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New petrological data on carbonate mineralogy in the Middle Jurassic siliciclastic deposits of the Kujawy region (Polish Lowlands)

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Carbonate minerals present in bioclasts, ooids, cements and veinlets of the Middle Jurassic rocks from the Kujawy area have been studied in detail. It has been found that the bioclasts are built of calcite and manganese calcite replaced by ferroan calcite, ankerite and minerals from the siderite group. Chamosite — the primary component of the ooids — is often replaced by siderite and magnesium siderite or ankerite. Cements of sandstones and mudstones are mainly built of ankerite while fillings of the veinlets — of ankerite and ferroan calcite. Widespread cementation with iron, calcium and magnesium carbonates as well as associated metasomatosis of grains and cements are related mainly to activity of salt tectonics.

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Key words: diagenetic cementation, calcite, ankerite, sideroplesite, siderite, Middle Jurassic, Kujawy region.

INTRODUCTION

Carbonate minerals in the Dogger deposits drilled by deep boreholes in the axial part of the Kujawy Swell and its slope (Fig. 1) are the objective of the present paper. Majority of the materials were obtained from the following boreholes: Ciechocinek IG 1, IG 2, IG 3, Czernikowo IG 1, Brześć Kujawski IG 1, IG 2, IG 3 and Wojszyce IG 1/1a, IG 3, IG 4. Rock samples from the boreholes Różyce 1 and Bodzanów 3 (the Warsaw–Płock Trough) as well as Poddębice PIG 2, Trześniew 1 and Koło IG 3, IG 4 (the Mogilno–Łódź Trough) were investigated as well. The aim of the present paper is the presentation of new results of the analyses of carbonate minerals obtained recently during the studies on diagenesis of the Mesozoic deposits in Central Poland.

Numerous publications were written in the 50-ies and 60-ies on geology of the Kujawy region. These most frequently quoted authors are: J. Znosko (1957*a*, *b*, 1959, 1969), W. Pożaryski (1952, 1957*a*, *b*), S. Różycki (1957), S. Marek (1961, 1967, 1969), R. Dadlez, S. Marek (1969), R. Krajewski (1957) and J. Dembowska (1957). The author of the present article is of the opinion that the paper of J. Znosko (1957*a*) on the uplift of the Kłodawa salt dome as well as on its influence on the origin of siderite coquinas was of an outstanding significance. It was an inspiration for the other students of the Kujawy region. It was and still remains to be often quoted.

J. Znosko's suggestions on the relationship between salt tectonics and the mineralisation of the Middle Jurassic rocks were further adopted by J. Wojciechowski and J. Ziomek (1966, 1968) who studied sphaleritic veinlets in the Łęczyca siderites. M. Turnau-Morawska (1961) in her excellent petrographical study on the ore-bearing deposits of the Łęczyca Vesulian confirmed J. Znosko's hypotheses on the relationship between coquina sedimentation and the movement of the salt masses and on the causes of accumulation of the iron-rich minerals in the Łęczyca deposit. The cited author distinguished different phases of pyrite, chamosite and siderite formation. Owing to M. Turnau-Morawska (1961) we obtained extremely detailed microscopic descriptions of different varieties of the siderite rocks and their components, as well as the detailed considerations on the origin of chamosite and siderite, and on the causes of the mineralisation of the Jurassic rocks.

The already mentioned paper by J. Znosko (1957*a*) was also the inspiration of studies on petrography of red-brownish

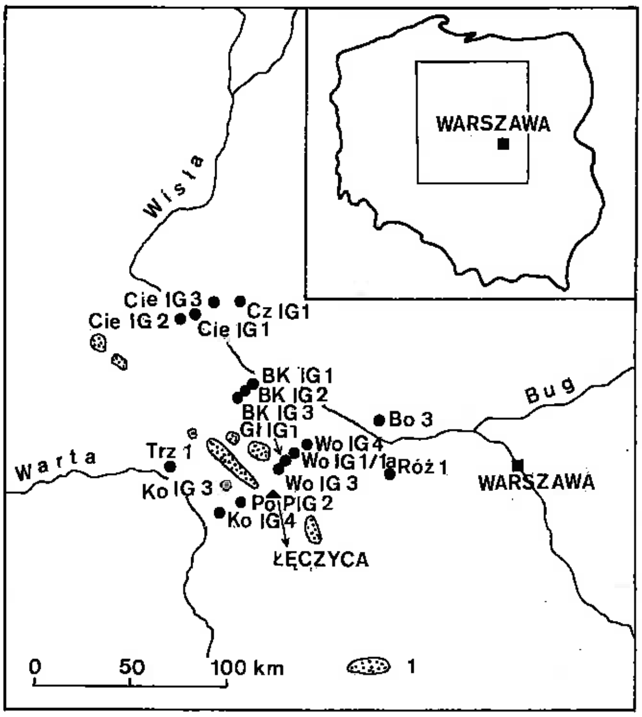

Fig. 1. Location of studied boreholes

Bo 3 — Bodzanów 3, BK IG 1 — Brześć Kujawski IG 1, BK IG 2 — Brześć Kujawski IG 2, BK IG 3 — Brześć Kujawski IG 3, Cie IG 1 — Ciechocinek IG 1, Cie IG 2 — Ciechocinek IG 2, Cie IG 3 — Ciechocinek IG 3, Cz IG 1 — Czernikowo IG 1, Gł IG 1 — Głogowiec IG 1, Ko IG 3 — Koło IG 3, Ko IG 4 — Koło IG 4, Po PIG 2 — Poddębice PIG 2, Róż 1 — Różyce 1, Trz 1 — Trześniew 1, Wo IG 1/1a — Wojszyce IG 1/1a, Wo IG 3 — Wojszyce IG 3, Wo IG 4 — Wojszyce IG 4; 1 — salt domes reaching the sub-Cainozoic surface (after S. Marek, 1977)

Szkic lokalizacyjny badanych otworów wiertniczych

1 — wysady solne przebijające się na powierzchnię podkenozoiczną (według S. Marka, 1977) (objaśnienia symboli otworów wiertniczych — patrz podpis angielski)

Bathonian sandstones in the borehole Głogowiec IG 1 done by A. Teofilak-Maliszewska (1968). J. Znosko found epigenetic haematite in these sandstones, whereas the geochemical analyses showed that the rocks are also enriched in copper, tin and molybdene. Moreover, they contain increased contents of Ba, Ti, V, Cr, Co, Ni, Zn and Pb. Some grains of potassium feldspar in sandstones have regeneration overgrowths. This fact suggests an influx of the potassium-rich pore waters. The results of the studies conducted on the Głogowiec rocks have proved, therefore, a distinct relation between the mineralisation of the Bathonian sandstones and the inflow of the Zechstein brines rich in ions of many chemical elements (also the accessory ones). The significance of brine migration also into the Upper Jurassic rocks from the Kujawy area was pointed out by: R. Krajewski (1957), S. R. Krażewski (1966), K. Radlicz (1967), T. Zydorowicz (1982), A. Świerczewska (1984), R. Chlebowski (1985) and E. Górecka (1985).

At the end of the 80-ies Polish Geological Institute drilled 10 deep exploration boreholes in the axial part of the Kujawy Swell, i.e. in the Ciechocinek–Wojszyce zone, as well as the borehole Poddębice PIG 2 in its western part — in the Mogilno–Łódź Trough. Descriptions of these boreholes are a very valuable information source on the geological structure of the swell, on lithological development of the deposits as well as their petroleum reservoir and source-rock properties. In these archive materials the petrological reports of the Middle Juras-

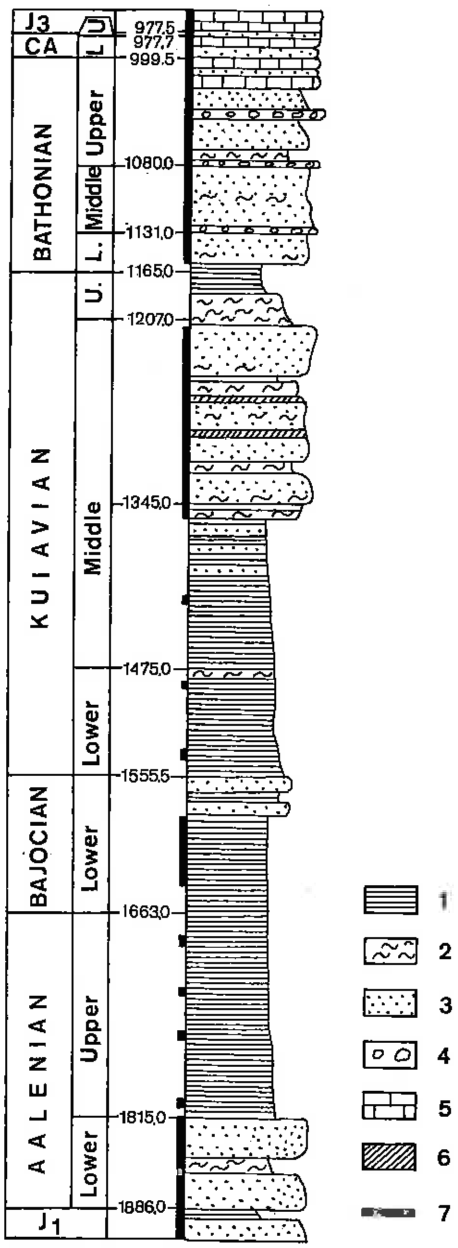

Fig. 2. Simplified lithological-stratigraphical section of the Middle Jurassic deposits from the borehole Wojszyce IG 4 (after A. Feldman-Olszewska, 1997)

1 — claystones, 2 — mudstones, 3 — sandstones, 4 — conglomerates, 5 — limestones, 6 — siderites, 7 — core intervals, J_1 — Lower Jurassic, CA — Callovian, J_2 — Upper Jurassic

Uproszczony profil litologiczno-stratygraficzny osadów jury środkowej z otworu wiertniczego Wojszyce IG 4 (według A. Feldman-Olszewskiej, 1997)

1 — iłowce, 2 — mułowce, 3 — piaskowce, 4 — zlepieńce, 5 — wapienie, 6 — syderyty, 7 — odcinki rdzeniowane, J_1 — jura dolna, CA — kelowej, J_2 — jura górna

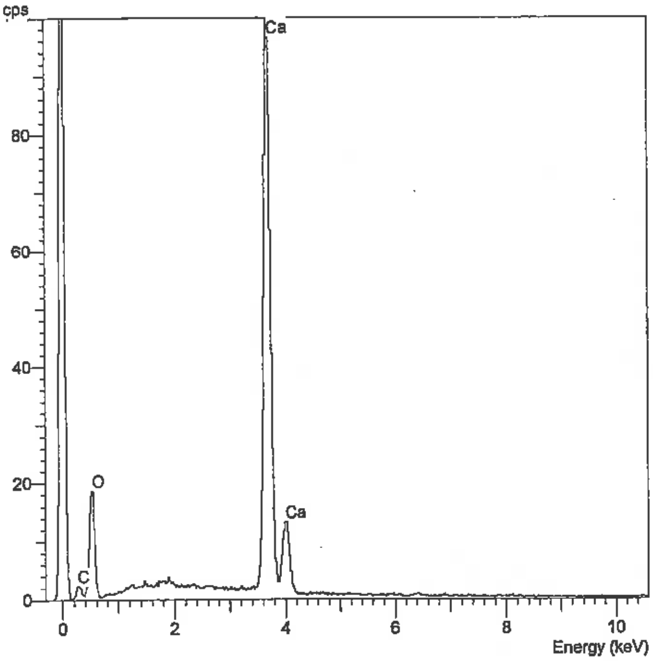

Fig. 3

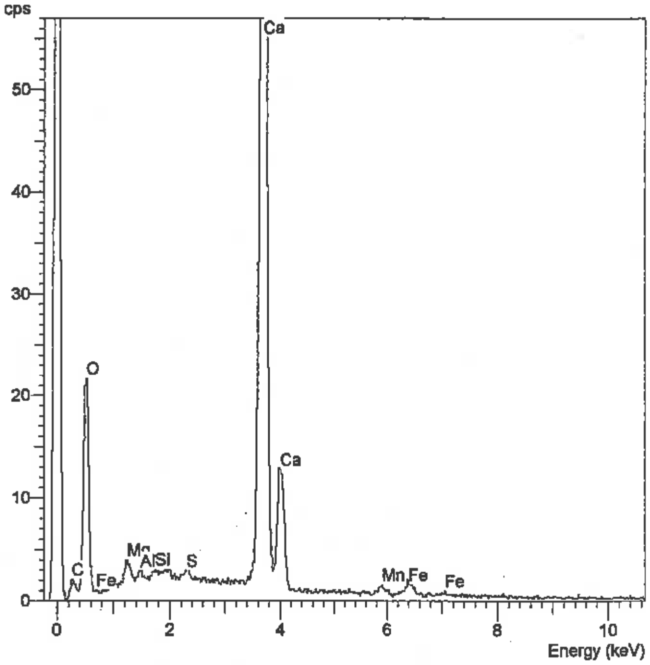

Fig. 4

Fig. 3. X-ray spectrum of calcite without impurities. Foraminifer test from Pl. I, Fig. 13, point B. Ankeritic sandstone, Poddębice PIG 2, depth of 3227.3 m, upper Bathonian

