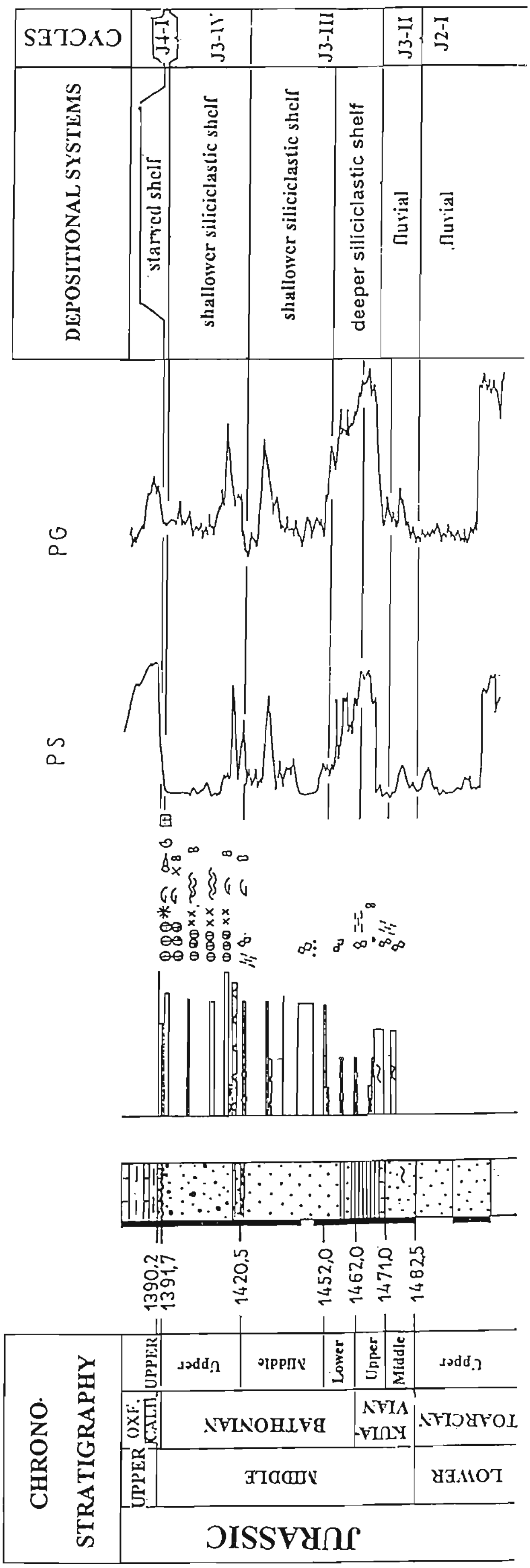
J3-III. This cycle spans Late Kuiavian through Middle Bathonian times. In the Mid-Polish Trough, the Late Kuiavian and Early Bathonian transgressive phase is marked by mudstones of siliciclastic deeper shelf system with siderite interbeds. The regressive phase is represented in this area by the Middle Bathonian sandstones of shallower siliciclastic shelf system (Wojszyce IG 4 — Fig. 6; Koło IG 3, Lędyczek 2 — Fig. 5; correlations — Figs. 2 and 3). The same succession of depositional systems can be observed south of the Mid-Polish Trough: in the Szczecin–Gorzów region (Choszczno IG 1 — Fig. 4, correlation — Fig. 2), Wielkopolska Ridge (Koło IG 4), Kalisz–Częstochowa region and in the southwestern part of the East European Platform (south-west of Nidzica–Olsztyn line) (Nidzica IG 1 — Fig. 7).

The Late Kuiavian transgression is very well evidenced in the whole Polish Lowlands area by the appearance of index ammonites (Z. Deczkowski, 1977; J. Znosko, 1957; A. Ryll, 1970, 1971; J. Kopik, 1979*a*) and locally microfossils (e.g. ostracods and foraminifers in the Bełchatów region, J. Kopik, 1979*a*) (Tab. 2). In some cases it has been possible to distinguish both ammonite zones (*ferruginea* and *compressa*). In the Szczecin–Gorzów region, macrofossils also provide a univocal dating of dark grey mudstones transgressing over this area again after a sedimentary break in the *schloenbachi* Zone. In borehole Gorzów Wlkp. IG 1, a sandy siderite with quartz gravel occurs at the base of these deposits, yielding fragments of thick-shelled bivalves and cephalopods pointing to the Late Kuiavian (K. Dayczak-Calikowska, J. Znosko, 1966).