Widmo rentgenowskie kalcytu bez domieszek (EDS, BEI). Skorupka otwornicy z tabl. I, fig. 13, punkt B. Piaskowiec ankerytowy, Poddębice PIG 2, głęb. 3227,3 m, baton górny

Fig. 4. X-ray spectrum of Fe/Mn calcite. Cement filling void in foraminifer test from Pl. I, Fig. 13, point A. Small admixtures of Mg, Si and Al may come from dispersed clayey pelite, S — from pyrite

Widmo rentgenowskie kalcytu Fe/Mn (EDS, BEI). Cement wypełniający pustkę w skorupce otwornicy z tabl. I, fig. 13, punkt A. Drobne domieszki Mg, Si i Al mogą pochodzić z rozproszonego pelitu ilastego, S — z pirytu

sic rock samples are to be mentioned, done mostly by J. Dadlez (1989*a–c*, 1990*a–c*, 1991*a–c*) and by A. Maliszewska (1989, 1994). The J. Dadlez reports (*ibidem*) contain not only the description of the rocks but also valuable remarks on their origin. The results of these studies supplement the earlier data from the boreholes in the Koło, Trześniew and Różyce area.

The Middle Jurassic deposits from the Kujawy region represent the sediments of the shallow epicontinental sea with the maximum extent in the late Callovian (K. Dayczak-Calikowska, 1967, 1997; K. Dayczak-Calikowska, W. Moryc, 1988). Majority of these deposits contains carbonate minerals of which calcite, dolomite and siderite have been found so far. Suggestions on possibilities of ankerite occurrence based on the studies on the relief of carbonate individuals are given in the papers by M. Turnau-Morawska (1961) and A. Teofilak-Maliszewska (1968), without, however, confirmation by other methods.

In the above cited papers by J. Dadlez and A. Maliszewska contents of calcite and dolomite determined during drilling are presented. They are given as CaO and MgO concentration in bulk samples and show a general composition of the carbonate minerals in a rock (without $FeCO_3$). A detailed identification of the carbonate components is possible only with applying newer analytical methods including stained thin sections, cathodoluminescence studies, SEM and X-ray microprobe chemical analysis.

Since the beginning of her work in Polish Geological Institute in 1959 the author of the present paper has been studying petrology of the Jurassic rocks. For this whole time span she has been kindly consulted and advised by Professor Jerzy Znosko. She owes Him the encouragement to prepare her habilitation thesis on petrography of the Middle Jurassic deposits in northeastern Poland. It is great pleasure to expresss her deepest thanks to Professor J. Znosko at the occasion of fiftieth anniversary of His scientific work.

ANALYTICAL METHODS

A standard analysis of the samples under a polarizing microscope (Nikon Optiphot 2) was the basic analytical method applied in the case of the Jurassic rocks. Two hundred twenty thin sections of new samples were studied, their composition being compared with the petrographic reports by J. Dadlez (1989*a–c*; 1990*a–c*, 1991*a–c*). Uncovered thin sections of one hundred fifty samples were prepared and stained with the Evamy's solution (1963). The latter is a solution of

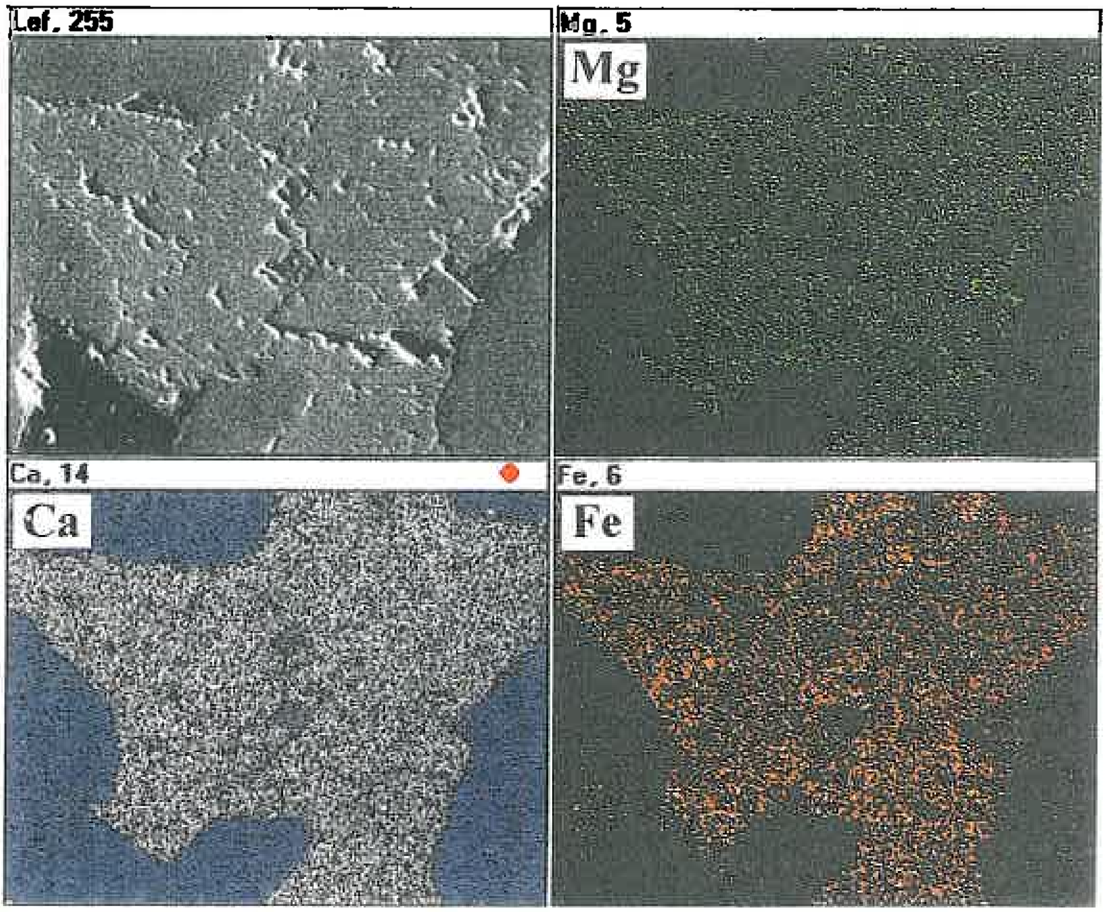

Fig. 5. Map of distribution of Ca, Mg and Fe in homogeneous ankeritic cement of sandstone (EDS, BEI). Czernikowo IG 1, depth of 1634.4 m, upper Bathonian; x 120

Mapa rozmieszczenia Ca, Mg i Fe w jednorodnym ankerytowym cemencie piaskowca (EDS, BEI). Czernikowo IG 1, głęb. 1634,4 m, baton górny; 120 x

alizarine red S, HCl and potassium ferrocyanide in the distilled water. The method was popularised by J. A. D. Dickson (1966) and adopted in Poland by Z. Migaszewski and M. Narkiewicz (1983). It results in the following colour reactions: iron-free calcite stains red, calcite with a low iron content — pink-violet, while Fe-rich calcite — purple. Iron-free dolomite remains colourless, ferroan dolomite turns to blue, ankerite — to dark blue. According to the observations by J. A. D. Dickson (1966), M. Scherer (1977), as well as D. K. Richter and H. Füchtbauer (1978) the blue colour may be imparted also on calcite which contains over 3.5 mol % of $FeCO_3$. To distinguish this type of calcite from the ferroan dolomite and ankerite staining with alizarine red S was applied (calcite is stained red) and exceptionally — the microprobe chemical control.

Twenty two uncovered and polished thin sections were studied in CL. The method is based on luminescence of some minerals induced by electron beam in the vacuum. The cathodoluminescence studies were conducted using the English equipment (Cambridge Image Technology — model *CCL* 8200 mk^3). The vacuum chamber for the sample is mounted on the stage of petrographic microscope (Nikon Optiphot 2). The following carbonate minerals were distinguished by this method: non-luminescent, pure calcite; manganese calcite with a yellow-orange luminescence; ferroan calcite with a weak brown luminescence. Mn/Fe calcite (recognised by other chemical methods) luminesces similarly to the non-ferroan manganese calcite (D. J. Marshall, 1988). The ferroan dolomite, ankerite and siderite do not show any luminescence because of the quenching Fe^{2+} content. Dolomites free of impurities and dolomites with a low iron content, displaying generally red or brown luminescence, were not observed in the studied material. Microphotographs of the minerals and rock structures described in the present paper are shown in Plates I–III.

The selected carbonate minerals present in a grain framework of the deposits and in the cements were chemically analysed by X-ray microprobe (EDS Link ISIS) coupled with SEM (JSM-35, JEOL). The analyses were conducted on the same uncovered thin sections, earlier studied in CL and stained. After polishing, these thin sections were coated with powdered coal and back-scattered electron images (BEI) as well as X-ray spectra of minerals were analysed. Quantitative analyses were further obtained using the computer programs QUANT and VSP (together 35 points). The results of the analyses of siderites, ankerites and some calcites are compiled

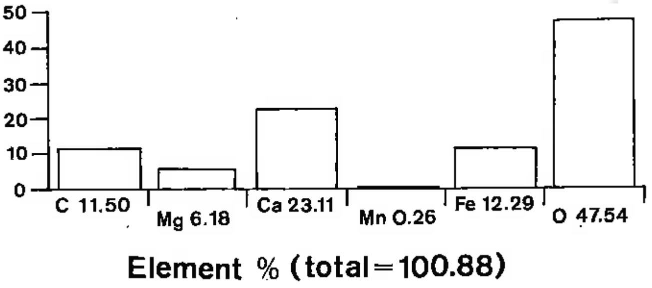

Fig. 6

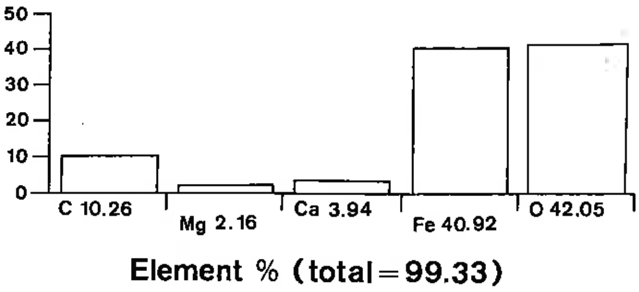

Fig. 7

Fig. 6. Quantitative chemical composition of ankerite from sandstone (EDS, BEI). Wojszyce IG 1/1a, depth of 702.3 m, Bathonian

Diagram ilościowego składu chemicznego ankerytu z piaskowca (EDS, BEI). Wojszyce IG 1/1a, głęb. 702,3 m, baton

Fig. 7. Quantitative chemical composition of sideroplesite from lense of sandy siderite in heterolith (EDS, BEI). Ciechocinek IG 1, depth of 654.2 m, upper Kuiavian–lower Bathonian

Diagram ilościowego składu chemicznego syderoplesytu z soczewki syderytu piaszczystego w heterolicie (EDS, BEI). Ciechocinek IG 1, głęb. 654,2 m, kujaw górny–baton dolny

in Table 1, examples of X-ray spectra are shown in Figs. 3 and 4, while Figs. 6, 7 and 9 present quantitative diagrams of a chemical composition of the minerals. The examples of distribution of the main components of different mineral phases are also given (Figs. 5, 8, 10).

Fifty three rock pieces coated with a gold powder were analysed in SEM aiming at recognition of the physiography of the minerals studied. The most characteristic images obtained (SEI) are shown in Plate IV. From 135 points the qualitative analyses in EDS were obtained, which appeared important for mineralogy identification. The SEM and microprobe studies were conducted in the Petrological Department of Polish Geological Institute. The final interpretation was done by the present author on the basis of the text-books by J. E. Welton (1984) and A. Bolewski (1982).

LITHOFACIES

The generalised petrological description of the lithofacies of the Middle Jurassic deposits from the Polish Lowlands was earlier presented by A. Maliszewska (1997, 1998). To avoid, therefore, a repetition in the present paper, only the most significant features of the lithofacies development will be mentioned.

The Aalenian, Bajocian and Kuiavian deposits in the axial part of the Kujawy Swell are alternating layers of grey sandstones and dark mudstones, claystones or psammitic-argillaceous heteroliths. They are quartz or quartz-clayey rocks which contain the organic matter as well as detritus of a coalified plant material. The claystones are extremely rich in the organic matter. The Lower Dogger rocks contain fine remnants of a marine fauna (K. Dayczak-Calikowska, 1967) and display a low percentage of carbonate cements. The most frequent here are clayey and siliceous cements. Bioturbation structures are common pointing to a shallow part of the basin (K. Dayczak-Calikowska, 1989*a–d*, 1990; A. Feldman-Olszewska, 1997). Lenses of clayey or sandy siderites and infrequent intercalations of siderite coquinas (similar to those in the Łęczyca region) occur there as well.

The Bathonian deposits display an increase in sandstone percentage towards the top (A. Feldman-Olszewska, 1990, 1991*a*, *b*, 1994; A. Feldman-Olszewska, K. Dayczak-Calikowska, 1990; A. Feldman-Olszewska, K. Leszczyński, 1991). The rocks contain frequent fragments of echinoderms, bryozoans, broken shells of molluscs, brachiopods and gastropods as well as remnants of foraminifers and tubes of serpulids. Some bioclasts not clear in thin sections may represent parts of the cephalopod shells and the algal structures. Layers and lenses of clayey-sandy siderites are still present. Towards the top of the Bathonian sequence a percentage of the carbonate cements increases. J. Dadlez (1990*a*) observed the organodetrital limestones in the upper Bathonian in the borehole Wojszyce IG 4 (Fig. 2). In some intervals there occur intraformational conglomerates.

The lower and upper Callovian deposits are also rich in carbonate cements. In the boreholes Wojszyce IG 3 and IG 4 the limestones are present. The ooids and chamosite cements, goethite and pyrite are the common components of the Kuiavian, Bathonian and Callovian deposits while phosphates and glauconite appear additionally in the Callovian.

According to the opinion of A. Feldman-Olszewska (1997) the deposits of six transgressive-regressive cycles composed of several depositional systems occur in the Middle Jurassic of the Mid-Polish Swell. The lower Aalenian deposits were formed in the shallow clastic shelf, while those of the upper Aalenian and Bajocian — in the deep shelf, in anoxic facies. The lower and middle Kuiavian was deposited in the deeper clastic shelf, while heteroliths and sandstones interpreted as regressive deposits — in its shallower parts. The time corresponding to the upper Kuiavian and lower and middle Bathonian was characterised by sedimentation mostly in a deeper part of the clastic shelf.

The upper Bathonian deposits and those of the lower Callovian were formed in the system of the deeper clastic shelf grading upwards into the deposits of the shallower carbonate-clastic shelf. The upper Callovian represented by a

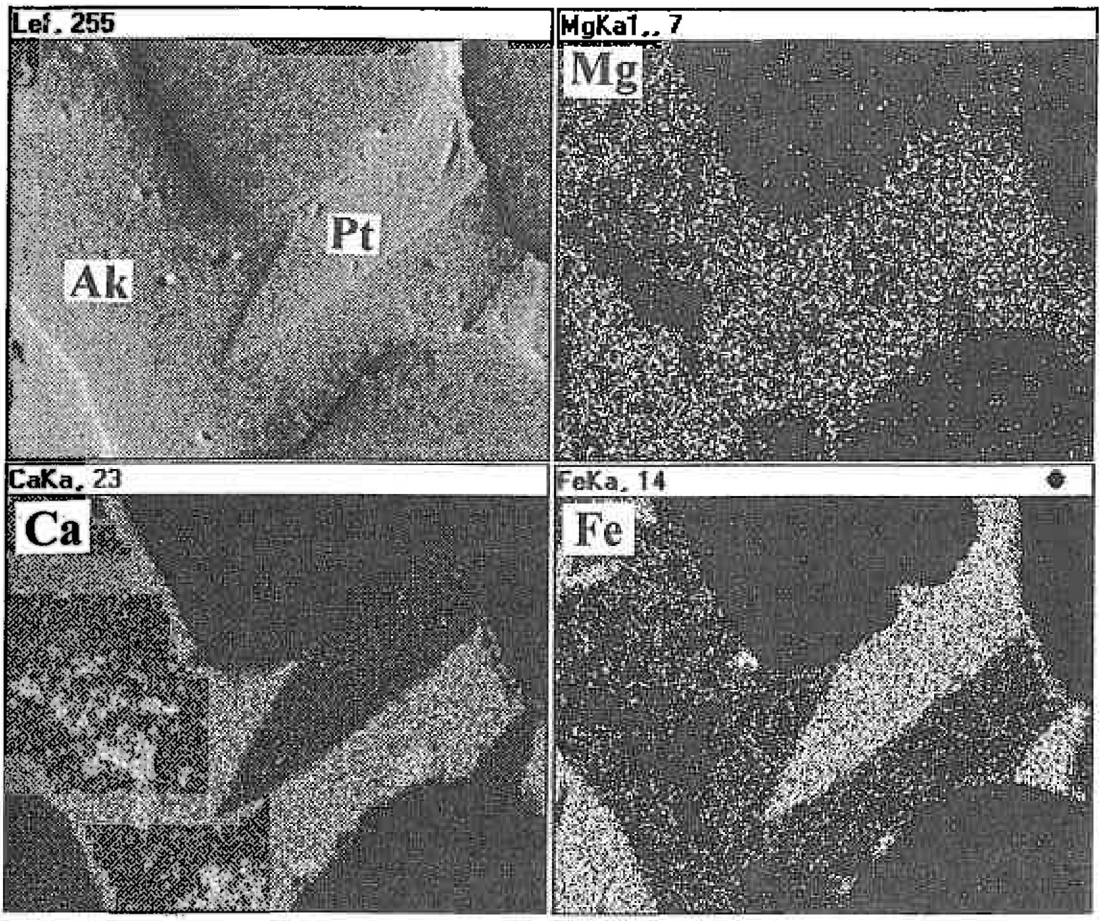

Fig. 8. Map of distribution of Ca, Fe and Mg in a sandstone with calcium pistomesite cement (Pt) and ankerite (Ak) (EDS, BEI). Mąkowary 1, depth of 1769.3 m, Kuiavian–Bathonian; x 200

Mapa rozmieszczenia Ca, Fe i Mg w mikroobszarze piaskowca o cemencie złożonym z pistomesytu wapniowego (Pt) i ankerytu (Ak) (EDS, BEI). Mąkowary 1, głęb. 1769,3 m, kujaw–baton; 200 x

very condensed conglomeratic nodular bed in the regressive stage is interpreted as the deposit of the starved shelf.

The upper Jurassic rocks analysed by A. Feldman-Olszewska (1997) display a good ammonite biostratigraphic documentation.

OCCURRENCE OF CARBONATE MINERALS

The carbonate minerals in the Middle Jurassic deposits compose both the grain framework and the cements. They build bioclasts, are incorporated in the ooids, occur in the intraclasts as well as they fill the intergranular space and are present in veinlets.

BIOCLASTS

The most frequent components of the Aalenian, Bajocian and Kuiavian skeletal elements are calcite without impurities detectable by means of the microprobe, and calcite with a low magnesium content. When stained with the Evamy's solution it shows a pink colour. It does not show luminescence in CL (Pl. I, Fig. 12). In the same plate in Fig. 13 a foraminifer test built of the described first calcite variety is visible (Fig. 3).

In some areas of the stained thin sections there occur fragments of shells built of violet-purple ferroan calcite. In the Bathonian and Callovian deposits more common are bioclasts composed of the manganese calcite which in CL displays a yellow or orange luminescence (Pl. I, Figs. 14, 15). In the sandstones with the ankerite cement and in the siderites, skeletal remains built of the ankerite spar have been frequently observed (Pl. I, Figs. 16, 17). In the Pl. II, Fig. 18 a fragment of the complex brachiopod shell is presented, being partly composed of calcite, ankerite and siderite. It has been observed that the calcite clasts may co-occur with ankeritised fragments built of ankerite and siderite. Thin siderite layers, however, have been noticed, in which all bioclasts were built of calcite.

Intraskeletal pores (e.g. in foraminifers or bryozoans) often contain a secondary filling with carbonate minerals, chamosite, goethite or pyrite. The chemical composition of the carbonate cements is generally different from that of shells. The latter are built of "pure" or low magnesium calcite and they may be filled either with the ferroan-manganese variety (Fig. 4) or with ankerite. The zoecia in the bryozoan branches contain manganese calcite, ankerite or siderite.

The metasomatic alterations of the bioclast and the process of carbonate recrystallisation in skeletons and pores have partly or even totally obliterated the primary organic structures. Some of them were traced only due to the cathodoluminescence studies. The mineral remains which do not show any luminescence, including siderite and ankerite, are still difficult to identify.

OOIDS

Ooids occur in siderite, clayey-sandy sandstones and in the limestones. These are mostly fine, elipsoidal grains with a characteristic concentric structure, built of chamosite. Their structure is occasionally enhanced by thin goethite layers inside the cortex. The goethite ooids are present in the upper Bathonian and Callovian deposits. The ooid content does not exceed 10% vol.

Fine quartz or skeletal grains usually form the ooid nuclei. Thin chamosite layers around the quartz are sometimes observed in the surficial ooids. Some ooids are partly pyritised.

The chamosite ooids often co-occur with the siderite ones. The term "ooid" refers to the coated grains in which either their concentric structure or its relics are seen. The process of the chamosite replacement by ankerite or siderite spar followed by recrystallisation (aggradation neomorphism) often led to a total obliteration of the concentric structure and to a formation of pseudomorphs termed pseudo-ooids here (Pl. II, Figs. 19–21).

M. Turnau-Morawska (1961) in her studies on the coated grains in the Łęczyca ore-deposit considered the possibility of their formation due to the diagenetic alteration of echinoderm fragments, the process observed by L. Déverin (1945) in the Middle Jurassic sediments of the Alps. She also considered the possibility of the ooid and siderite pseudo-ooid formation directly due to a precipitation of a ferroan carbonate from a solution. On the basis of a detailed analysis of these grains in thin sections, however, the quoted author came to the conclusion that the chamosite ooids were formed from the clay pelite during the early diagenesis of the poorly cemented bottom sediments, while the ooids and siderite pseudo-ooids result from sideritisation of the chamosite ones.