The Late Kuiavian also saw a transgression over the East European Platform. Microfossils known from boreholes Ni-

[1]Kuiavian = local Polish equivalent of the Upper Bajocian (Lower and Middle Kuiavian) and lowermost Bathonian (Upper Kuiavian).

N u m b e r s i n c i r c l e s : 1 — A. Ryll (1970), 2 — J. Znosko (1957), 3 — Z. Deczkowski (1977), 4 — K. Dayczak-Calikowska (1965), 5 — K. Dayczak-Calikowska, J. Znosko (1966), 6 — K. Dayczak-Calikowska (1990), 7 — A. Ryll (1971), 8 — K. Dayczak-Calikowska (1977*e*), 9 — S. Z. Różycki (1953), 10 — J. Kopik (unpubl.), 11 — J. Kopik (1979*a*), 12 — J. Znosko (1954*a*, *b*), 13 — K. Dayczak-Calikowska (1977*b*), 14 — K. Dayczak-Calikowska (1977*a*), 15 — K. Dayczak-Calikowska (1977*e*), 16 — K. Dayczak-Calikowska (1964), 17 — M. Giżejewska (1981), 18 — M. Siemiątkowska-Giżejewska (1974), 19 — J. Kopik (1979*b*); l e t t e r s i n c i r c l e s : A — Krośniewice IG 1, B — Łęczyca–Ozorków area, C — Borucice K30, D — Odechów 5/XI, E — Sylwestrynów, F — Szczecin IG 1, G — Gorzów Wlkp. IG 1, H — Koło IG 3, I — Justynów Anticline, J — Choszczno IG 1, K — Brześć Kujawski IG 2, L — Bełchatów, M — Gomunice 13, N — Bytów IG 1, O — Oświno IG 1, Piekary IG 1, P — Nidzica IG 1, R — Lędyczek 2, S — Pasłęk IG 1, T — Gołdap IG 1



dzica IG 1 and Olszyny IG 1 are characteristic of both the Late Kuiavian and Early Bathonian with a slight prevalence of the former (K. Dayczak-Calikowska, 1964).

Cycle J3-III corresponds to both B. U. Haq *et al.* (1988) and A. Hallam curves (1988) (Fig.10).

J3-IV. This cycle comprises the Late Bathonian–Early Callovian (*typicus* Zone). In Pomerania, the Late Bathonian transgressive systems tract is represented by deeper siliciclastic shelf deposits whereas in the central region this system occurs only in the lowermost part passing upwards into shallower shelf sandstones with Fe-oolites at the top.

At the beginning of the Late Bathonian, a widespread transgression over the whole East European Platform took place. In Pomerania (Bytów IG 1), the transgressive phase is represented by shallower shelf sandstones with Fe-oolites; similar sediments with a sandy-gravel conglomerate at the base or shallower carbonate-clastic shelf deposits were accumulated in the central region. In the Podlasie–Lublin area, the transgression usually spread upon older units (Lower Jurassic or even Carboniferous–Precambrian). The sedimentation began here with a transgressive conglomerate rich in pebbles of basement rocks overlain by shallower shelf sandy organodetrital limestones with thick-shelled bivalves and Fe-oolites. A stromatolitic or intraformational conglomerate layer occurs at their top. Above, sandy organodetrital limestones with very abundant limonite appear again (K. Dayczak-Calikowska, J. Kopik, 1973).

The regressive phase in Poland is very distinctly marked in the *typicus* Zone (Lower Callovian). The sea retreated from the marginal parts of the basin at that time (the Szczecin–Gorzów region and East European Platform from Pomerania as far as the Lublin area) and a continuous sedimentation took place only in the Mid-Polish Trough (excluding the Holy Cross Mts. — M. Siemiątkowska-Giżejewska, 1974) and Kalisz–Częstochowa region (K. Dayczak-Calikowska, 1966).

The Late Bathonian age of the transgression is very well evidenced in Pomerania. In the Mid-Polish Trough it began as early as during the *heterocostatus* Zone and is proved by index ammonites of this zone (K. Dayczak-Calikowska, 1977*a*). Ammonites documenting the *heterocostatus* Zone in central and southern Polish Lowlands have only been described from the Częstochowa region so far (Z. Deczkowski, 1977) (Tab. 2).