There occur also forms similar to the pseudo-ooids, in which the process of siderite spar recrystallisation is so advanced that the origin of the neomorphic grain is totally unclear.

CEMENTS

The ankerite is one of the most common cements in the detrital rocks of Middle Jurassic. The pure mineral of the composition of $CaFe(CO_3)_2$ is not known in the nature. Its different varieties transitional to a dolomite $CaFe(CO_3)_2$–$CaMg(CO_3)_2$ have been, however, described. According to A. Bolewski (1982) non-hydrous Ca, Fe, Mg carbonate with FeO content above 6 weight % is to be considered as the mineral from the ankerite group. With an increase in FeO the chemical composition of the ankeritic minerals moves to the isomorphic range $MgCO_3$–$FeCO_3$, particularly to sideroplesite (Fig. 11).

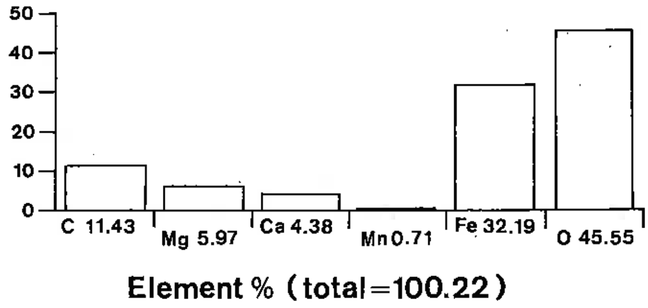

Fig. 9. Quantitative chemical composition of calcium pistomesite from Fig. 8
Diagram ilościowego składu chemicznego pistomesytu wapniowego z fig. 8

The ankerite occurs in a form of rhombohedrons (Pl. IV, Fig. 30) and hipautomorphic individuals. It mostly forms pore filling, more rarely — the cement of a basal character (Fig. 5). The ankerite rhombohedrons are mostly isometric and about 0.2 mm in size. When stained, the ankerite displays a blue or dark blue colour (Pl. II, Fig. 22). It shows no luminescence in CL. The following weight composition of the ankerite individuals was detected using the microprobe: 21.9–24.49% Ca, 6.73–12.2% Fe, 4.18–7.15% Mg, 0.00–0.78% Mn, 47.57–52.14% O and 9.90–12.30% C (Fig. 6; Tab. 1). Apart from the ankerite some other non-luminescent carbonate individuals stained light blue are often noticed. They probably represent ferroan dolomite with the chemical composition close to an ankerite. Some of them (not analysed in CL or EDS) may be also the most iron-rich calcite (M. Scherer, 1977).

The magnesium siderite is common in the Middle Jurassic carbonate deposits. It mostly occurs as the synsedimentary component of small layers and lenses of the clayey or sandy siderites. It appears there either as micrite or microspar individuals or as fine-crystalline spar with the most frequent crystal diameter 0.04 mm. It forms very fine rhombohedrons, hipauto-. or panxenomorphic. Sometimes it developed on faunal clasts (Pl. II, Fig. 23). The siderite in the sandstones and mudstones occurs in the similar habit, often co-occurring with ankerite. Figure 31 in Plate IV presents a detrital grain coated with a fine crystalline magnesium siderite. In another photograph (Pl. IV, Fig. 32) largely dissolved rhombohedrons of Mg-siderite are visible. Figure 24 in Plate III is the photomicrograph of the coarse crystalline siderite which forms the drusy cement in the coquina, while in Pl. IV, Fig. 33 — the rhombohedrons of Mg-siderite co-occur with vermicular kaolinite.

Magnesium siderites analysed in microprobe have the following composition: 38.73–40.92 weight % Fe, 1.45–2.57% Mg, 3.16–3.94% Ca, 0.00–0.34% Mn, 42.05–44.76% O and 10.26–11.63% C (Fig. 7; Tab. 1). Because of their $MgCO_3$ content exceeding 5 weight % they have been defined as sideroplesites (A. Bolewski, 1982). Usually an increase in

Table 1

Quantitative chemical composition of carbonate minerals expressed as both elements and oxides as determined by EDS Link ISIS method

Mineral	Borehole	Depth [m]	Fe	Mg	Ca	Mn	O	C	Total	FeO	MgO	CaO	MnO	CO_2
Sideroplesite (micrite)	Ciechocinek IG 1	654.2	40.92	2.16	3.94	0.00	42.05	10.26	99.33	52.65	3.57	5.51	0.00	37.60
Sideroplesite (spar)	Ciechocinek IG 2	1228.1	38.96	2.15	3.27	0.13	44.76	11.58	100.85	50.12	3.57	4.58	0.17	42.41
Sideroplesite (micrite)	Ciechocinek IG 2	1228.1	38.73	1.45	3.17	0.12	44.34	11.63	99.45	49.83	2.41	4.44	0.16	42.61
Sideroplesite (micrite)	Brześć Kujawski IG 2	756.8	39.94	2.45	3.16	0.34	42.89	10.69	99.46	51.38	4.05	4.41	0.44	39.17
Sideroplesite (micrite)	Brześć Kujawski IG 3	877.8	39.35	2.57	3.91	0.18	42.99	10.66	99.66	50.62	4.27	5.47	0.23	39.07
Pistomesite Ca (spar)	Mąkowary 1	1769.3	32.19	5.97	4.38	0.71	45.55	11.43	100.22	41.42	9.90	6.13	0.91	41.87
Ankerite (spar)	Ciechocinek IG 3	1207.7	7.73	6.73	23.80	0.20	48.83	12.25	99.53	9.94	11.15	33.30	0.26	44.88
Ankerite (spar)	Ciechocinek IG 3	1207.7	12.21	4.18	23.64	0.00	48.08	12.16	100.27	15.71	6.94	33.08	0.00	44.55
Ankerite (spar)	Czernikowo IG 1	1636.4	9.01	7.15	22.94	0.09	49.24	12.30	100.73	11.59	11.85	32.09	0.12	45.07
Ankerite (spar)	Brześć Kujawski IG 2	489.9	10.24	5.96	24.48	0.35	47.57	11.58	100.18	13.18	9.87	34.26	0.46	42.42
Ankerite (spar)	Brześć Kujawski IG 2	713.0	8.27	6.20	23.85	0.61	48.82	12.27	100.02	10.64	10.28	33.37	0.79	44.94
Ankerete (spar)	Brześć Kujawski IG 2	713.0	9.28	5.45	23.94	0.78	48.48	12.18	100.12	11.94	9.04	33.50	1.00	44.63
Ankerite (spar)	Poddębice PIG 2	3191.5	6.80	6.37	23.46	0.31	52.14	9.90	98.98	8.84	10.51	32.84	0.40	47.39
Ankerite (spar)	Wojszyce IG 1/1a	701.3	11.23	6.43	21.90	0.35	47.70	11.79	99.54	14.45	10.66	30.65	0.45	43.19
Ankerite (spar)	Wojszyce IG 1/1a	701.3	12.29	6.18	23.11	0.26	47.54	11.50	99.40	15.82	10.25	32.34	0.33	42.15
Ankerite (spar)	Mąkowary 1	1769.3	6.73	7.01	24.49	0.04	49.00	12.26	94.54	8.66	11.62	34.26	0.05	44.94
Calcite (spar)	Poddębice PIG 2	3188.5	0.00	0.72	39.82	0.00	47.48	11.91	99.92	0.00	1.17	55.75	0.00	43.00
Calcite Fe/Mn (spar)	Brześć Kujawski IG 2	657.8	1.68	0.07	38.21	0.29	47.52	11.88	99.65	2.16	0.12	53.47	0.37	43.53
Calcite Fe/Mn (spar)	Brześć Kujawski IG 2	657.8	5.19	0.41	34.40	0.14	47.83	12.12	100.09	6.68	0.68	48.14	0.18	44.42
Calcite Mn/Fe (spar)	Poddębice PIG 2	3227.3	1.99	0.43	35.87	0.51	50.04	11.54	100.90	1.03	0.79	50.34	0.66	48.08
Cacite Fe (spar)	Wojszyce IG 4	980.9	0.05	0.21	39.51	0.00	47.98	1.03	99.79	0.07	0.36	55.28	0.00	44.08

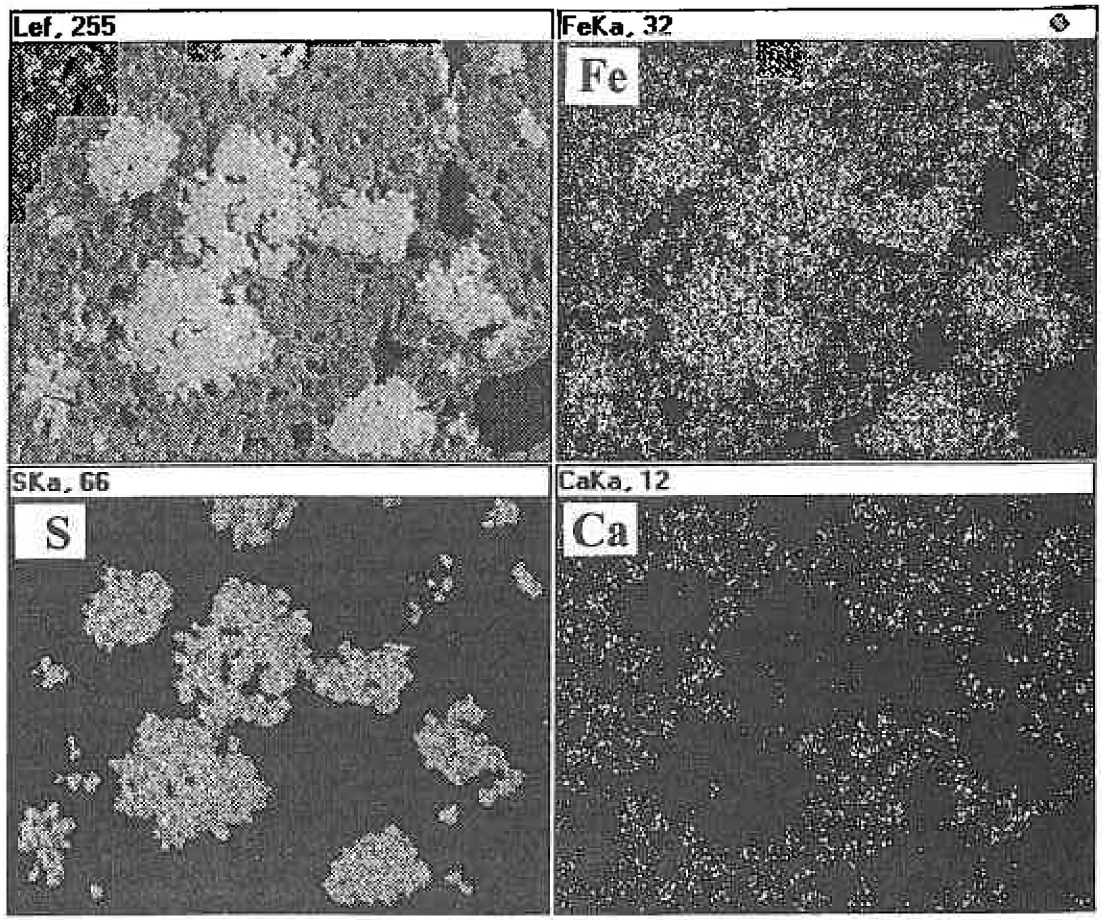

Fig. 10. Map of S, Fe and Ca distribution in pyritised sandy siderite; pyrite contains admixture of Cu (EDS, BEI). Brześć Kujawski IG 3, depth of 877.7 m, middle Kuiavian; x 260

Mapa rozmieszczenia S, Fe i Ca w spirytyzowanym syderycie piaszczystym; piryt zawiera domieszkę Cu (EDS, BEI). Brześć Kujawski IG 3, głęb. 877,7 m, kujaw środkowy; 260 x

Mg content in minerals from the isomorphic series $FeCO_3$–$MgCO_3$ is accompanied by an increase in the length of the rhombohedrons. In the comparative studies of the Middle Jurassic deposits in the northwestern part of the Polish Lowlands (Mąkowary 1, the Szczecin Trough) a variety of calcium pistomesite with the hitherto highest content of $MgCO_3$ corresponding to 20.71 weight % has been noticed. It forms strongly elongated bladed crystals older than the accompanying ankerite cement (Figs. 8, 9; Pl. III, Fig. 25). This is the first case of the pistomesite occurrence in the Middle Jurassic deposits in Poland.

Thin sideritic layers and lenses are often mineralised with pyrite (Fig. 10). This mineral is also present in the detrital rocks, among others as veinlets. Calcite is less common than ankerite in the Middle Jurassic cements. The least common is the pure variety (Pl. IV, Fig. 34), which is pink when stained, and shows no luminescence. The most common is the calcite with Fe and Mn impurities, displaying yellow or orange luminescence (Pl. III, Fig. 26; Pl. IV, Fig. 35). The percentage of calcite in the Middle Jurassic deposits increases towards the top of the sequence, and in the Callovian deposits calcite dominates over ankerite. In the Wojszyce region there occur organodetrital limestones (Fig. 2). Usually calcite individuals in the cements of the sandstones are about 0.2 mm in size, while in the limestone the calcite crystals are much larger, reaching the diameter of about 0.45 mm. These are mostly hipautomorphic grains, occasionally — the rhombohedral forms.

The chemical composition of the carbonate cements described above is presented in Fig. 11.

VEINLETS

The Middle Jurassic deposits are often cut with veinlets composed of light-coloured carbonate minerals. These fillings have been generally found to represent ankerite, locally — ferroan calcite (Pl. III, Fig. 26). In the thin siderite bed in the borehole Brześć Kujawski IG 2 the veinlets of a complex and interesting mineral composition have been observed. Medium crystalline ankerite and vermicular clay mineral from the kaolinite group have been noticed there, being accompanied by ferroan calcite, ferroan dolomite and siderite (Pl. III, Figs. 27, 28). The mineral of kaolinite composition may be in fact dickite or hydrothermal nacrite (A. Bolewski,

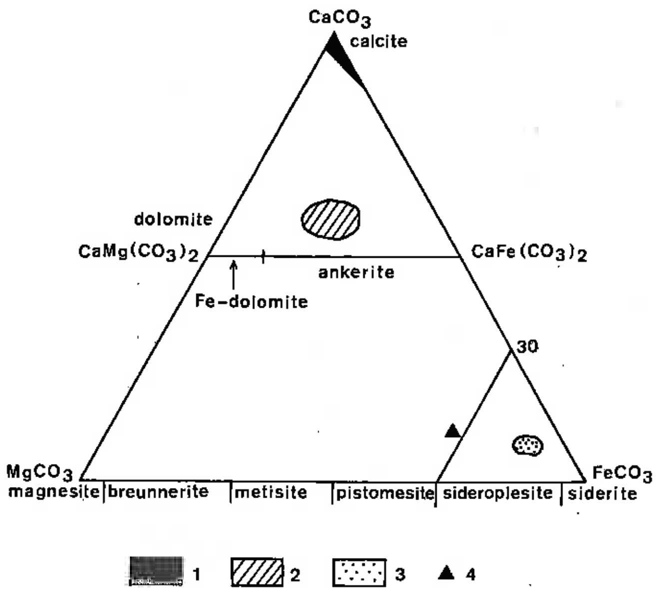

Fig. 11. Carbonate minerals in projection diagram $CaCO_3$–$MgCO_3$–$FeCO_3$
1 — calcite samples, 2 — ankerite samples, 3 — sideroplesite samples, 4 — sample of calcium pistomesite from borehole Mąkowary 1 (Szczecin Trough)

Minerały węglanowe w diagramie projekcyjnym $CaCO_3$–$MgCO_3$–$FeCO_3$
1 — próbki kalcytów, 2 — próbki ankerytów, 3 — próbki syderoplesytów, 4 — próbka pistomesytu wapniowego z otworu Mąkowary 1 (niecka szczecińska)

1982). Fine crystal habit of the mineral plates does not allow the author of the present paper to define this mineral precisely basing on the optical studies. Some of the plates underwent carbonatisation — they are at present composed either of ferroan calcite (Pl. III, Fig. 29) or of ankerite depending on the part of the veinlet.

INTERPRETATION AND SUMMARY

The following conclusions may be drawn basing on the results of the petrological studies described above:

1. The skeletal elements which occur in the siliciclastic Middle Jurassic rocks in the Kujawy area are at present built of calcite (partly containing impurities of Mg, Mn or Fe), often with ankerite or even siderite. As it is known from the studies on the carbonate rocks (among others: R. G. C. Bathurst, 1975; D. K. Richter, H. Füchtbauer, 1978; M. Scherer, 1977) the aragonite or high magnesium calcite are the primary components of the majority of marine organisms. These both minerals are unstable and they are altered into the impurities-free or low magnesium calcites in the course of diagenetic processes (R. C. Murray, F. J. Lucia, 1967). They may also undergo the process of dolomitisation. M. Narkiewicz (1991) observed the uniform susceptibility of various skeletal remains with different original mineralogy in the Devonian carbonates in the Holy Cross Mts. Therefore, he concluded that stabilisation of mineralogy and chemistry of the skeletons preceded the dolomitisation (see also R. G. C. Bathurst, 1975).

In the Middle Jurassic rocks the present composition of the bioclasts is not uniform. This fact suggests, therefore, that the replacement of the original calcium carbonate by ferroan calcite, ankerite and siderite took place mostly in the early stage of the diagenesis before the stabilisation of the skeletons. The most common components of the bioclasts are: calcite (without Mn and Fe) and Mn-calcite. It seems that the crystallisation sequence of the carbonates was as following: aragonite or Mg-calcite → Mn/(Mg)-calcite or Fe-calcite; "pure" or Fe-calcite → locally siderite or ankerite. In the upper Bathonian and Callovian limestones organic skeletons are composed of the calcite and the Mn-calcite. According to D. K. Richter and H. Füchtbauer (1978) the presence of the Fe-calcite in the bioclasts points to diagenetic replacement of the high magnesium calcite.

2. Chamosite is the original component of the ooids. The process of sideritisation mostly obliterated the concentric structure of the ooids, while the neomorphic development of siderite individuals destroyed it totally. The chamosite replacement by siderite must have occurred in the early diagenetic stage under a weak compaction because both the ooids and siderite pseudo-ooids still have their rounded forms or are weakly flattened. The numerous chamosite ooids which had not undergone carbonatisation were mechanically flattened or even squeezed due to the increasing compaction (M. Turnau-Morawska, 1961; A. Maliszewska, 1998). The presence of chamosite in the deposits is the proof of reducing environmental conditions (W. C. Krumbein, R. M. Garrels, 1952). The chamosite ooids from the Callovian deposits were altered into the goethite ones due to the shallowing and oxidation in the sedimentary basin. It is also probable that the goethite ooids were formed directly from the marine water on oxidising environment.

3. Calcite and siderite were possibly (depending on variable pH and Eh conditions) the earliest carbonate components of the synsedimentary cements in the sandstones and mudstones. Siderite formed also in the mesodiagenesis. In the organodetrital limestones the manganese calcite might have been the synsedimentary cement although this suggestion has not been proved so far. The ankerite, which at present forms pore or basal cements in the sandstones, mudstones and heteroliths is certainly the product of the widespread cementation as well as the related a metasomatosis of a calcite. In the cases of siderite and ankerite co-occurrence that second mineral is always genetically younger. The process of ankeritisation, although intensive, had not affected all the Middle Jurassic deposits. Numerous sandstone beds containing calcite or calcite-ankerite cements as well as limestones are still preserved. Siderite has been noticed in the latter rocks (Pl. I, Figs. 14, 15). It is possible that the dolomites and dolomitic sandstones described from some localities in the Kujawy region (J. Znosko, 1957*b*), and till present not analysed using modern methods, also have the ankeritic composition. This supposition, however, does not concern thoroughly studied Upper Jurassic dolomites (among others K. Radlicz, 1967).

4. It appears from the earlier quoted papers on the geology of the Kujawy region (among others: S. Różycki, 1957; J. Znosko, 1957*a*) and also from the paper by S. Marek and J. Znosko (1972*b*) that the uplift of salt domes and pillows

generated by the Late Kimmerian tectonics played a significant role in the sedimentation of the Jurassic deposits. It may be further supposed that the mobilisation of strongly saturated metal-rich deep-subsurface brines in salt structures was of great importance for the diagenetic alterations of the Jurassic deposits. These fluids represented a source of the mineral components necessary for the cementation with the iron, calcium and magnesium compounds. They were also responsible for the majority of the metasomatic changes within the organic remains, ooids and cements.

The significance of the salt tectonics was emphasized in the paper on the origin of the Upper Jurassic dolomites from the Zalesie Anticline. S. R. Krażewski (1966), T. Zydorowicz (1982), A. Świerczewska (1984) and R. Chlebowski (1985) have considered the source of the magnesium in the dissolved Zechstein salts. The process of dolomitisation could have occurred due to infiltration of brines into the limestones and mixing with meteoric waters.

5. The tectonic inversion of the Kujawy Swell in the latest Cretaceous was another control on the present mineral composition of the rocks under discussion. It created new fractures, re-mobilised brine flows and finally caused the filling of the fractures with the carbonates and ore minerals. A good example of this process is the origin of the sphalerites from Łęczyca, which occur in the veinlets cutting the Middle Jurassic siderites (J. Wojciechowski, J. Ziomek, 1966, 1968). The trace element composition of these minerals is a proof of their hydrothermal origin. The contents of the elements point to a relatively low and moderate temperatures of crystallisation. These temperatures may have been close to the fluid inclusion homogenisation data from the Upper Jurassic deposits in the Zalesie structure referred by E. Górecka (1985) as 66–73°C. The cited author believes that the heat of the hydrothermal liquids was generated from the salt masses. With regard to the material studied by the author of the present paper hydrothermal origin is indicated by the filling of the veinlets in the borehole Brześć Kujawski IG 2 (Pl. III, Figs. 27–29). As it has been already mentioned, in addition to the carbonate minerals these veinlets are filled with the vermicular clay mineral from the kaolinite group (dickite? nacrite?). A detailed identification of this mineral requires X-ray structural studies which may prove its hydrothermal origin.

6. The general conclusions which might be drawn from the petrological studies described above are in agreement with the hypothesis on the strong influence of salt tectonics not only on the dynamics of the sedimentation processes of the Mesozoic deposits in the Kujawy region (J. Znosko, 1957*a*; S. Marek, 1961, 1977; R. Dadlez, S. Marek, 1969; S. Marek, J. Znosko, 1972*a*), but also on their diagenetic alteration. There exist, however, some unexplained problems. The most important seems to be the necessity of a more detailed characterisation of the role of the Zechstein brines and the explanation of the causes of ore mineralisation in the Kujawy region. Determination of a stable isotope composition of the hitherto described carbonate minerals together with the fluid inclusion studies may provide clues to solve above questions.