The *paradoxus* and *discus* Zones are documented in the Pomeranian Trough by many index ammonites (K. Dayczak-Calikowska, 1977*a*). A number of ammonites have also been found in the Szczecin Trough. It seems, however, that this area was transgressed by the sea as late as in the *paradoxus* Zone. It is evidenced by the occurrence of index fossils of *Oecotraustes (Paroecotraustes) paradoxus* (Roemer) in borehole Choszczno IG 1 within sandstones appearing just above the transgressive conglomerate.

Fig. 7. Middle Jurassic depositional systems and cyclicity in the Nidzica IG 1 borehole section

For explanations see Fig. 4

Systemy depozycyjne i cykliczność w jurze środkowej w otworze Nidzica IG 1

Objaśnienia jak na fig. 4

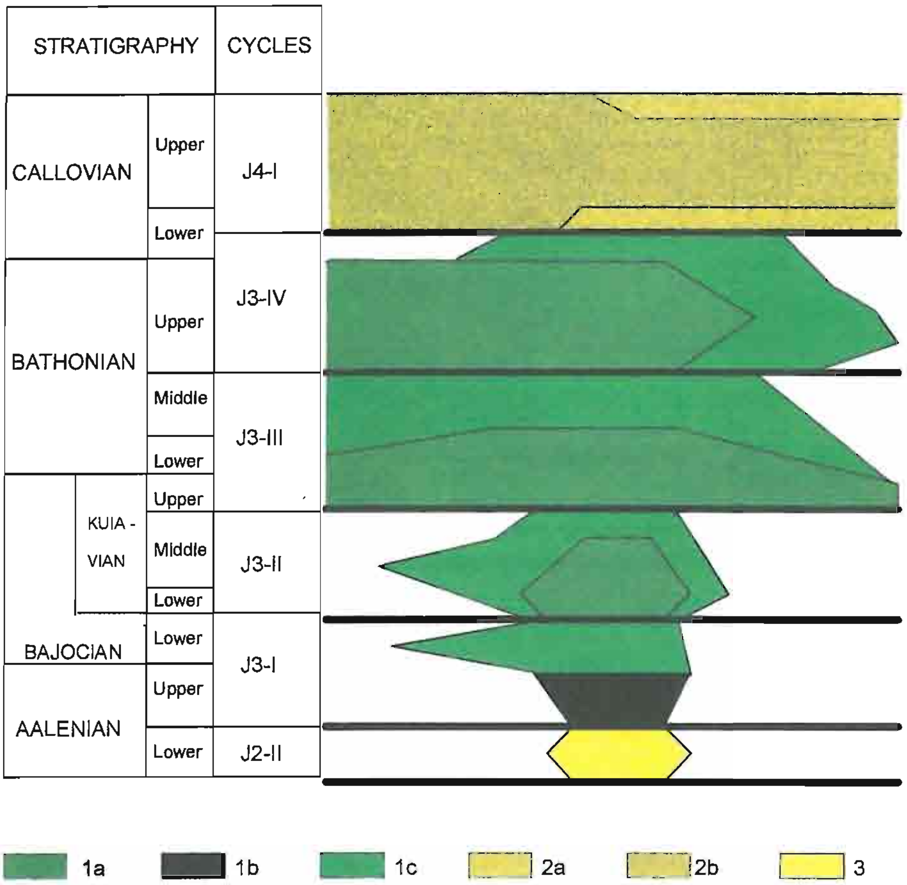


Fig. 8. Schematic diagram showing the succession of the Middle Jurassic depositional systems in the Pomeranian region

1 — siliciclastic shelf system (a — deeper siliciclastic shelf sub-system, b — anoxic shelf facies, c — shallower siliciclastic shelf sub-system); 2 — carbonate-clastic shelf system (a — deeper shelf, b — shalower shelf); 3 — fluvial system

Schematyczny przekrój obrazujący następstwo systemów depozycyjnych w jurze środkowej regionu pomorskiego

1 — system szelfu klastycznego (a — podsystem szelfu głębszego, b — facje szelfu anoksycznego, c — podsystem szelfu płytszego); 2 — system szelfu węglanowo-klastycznego (a — głębszego, b — płytszego); 3 — system fluwialny

The Late Bathonian transgression also encroached the East European Platform. It is dated by the appearance of abundant brachiopods of *Thurmanella alemantica* Roll in borehole Bytów IG 1 (K. Dayczak-Calikowska, 1977*b*), and in the Mazury region by the ammonite *Clydoniceras* sp. in borehole Olszyny IG 1 (K. Dayczak-Calikowska, 1964) and Late Bathonian foraminifers in borehole Nidzica IG 1.