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NOWE DANE PETROLOGICZNE O MINERAŁACH WĘGLANOWYCH W ŚRODKOWOJURAJSKICH UTWORACH KLASTYCZNYCH REGIONU KUJAW

Streszczenie

Przedstawiono wyniki badań minerałów węglanowych występujących w osadach jury środkowej nawierconych głębokimi otworami w osiowej części wału kujawskiego oraz na jego zboczach (fig. 1). Osady te utworzyły się w płytkim morzu epikontynentalnym, którego największy zasięg stwierdzono w keloweju górnym (K. Dayczak-Calikowska, 1967; K. Dayczak-Calikowska, W. Moryc, 1988). Utwory aalenu, bajosu i kujawu w osiowej strefie wału kujawskiego, to występujące na przemian warstwy szarych piaskowców oraz ciemnych mułowców, iłowców i heterolitów. Materiał detrytyczny jest tu spojony minerałami ilastymi i krzemionką, cementy węglanowe są nieliczne. Pojawiają się wkładki syderytów ilastych lub piaszczystych. Osady batonu odznaczają się wzrostem zawartości piaskowców ku stropowi profilów, a także wzrostem zawartości bioklastów i cementów węglanowych. Miejscami w batonie górnym pojawiają się wapienie oraz wkładki zlepieńców śródformacyjnych. W keloweju również notowano wapienie (fig. 2) (A. Feldman-Olszewska, 1990, 1991*a*, *b*; A. Feldman-Olszewska, K. Dayczak-Calikowska, 1990; J. Dadlez, 1989*a*–*c*, 1990*a*–*c*, 1991*a*–*c*; A. Maliszewska, 1989, 1994, 1997).

Minerały węglanowe w osadach jury środkowej są składnikami szkieletu ziarnowego i cementów. Budują one bioklasty, wchodzą w skład ooidów, występują w intraklastach, cementach, a także w żyłkach.

Zbadano 220 próbek w płytkach cienkich, w większości barwionych płynem Evamy'ego, co pozwoliło wyróżnić kalcyt i kalcyt żelazisty oraz dolomit, dolomit żelazisty i ankeryt. 22 próbki zbadano za pomocą analizy katodoluminescencyjnej w angielskiej aparaturze (firmy Cambridge Image Technology — model CCL 8200 mk^3) zamocowanej na stoliku mikroskopu polaryzacyjnego Optiphot 2 (Nikon). Wykonano również 135 analiz jakościowych i 35 analiz ilościowych w mikroobszarach za pomocą rentgenowskiej mikrosondy energetycznej EDS Link ISIS sprzężonej z elektronowym mikroskopem skaningowym JSM-35 firmy JEOL (fig. 3–10). Wyniki analiz ilościowych zebrano w tabeli 1 i na figurze 11. Mikrofotografie minerałów uzyskane w mikroskopie polaryzacyjnym zestawiono na tablicach I–III, a obrazy SEM — na tablicy IV.

Stwierdzono, że bioklasty najczęściej są złożone z kalcytu czystego i kalcytu Mn. Notuje się też elementy szkieletowe, w których kalcyt został zastąpiony przez kalcyt Fe, ankeryt bądź syderyt (tabl. I, fig. 12–17; tabl. II, fig. 18). Ooidy pierwotnie złożone z szamozytu uległy miejscami syderytyzacji lub ankerytyzacji (tabl. II, fig. 19–21). Przemiany te przebiegały we wczesnej diagenezie osadów, gdyż formy zsyderytyzowane są kuliste, natomiast nie przeobrażone ooidy szamozytowe uległy silnemu spłaszczeniu pod wpływem kompakcji.

W obrębie cementów najpospolitszy jest ankeryt. Często współwystępuje on z syderytem magnezowym, reprezentowanym przez syderoplesyt (tabl. II, fig. 22, 23; tabl. III, fig. 24; tabl. IV, fig. 30–33). Wraz ze wzrostem zawartości Mg w minerałach szeregu izomorficznego $FeCO_3$–$MgCO_3$ wzrasta wydłużenie romboedrów. Niektóre formy przypominają pistomesyt. Minerał ten został stwierdzony w badaniach porównawczych skał jury środkowej z otworu Mąkowary 1 (niecka szczecińska) (tabl. III, fig. 25). W piaskowcach batonu górnego i keloweju częściej pojawia się kalcyt i kalcyt Fe/Mn (tabl. III, fig. 26; tabl. IV, fig. 34, 35). W wapieniach notowano kalcyt Mn/Fe, a także syderyt (tabl. I, fig. 14, 15).

Minerały węglanowe występują także w żyłkach tnących opisywane skały. Dostrzegano tu ankeryt lub kalcyt Fe. W syderycie z otworu Brześć Kujawski IG 2 (tabl. III, fig. 27–29) zanotowano wypełnienie żyłek przez ankeryt, syderyt, kalcyt Fe, dolomit Fe i robakowaty minerał z grupy kaolinitu (dickit? nakryt?).

Na podstawie wyników badań stwierdzono, że większość minerałów węglanowych z osadów jury środkowej Kujaw jest produktem cementacji diagenetycznej oraz związanej z nią, szeroko rozwiniętej metasomatozy. Przyczyn tych zjawisk, zgodnie z poglądami J. Znoski (1957*a*), S. Różyckiego (1957), R. Krajewskiego (1957), M. Turnau-Morawskiej (1961) oraz J. Wojciechowskiego i J. Ziomka (1966), a także innych badaczy geologii Kujaw, należy upatrywać w uruchomieniu bogatych w jony metali solanek cechsztyńskich przez tektonikę salinarną.

EXPLANATIONS OF PLATES

PLATE I

Fig. 12. Calcareous sandstone, CL image. Ra — fragment of brachiopod shell composed of calcite with no impurities detectable in microprobe, and non-luminescent. KaMn — manganese calcite cement. Ciechocinek IG 1, depth of 521.2 m, middle and upper Bathonian. One nicol

Piaskowiec wapnisty, obraz w CL. Ra — fragment skorupki ramienionoga, złożony z kalcytu nie zawierającego domieszek uchwytnych w mikrosondzie i nie wykazującego luminescencji; KaMn — kalcyt manganowy, cement. Ciechocinek IG 1, głęb. 521,2 m, baton środkowy i górny. Bez analizatora

Fig. 13. Foraminifer test composed of non luminescent calcite (pure), filled with brown Fe/Mn calcite with orange luminescence in CL. A–D — points analysed in microprobe. Sandstone from borehole Poddębice PIG 2, depth of 3227.3 m, upper Bathonian. One nicol

Skorupka otwornicy złożona z kalcytu nieluminescencyjnego (bez domieszek), wypełniona brunatnym kalcytem Fe/Mn, świecącym w obrazie CL pomarańczowo. A–D — punkty badania w mikrosondzie EDS. Piaskowiec z otworu Poddębice PIG 2, głęb. 3227,3 m, baton górny. Bez analizatora

Fig. 14. Fragment of organodetrital limestone with crinoid ossicle in central part of photograph. Wojszyce IG 4, depth of 995.3 m, upper Bathonian–Callovian. Crossed nicols

Fragment wapienia organodetrytycznego, w centralnej części zdjęcia — przekrój przez człon liliowca. Wojszyce IG 4, głęb. 995,3 m, baton górny–kelowej. Nikole skrzyżowane

Fig. 15. CL image of limestone from Fig. 14. Bioclasts and cement with orange luminescence are built of Mn calcite. Non luminescing cement (black) — siderite. One nicol

Obraz w CL wapienia z fig. 14. Bioklasty i cementy świecące pomarańczowo złożone są z kalcytu Mn. Cement nieluminescencyjny (czarny) — syderyt. Bez analizatora

Fig. 16. Fragment of ankeritic mollusc(?) shell in sandstone with ankerite cement. Thin section stained with Evamy's solution. Czernikowo IG 1, depth of 1455.0 m, Bathonian. One nicol

Fragment ankerytowej skorupki małża(?) w piaskowcu o cemencie złożonym z ankerytu. Płytka cienka barwiona roztworem Evamy'ego. Czernikowo IG 1, głęb. 1455,0, baton. Bez analizatora

Fig. 17. Fragment of serpulid tube in sandstone. Wall is composed of ankerite, interior is filled with ankerite (blue) and minerals from siderite group (brown). Thin section stained with Evamy's solution. Ciechocinek IG 3, depth of 1262.1 m, Bathonian and Callovian. One nicol

Fragment rurki serpuli w piaskowcu. Ścianka rurki złożona jest z ankerytu, a wnętrze wypełnia ankeryt (niebieski) i minerały z grupy syderytu (brunatne). Płytka cienka barwiona płynem Evamy'ego. Ciechocinek IG 3, głęb. 1262,1 m, baton i kelowej. Bez analizatora

PLATE II

Fig. 18. Fine crystalline siderite with bioclasts. Fragment of brachiopod(?) shell is visible, in which primary calcite (pink) was replaced by siderite (light crystals) and ankerite (dark blue). Thin section stained with Evamy's solution. Brześć Kujawski IG 2, depth of 657.8 m, upper Kuiavian. One nicol

Syderyt drobnokrystaliczny z bioklastami. Widoczny fragment skorupki ramienionoga(?), w której pierwotny kalcyt (różowy) został wyparty przez syderyt (jasne kryształy) i ankeryt (ciemnoniebieski). Płytka cienka barwiona roztworem Evamy'ego. Brześć Kujawski IG 2, głęb. 657,8 m, kujaw górny. Bez analizatora

Fig. 19. Chamosite ooid, partly filled with ankerite. Thin section stained with Evamy's solution. Wojszyce IG 3, depth of 570.0 m, upper Bathonian. One nicol

Ooid szamozytowy, częściowo wypełniony ankerytem. Płytka cienka barwiona roztworem Evamy'ego. Wojszyce IG 3, głęb. 570,0 m, baton górny. Bez analizatora

Fig. 20. Siderite ooid, with relics of concentric structure, in clayey-sandy siderite matrix. Thin section stained with Evamy's solution. Trześniew 1, depth of 2838.0 m, upper Bathonian. One nicol

Ooid syderytowy z reliktami budowy współśrodkowej w syderycie ilasto-piaszczystym. Płytka cienka barwiona płynem Evamy'ego. Trześniew 1, głęb. 2838,0 m, baton górny. Bez analizatora

Fig. 21. Clayey-sandy siderite with siderite pseudoooids (in cores — quartz grains are present). Ciechocinek IG 1, depth of 902.7 m, upper Aalenian. Crossed nicols

Syderyt ilasto-piaszczysty z pseudoooidami syderytowymi (w jądrach tkwią ziarna kwarcu). Ciechocinek IG 1, głęb. 902,7 m, aalen górny. Nikole skrzyżowane

Fig. 22. Sandstone with siderite (brown) and ankerite (blue) cements. Siderite is older than ankerite. Thin section stained with Evamy's solution. Wojszyce IG 4, depth of 1215.6 m, middle Kuiavian. One nicol

Fragment piaskowca o spoiwie syderytowym (brunatny) i ankerytowym (niebieski). Syderyt jest tu starszy od ankerytu. Płytka cienka barwiona roztworem Evamy'ego. Wojszyce IG 4, głęb. 1215,6 m, kujaw środkowy. Bez analizatora

Fig. 23. Faunal fragment composed of Fe calcite (purple) overgrown by colourless spar of magnesium siderite (sidroplesite, pistomesite?). Thin section stained with Evamy's solution. Ciechocinek IG 3, depth of 1221.6 m, Bathonian–Callovian. One nicol

Okruch fauny złożony z kalcytu Fe (purpurowy), obrastany przez spar bezbarwnego syderytu magnezowego (syderoplesyt, pistomesyt?). Płytka cienka barwiona roztworem Evamy'ego. Ciechocinek IG 3, głęb. 1221,6 m, baton–kelowej. Bez analizatora

PLATE III

Fig. 24. Fragment of coquina with drusy siderite cement. Brześć Kujawski IG 2, depth of 658.0 m, upper Kuiavian. One nicol

Fragment muszlowca z druzowym cementem syderytowym. Brześć Kujawski IG 2, głęb. 658,0 m, kujaw górny. Bez analizatora

Fig. 25. Sandstone cement built of bladed crystals of calcium pistomesite (Pt) and ankerite (Ak). Thin section stained with Evamy's solution. Mąkowary 1, depth of 1769.3 m, Kuiavian–Bathonian. One nicol

Cement piaskowca złożony z ostrzowych kryształów pistomesytu wapniowego (Pt) i ankerytu (Ak). Płytka cienka barwiona roztworem Evamy'ego. Mąkowary 1, głęb. 1769,3 m, kujaw–baton. Bez analizatora

Fig. 26. Calcareous sandstone, CL image. Well visible: non-luminescent quartz grains, yellow luminescing cement (Mn/Fe calcite) and veinlets filled with weakly luminescing Fe calcite. Ciechocinek IG 1, depth of 521.2 m, middle and upper Bathonian. One nicol

Piaskowiec wapnisty, obraz w CL. Widoczne są: nieluminescencyjne ziarna kwarcu, żółto świecący cement (kalcytMn/Fe) i żyłki wypełnione słabo świecącym kalcytem Fe. Ciechocinek IG 1, głęb. 521,2 m, baton środkowy i górny. Bez analizatora

Fig. 27. Fragment of veinlet cutting siderite layer. Visible: ferroan dolomite (DoFe), siderite (Sy), ferroan calcite (KaFe) and ankerite (Ak). Thin section stained with Evamy's solution. Brześć Kujawski IG 2, depth of 657.8 m, upper Kuiavian. One nicol

Fragment żyłki tnącej warstewkę syderytową. Widoczne: dolomit Fe (DoFe), syderyt (Sy), kalcyt Fe (KaFe) i ankeryt (Ak). Płytka cienka barwiona płynem Evamy'ego. Brześć Kujawski IG 2, głęb. 657,8 m, kujaw górny. Bez analizatora

Fig. 28. Another fragment of veinlet from Fig. 27, studied in SEM and EDS. In ankerite (blue) background there occur vermicular aggregates of mineral from kaolinite group. Ferroan calcite (point B) is also present, stained violet only after re-treatment with Evamy's solution. One nicol

Inny fragment żyłki z fig. 27, badany w SEM i EDS. W tle ankerytowym (niebieski) robakowate agregaty minerału z grupy kaolinitu. Występuje tu również kalcyt Fe (punkt B), który zabarwił się fioletowo dopiero po powtórnym powleczeniu płynem Evamy'ego. Bez analizatora

Fig. 29. Enlarged fragment of veinlet from Fig. 28. Partial replacement of plates of clay mineral (Kl) by carbonate minerals is visible. Analysed points (EDS–BEI): B — calcite with iron content of 1.68%, C — calcite with iron content of 5.19%, D — kaolinite (or dickite, nacrite?). Crossed nicols

Powiększony fragment żyłki z fig. 28. Widoczne częściowe zastąpienie płytek minerału ilastego (Kl) przez minerały węglanowe. Punkty badania w (EDS –BEI): B — kalcyt o zawartości 1,68% Fe, C — kalcyt o zawartości 5,19% Fe, D — kaolinit (lub dickit, nakryt?). Nikole skrzyżowane

PLATE IV

Fig. 30. Rhombohedrons of ankeritic cement in sandstone. SEM image. Brześć Kujawski IG 3, depth of 775.6 m, middle and upper Bathonian

Romboedry cementu ankerytowego w piaskowcu. Obraz w SEM. Brześć Kujawski IG 3, głęb. 775,6 m, baton środkowy i górny

Fig. 31. Detrital grains overgrown with micritic magnesium siderite. SEM image. Brześć Kujawski IG 3 , depth of 713.0 m, middle and upper Bathonian

Ziarna detrytyczne oskorupione mikrytowym syderytem Mg. Obraz w SEM. Brześć Kujawski IG 3, głęb. 713,0 m, baton środkowy i górny

Fig. 32. Partly dissolved rhombohedrons of magnesium siderite in intergranular pore space. Sample from Fig. 30. SEM image

Częściowo rozpuszczone romboedry syderytu Mg w przestrzeni międzyziarnowej. Próbka z fig. 30. Obraz w SEM

Fig. 33. Rhombohedrons of magnesium siderite co-occurring with vermicular aggregate of kaolinite displaying booklet structure. SEM image. Wojszyce IG 4, depth of 1320.4 m, middle Kuiavian

Romboedry syderytu Mg współwystępujące z robakowatym skupieniem kaolinitu o strukturze książeczkowej. Obraz w SEM. Wojszyce IG 4, głęb. 1320,4 m, kujaw środkowy

Fig. 34. Calcite spar and microspar in sandstone ("pure calcite"). SEM image. Wojszyce IG 4, depth of 995.3 m, upper Bathonian–Callovian

Spar i mikrospar kalcytowy w piaskowcu (kalcyt „czysty"). Obraz w SEM. Wojszyce IG 4, głęb. 995,3 m, baton górny–kelowej

Fig. 35. Fe-calcite in sandstone. SEM image. Brześć Kujawski IG 2, depth of 517.7 m, middle and upper Bathonian

Kalcyt Fe w piaskowcu. Obraz w SEM. Brześć Kujawski IG 2, głęb. 517,7 m, baton środkowy i górny

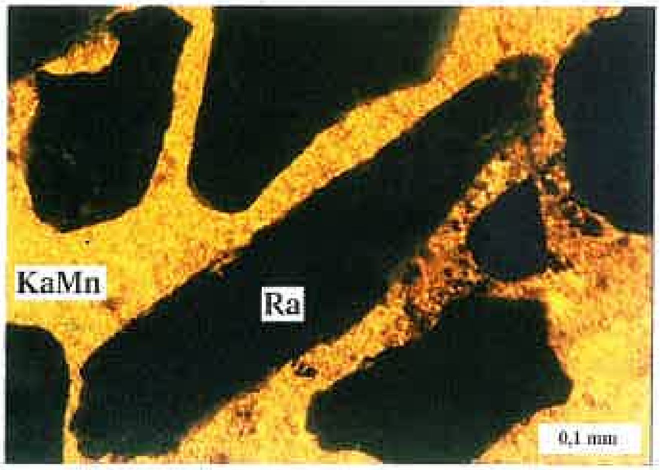

Fig. 12

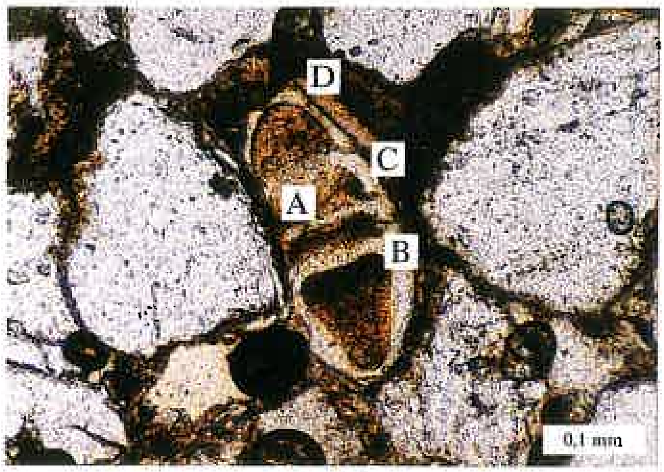

Fig. 13

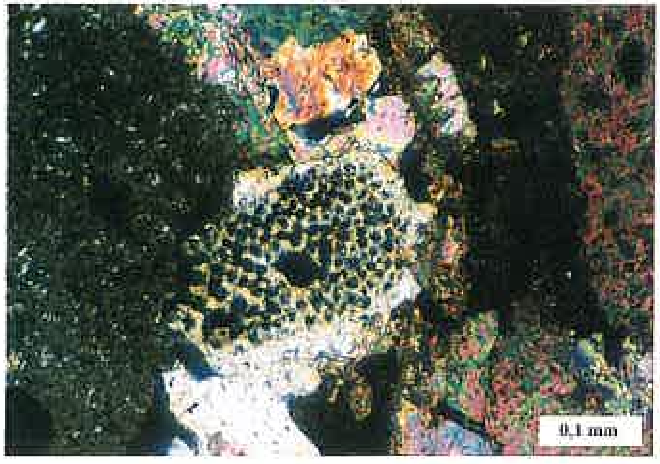

Fig. 14

Fig. 15

Fig. 16

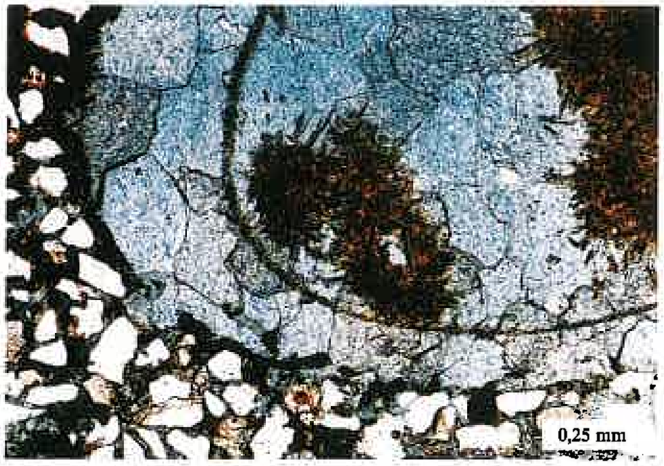

Fig. 17

Anna MALISZEWSKA — New petrological data on carbonate mineralogy in the Middle Jurassic siliciclastic deposits of the Kujawy region (Polish Lowlands)