As it was mentioned above, the regression of the *typicus* Zone caused the sea to retreat from marginal parts; in these areas, a gap between the Bathonian and the upper Lower Callovian zone (*calloviense*) or even Upper Callovian (eastern part of the Mazury High, Pomeranian Trough and western part of the Peribaltic Syneclise) is observed. In the remaining area, calcareous sandstones occasionally with Fe-oolites, occur. They are documented by index ammonites of the genus *Macrocephalus* (K. Dayczak-Calikowska, 1977*a*; A. Ryll, 1970; Z. Deczkowski, 1977) (Tab.2). It is likely that in the central part of the Mid-Polish Trough (Wojszyce IG 4 — Fig. 6), there is also a gap comprising the *typicus* Zone. It is indicated by the occurrence of a well marked erosional surface above the calcareous sandstones with Fe-oolites and crinoid trochytes, overlain by sandy limestones with glauconite. No dating is available for these deposits, but regional correlations show that the glauconitic limestones probably represent the *calloviense* Zone.

The transgression of cycle J3-IV corresponds to the transgression of cycle LZA-2.3 in the B. U. Haq *et al.* (1988) curve whereas the regressive phase in the *typicus* Zone does not correspond to the worldwide strong sea-level fall, which in this curve begins earlier in the preceding zone (*discus*). During the latter, a sedimentation of black claystones representing deep shelf, took place in Poland. The Middle Jurassic J3-IV cycle is in harmony with the A. Hallam's curve (1988) (Fig. 10).

J4-I. This cycle comprises Lower Callovian (*calloviense* Zone), Upper Callovian and Lower Oxfordian deposits[2]. Two distinct sedimentological provinces are seen in the Polish Lowlands: the Pomeranian province and central-eastern province extending into the Częstochowa region (Figs. 8, 9).

[2] The Callovian/Oxfordian boundary in Polish Lowlands is located between the *duncani* (= *athleta*) Zone and *flexicostatum* (=lower part of the *lamberti*) Zone.

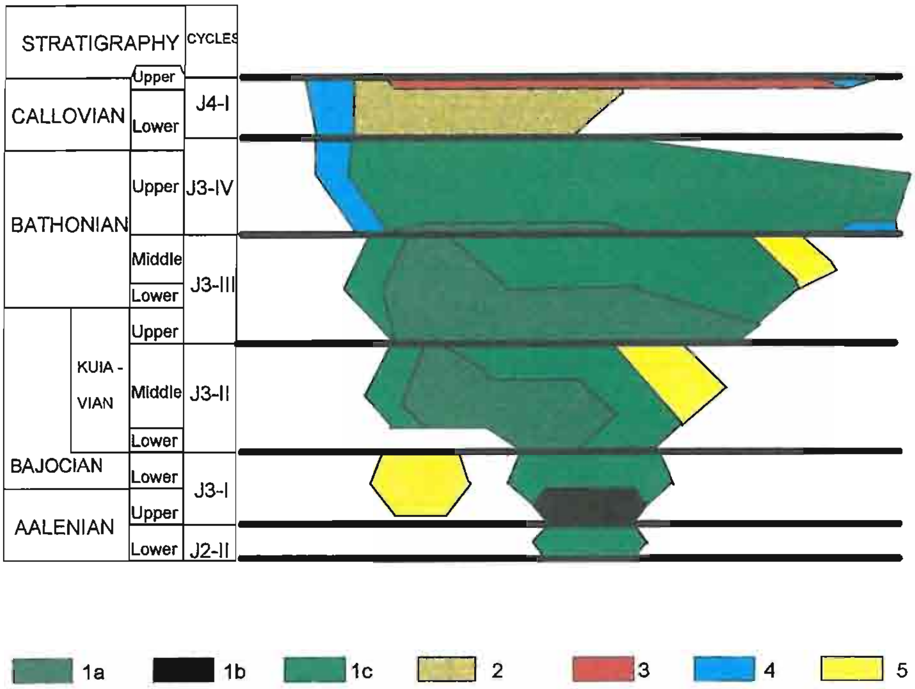


Fig. 9. Schematic diagram showing the succession of the Middle Jurassic depositional systems in the Central, Eastern and Southern regions
1 — siliciclastic shelf system (a — deeper siliciclastic shelf sub-system, b — anoxic shelf facies, c — shallower siliciclastic shelf sub-system); 2 — carbonate-clastic shelf system; 3 — starved shelf system; 4 — carbonate ramp system; 5 — fluvial system

Schematyczny przekrój obrazujący następstwo systemów depozycyjnych w jurze środkowej regionu centralnego, wschodniego i południowego
1 — system szelfu klastycznego (a — podsystem szelfu głębszego, b — facje szelfu anoksycznego, c — podsystem szelfu płytszego); 2 — system szelfu węglanowo-klastycznego; 3 — system szelfu wygłodzonego; 4 — system rampy węglanowej; 5 — system fluwialny

In Pomerania, in both the Mid-Polish Trough and Szczecin region, shallower carbonate-clastic shelf deposits: calcareous and dolomitic sandstones or siltstones with index ammonites of the *calloviense* Zone, occur at the base of this cycle (Figs. 4, 5). No sedimentation has been recorded in the Pomeranian part of the East European Platform at that time (the gap comprises the upper part of the Upper Bathonian — *discus* Zone — and the whole Lower Callovian) (Bytów IG 1).

The sandy deposits pass upwards into deeper shelf calcareous mudstones or marls. A transgression was simultaneously developing in the Pomeranian part of the East European Platform (Upper Callovian claystones overlie a hardground appearing at the top of Upper Bathonian deposits in borehole Bytów IG 1). Vertical succession of facies shows that the basin was deepest during the *pollux* Zone and then, in the *duncani* Zone and Early Oxfordian the basin was gradually shallowing. All the three Upper Callovian zones are very well dated in Pomerania by index fossils (K. Dayczak-Calikowska, 1977*a*).

A different type of sedimentation took place east of approximately 18°W meridian. The transgressive phase is represented here by shallower carbonate-clastic shelf deposits: sandy limestones, calcareous sandstones and gaizes with glauconite, cherts and flints (Fig. 6, 7). Only in the Podlasie–Lublin area, crinoid limestones of carbonate ramp system occur (T. Niemczycka, 1965). The ammonite fauna points to the beginning of the Early Callovian (*calloviense* Zone) transgression. Only in the Mazury High it began in the *jason* Zone and the basal conglomerate overlies the Bathonian deposits there. In the whole area, a "nodular bed" representing starved basin system appears above. This is a condensed layer formed during a high stand of sea-level (HST) by a very quick transgression upon a flat peneplenized land. Such a transgression resulted in a separation of this part of the basin from the source area and thus a lack of clastic material supply into the basin. Simultaneously, factors unknown so far, hampered at that time the precipitation of calcium carbonate or caused it to be dissoluted. The "nodular bed" comprises the whole Late Callovian (*sensu polonico*) and locally also the early Early Oxfordian.

The transgression of the sixth cycle (*calloviense* Zone) is very well dated. Index fossils occur in the Częstochowa region (Z. Deczkowski, 1977; S. Z. Różycki, 1953; J. Kopik, 1979*b*), Łęczyca–Ozorków area (J. Znosko, 1957) and Holy Cross Mts. margins (M. Siemiątkowska-Giżejewska, 1974) (Tab. 2). In the East European Platform, the transgression is also very well dated by index ammonites (K. Dayczak-Calikowska, 1964).