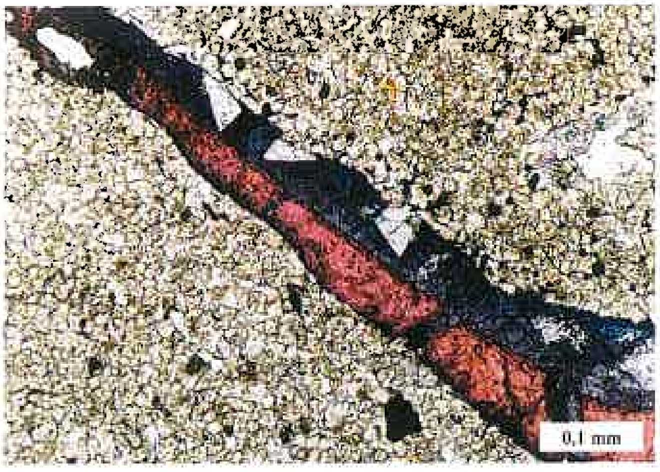

Fig. 18

Fig. 19

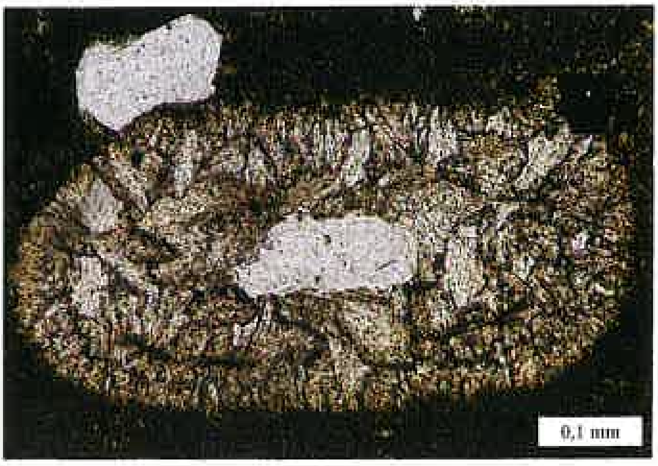

Fig. 20

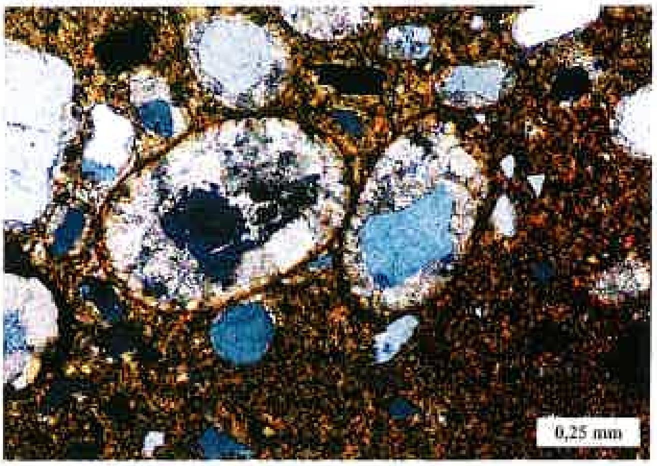

Fig. 21

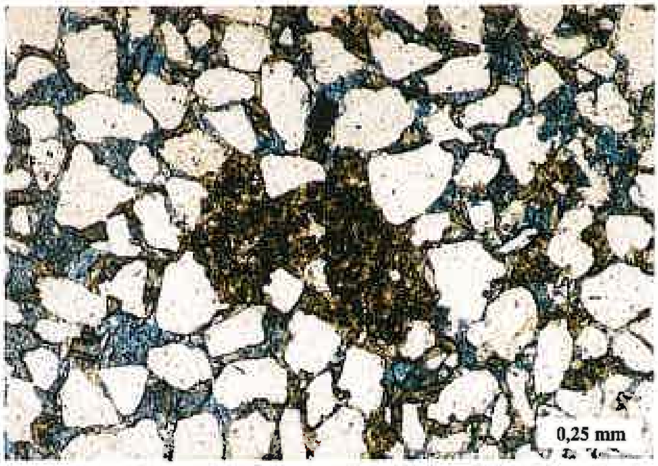

Fig. 22

Fig. 23

Fig. 24

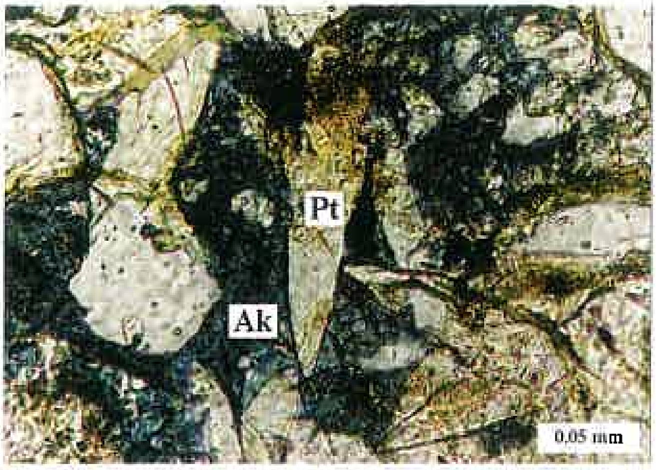

Fig. 25

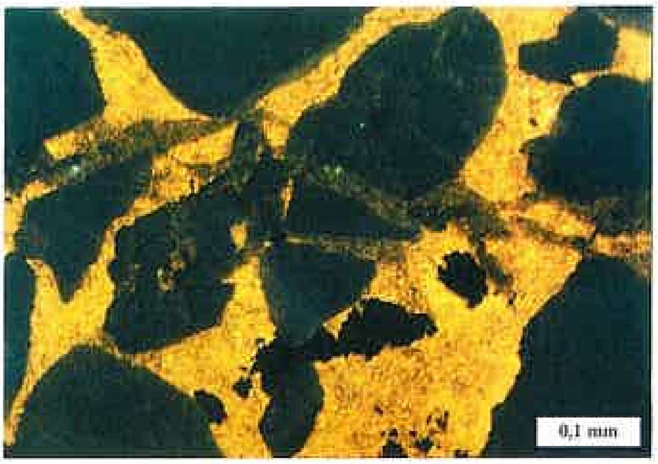

Fig. 26

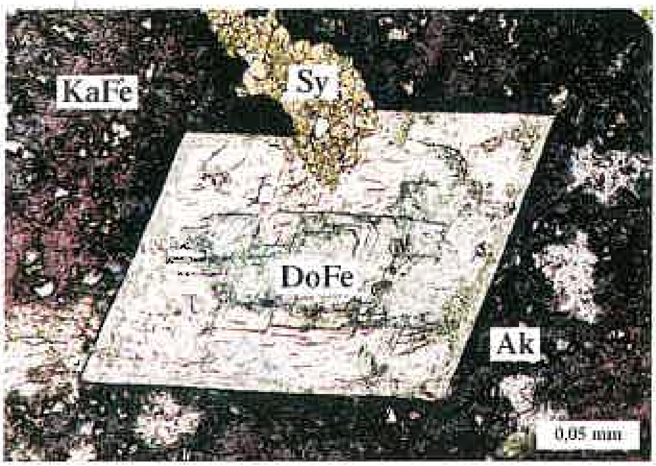

Fig. 27

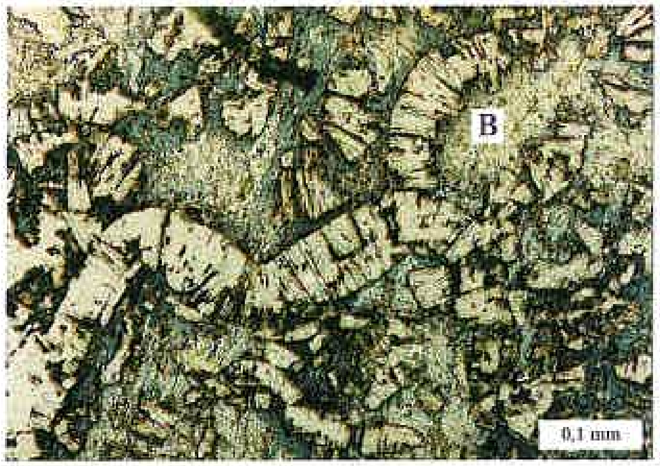

Fig. 28

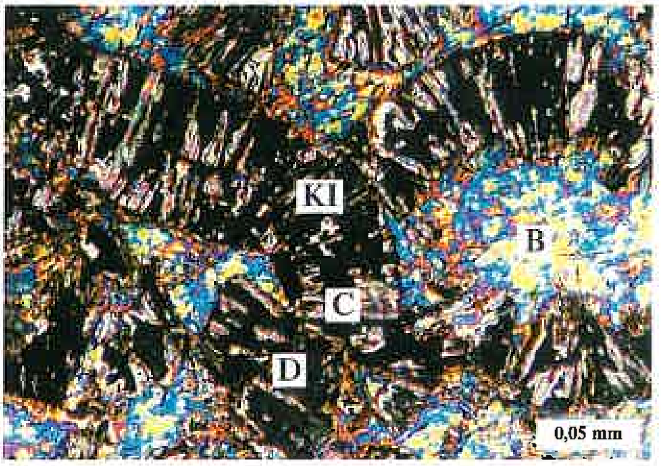

Fig. 29

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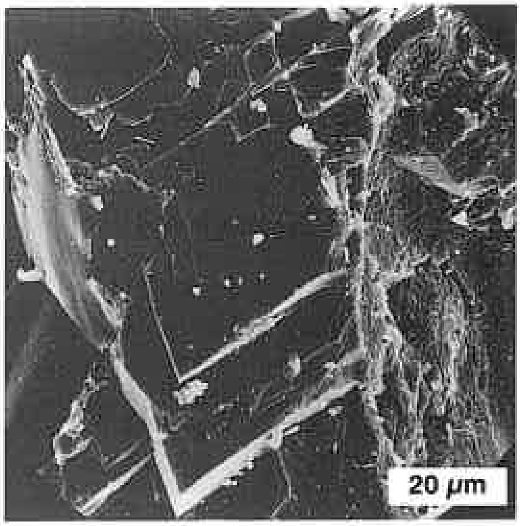

Fig. 30

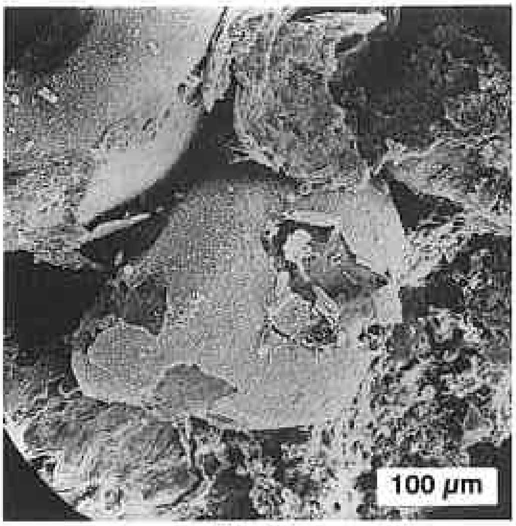

Fig. 31

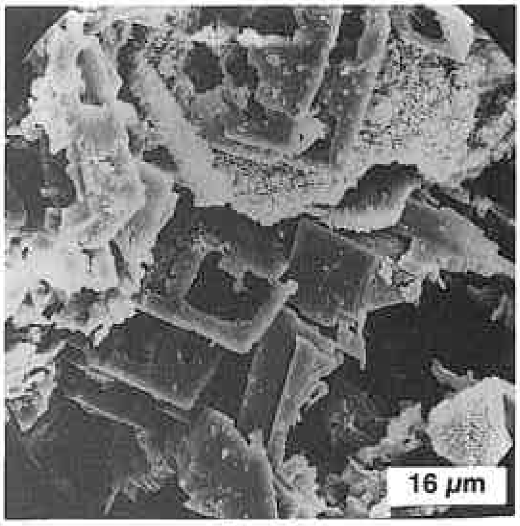

Fig. 32

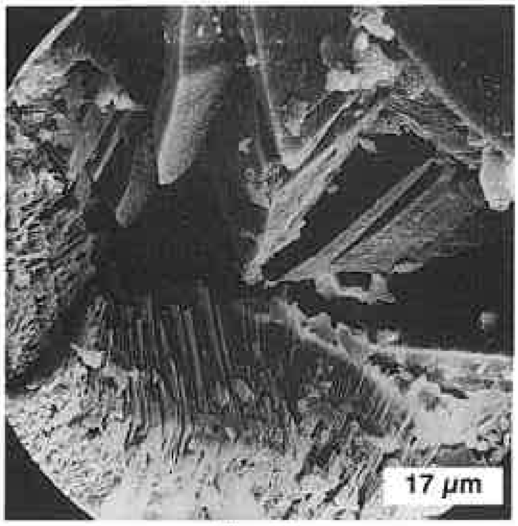

Fig. 33

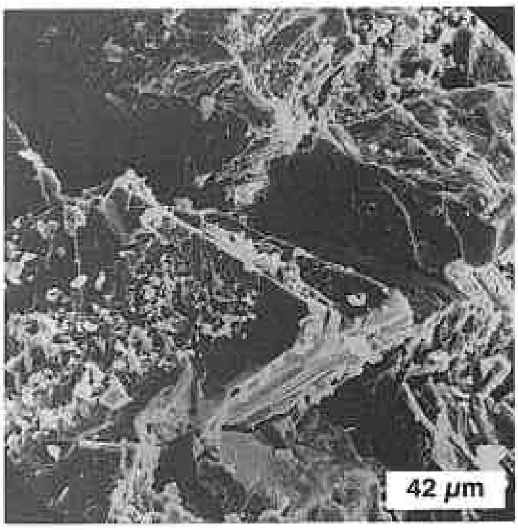

Fig. 34

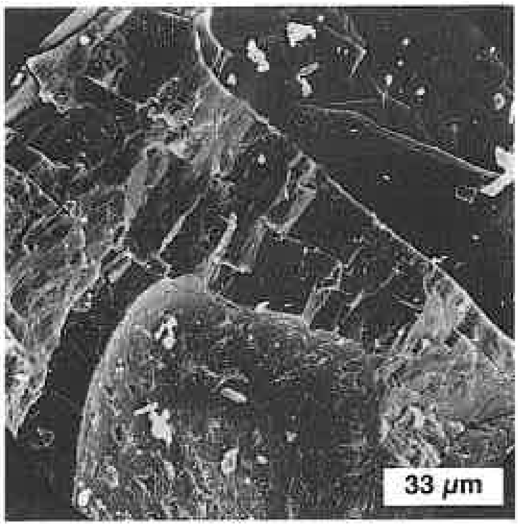

Fig. 35

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