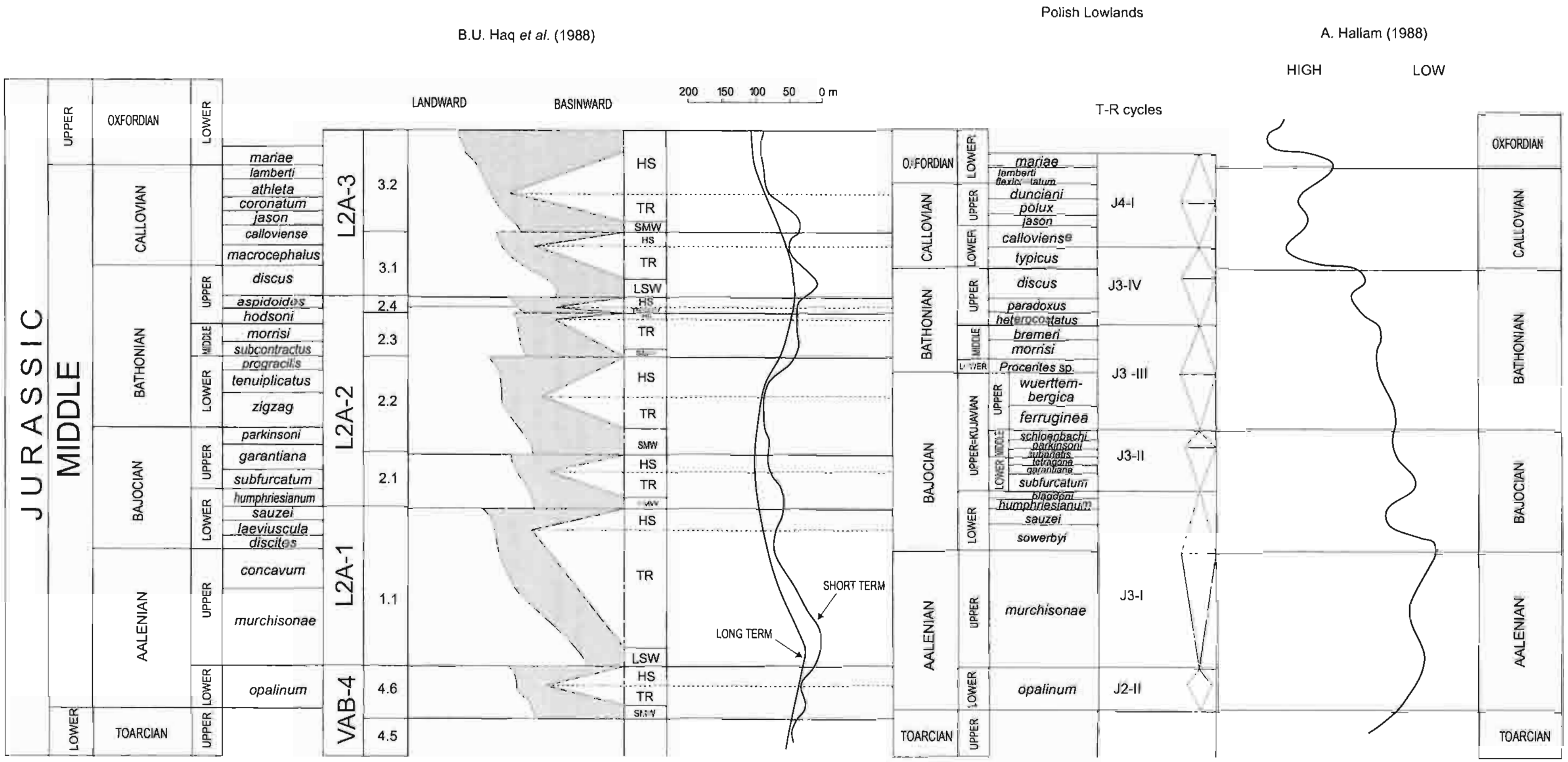


Fig. 10. Transgressive-regressive cycles in Central Poland compared with eustatic curve of B. U. Haq *et al.* (1988) and with eustatic curve of A. Hallam (1988)
Porównanie cykli transgresywno-regresywnych Polski centralnej z krzywą eustatyczną według B. U. Haqa i in. (1988) oraz krzywą według A. Hallama (1988)

J4-I transgression, considered to have occurred in the *calloviense* Zone, is not in coincidence with the curve of B. U. Haq *et al.* (1988). However, it corresponds to the Hallam's curve (1988) (Fig. 10).

CONCLUSIONS

1. The Middle Jurassic sedimentation took place within a shelf basin. During transgressive phases, deep-shelf mudstones were deposited. Regressive phases were the periods of shallow-shelf sandy and heterolithic sedimentation. Fluvial deposition occurred only during the Early Aalenian in northeastern Poland. From the Callovian, carbonate-clastic and carbonate shelf deposits are known.

2. The Early Jurassic basin shows an oscillatory character. Continuous sedimentation took place only in the Mid-Polish Trough. In the marginal parts, numerous sedimentary and erosional gaps are observed.

3. Abundant ammonite fossils allow a precise timing of transgressive and, to a lesser extent, regressive phases.

4. Six 3rd-order transgressive-regressive cycles have been recognized in the Polish Basin. They well correspond to the cycles distinguished either in the B. U. Haq *et al.* curve (1988) or in the A. Hallam curve (1988) (Fig. 10). Only cycle J3-II does not correspond to those curves. It seems that it results from local tectonism in the Mid-Polish Trough.

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ARCHITEKTURA DEPOZYCYJNA ŚRODKOWOJURAJSKIEGO EPIKONTYNENTALNEGO BASENU POLSKIEGO

Streszczenie

Analizę basenową utworów jury środkowej wykonano na podstawie otworów zlokalizowanych zarówno w bruździe śródpolskiej, jak i na jej obrzeżeniach (fig. 1). Otwory wiertnicze pełnordzeniowane lub o dużym procencie rdzeniowania zostały przedstawione w sposób graficzny na oddzielnych profilach oraz przekrojach korelacyjnych przebiegających poprzecznie do bruzdy: Choszczno IG 1 (fig. 4), Lędyczek 2 (fig. 5), Złotów 1, Charzykowy IG 1 i Bytów IG 1 — linia pomorska (fig. 2); Koło IG 4, Koło IG 3, Poddębice PIG 2 i Wojszyce IG 4 (fig. 6) i Nidzica IG 1 (fig. 7) — linia centralna (fig. 3).

W wyniku analizy sedymentologicznej utwory jury środkowej Niżu Polskiego podzielono na systemy depozycyjne: fluwialny, szelfu klastycznego (z podsystemami szelfu płytszego i głębszego z facją szelfu anoksycznego), szelfu węglanowo-klastycznego, rampy węglanowej i szelfu wygłodzonego.

Na podstawie analizy następstwa pionowego oraz przejść obocznych utwory jury środkowej podzielono na 6 cykli transgresywno-regresywnych.

J2-II. Cykl ten obejmujący aalen dolny występuje jedynie w bruździe śródpolskiej. Na obszarze kujawskim i południowym wykształcony jest w postaci piaskowców płytszego szelfu klastycznego, w obrębie których można wydzielić człon transgresywny z *Diplocraterion* ichnosp. oraz człon regresywny z coraz większym udziałem rozproszonej substancji węglistej. W regionie pomorskim są to piaskowce fluwialne. Utwory te są bardzo słabo datowane jedynie na podstawie otwornic.

Cykl odpowiada dolnoaaleńskiemu cyklowi na krzywej B. U. Haqa i in. (1988), natomiast nie jest zgodny z krzywą A. Hallama (1988) (fig. 10).

J3-I. Cykl datowany jest na aalen górny–bajos dolny. W bruździe śródpolskiej utwory tego cyklu występują w ciągłości sedymentacyjnej z utworami aalenu dolnego, natomiast w niecce szczecińskiej i na bloku Gorzowa oraz regionie kalisko-częstochowskim zalegają na podłożu dolnojurajskim. W fazie transgresywnej wykształcony jest w postaci utworów ilasto-mułowcowych reprezentujących fację anoksyczną głębszego szelfu (z wyjątkiem regionu częstochowskiego), natomiast w fazie regresywnej w postaci piaskowców i mułowców płytszego szelfu.

Transgresywna część cyklu jest dobrze datowana przewodnimi amonitami. Część regresywna jest datowana jedynie na obszarze kalisko-częstochowskim (tab. 2).

Cykl odpowiada cyklowi na krzywej B. U. Haqa i in. (1988), natomiast nie pokrywa się z krzywą A. Hallama (1988).

J3-II reprezentuje przedział czasowy kujaw dolny–kujaw środkowy. Utwory tego cyklu występują w ciągłości sedymentacyjnej jedynie w bruździe śródpolskiej, natomiast na obszarze szczecińsko-gorzowskim i kalisko-częstochowskim między cyklami występuje luka obejmująca górną część bajosu dolnego oraz kujaw dolny lub jego niższą część. W osiowej części basenu fazę transgresywną tworzą iłowce i mułowce głębszego szelfu klastycznego, a w partiach brzeżnych piaskowce płytszego szelfu. W fazie regresywnej utwory głębokiego szelfu przechodzą w heterolity i utwory piaskowcowe płytkiego szelfu, natomiast na obszarach brzeżnych następuje progradacja utworów płytkiego szelfu, po której morze wycofuje się, a obszar lądowy ulega erozji (Choszczno IG 1 — fig. 4).

Odcinek transgresywny cyklu jest bardzo dobrze datowany na podstawie amonitów, natomiast regresywny jedynie na obszarze południowym Niżu Polskiego.

Cykl nie jest zgodny z żadną krzywą zmian poziomu morza (fig. 10). Wydaje się, że na jego przebieg miała wpływ lokalna tektonika w bruździe śródpolskiej. Prawdopodobnie silna subsydencja w poziomach *subarietis* i *parkinsoni* spowodowała utrzymywanie się warunków głębokiego morza podczas światowej regresji.

J3-III. Cykl ten obejmuje przedział czasowy kujaw górny–baton środkowy. Część transgresywną cyklu znaczą iłowce i mułowce z pokładami syderytów reprezentujące system głębszego szelfu klastycznego, natomiast fazę regresywną utwory piaskowcowe szelfu płytszego. Transgresja górnego kujawu wkroczyła również po raz pierwszy w jurze środkowej na platformę wschodnioeuropejską i objęła jej część północno-zachodnią. Na całym Niżu Polskim jest ona dobrze udokumentowana wiekowo na podstawie amonitów, a niekiedy mikrofauny.

Cykl jest zgodny zarówno z krzywą B. U. Haqa i in. (1988), jak i A. Hallama (1988).

J3-IV. Cykl ten jest datowany na baton górny–kelowej dolny (poziom *typicus*). W regionie pomorskim ciąg transgresywny tworzą osady głębszego szelfu klastycznego; w regionie centralnym osady tego systemu występują jedynie w części najniższej cyklu, a ku górze przechodzą w piaskowce płytszego szelfu z oolitami Fe w stropie. Transgresja objęła również całą platformę wschodnioeuropejską, łącznie z obszarem podlasko-lubelskim, gdzie występują utwory jury środkowej płytszego szelfu węglanowo-klastycznego.

Faza regresywna zaznacza się bardzo wyraźnie w poziomie *typicus*. Morze wycofuje się w tym czasie z regionów brzeżnych (K. Dayczak-Calikowska, 1966), a sedymentacja trwa jedynie w bruździe śródpolskiej (oprócz obszaru świętokrzyskiego — M. Siemiątkowska-Giżejewska, 1974) oraz regionie kalisko-częstochowskim.

Transgresja górnobatońska jest dobrze udokumentowana na podstawie amonitów jedynie w regionie pomorskim (K. Dayczak-Calikowska, 1977*a*) i częstochowskim (Z. Deczkowski, 1977).

Transgresja pokrywa się z początkiem transgresji górnobatońskiej zarówno na krzywej B. U. Haqa i in. (1988) i A. Hallama (1988), natomiast regresja w poziomie *typicus* zgodna jest jedynie z krzywą A. Hallama. Na krzywej B. U. Haqa faza regresywna przypada wcześniej (w poziomie

discus), a w poziomie *typicus* rozpoczyna się już transgresja cyklu następnego (fig. 10).

J4-I. Cykl ten obejmuje utwory od keloweju dolnego (poziom *calloviense*) po oksford dolny. W czasie trwania tego cyklu wyraźnie zaznaczają się dwie prowincje sedymentacyjne na Niżu Polskim. Część pomorska jest dobrze datowana faunistycznie. Występują tu utwory płytszego szelfu węglanowo-klastycznego przechodzące w szelf głębszy z marglami i wapnistymi iłowcami, a następnie w fazie regresywnej ponownie w wapniste piaskowce i heterolity płytszego szelfu. Odmienny typ sedymentacji notowany jest na wschód od południka 18°. Początkowo są to wapienie piaszczyste, gezy z glaukonitem zaklasyfikowane jako utwory płytszego szelfu węglanowo-klastycznego. W etapie regresywnym doszło do silnej kondensacji osadu i powstania tzw. warstwy bulastej. Również w tej części Niżu cykl ma dobrą dokumentację amonitową.

Wydzielony cykl nie jest zgodny z krzywą B. U. Haqa i in. (1988), natomiast jest zgodny z krzywą A. Hallama (1988) (fig. 10).