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THE LOWER CRETACEOUS IN THE PRE-MIOCENE SUBSTRATUM OF THE SOUTHERN PART OF THE CARPATHIAN FOREDEEP IN POLAND

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Abstract: Lower Cretaceous epicontinental deposits have been documented in several exploration wells drilled in the Sędziszów Małopolski–Dębica–Pilzno region. These are marine deposits of Valanginian age, developed in a clayey-carbonate facies. They are only found in the areas of the thickest and most stratigraphically complete Upper Jurassic deposits, ranging in age from Oxfordian to Kimmeridgian. The Lower Cretaceous deposits occur beneath sediments of Late Cretaceous (Cenomanian and Turonian) age, forming small isolated caps on top of the Upper Jurassic surface. The whole region was originally completely covered by Lower Cretaceous deposits, as the Early Cretaceous sea invaded the whole area. An abundant alpine fauna recovered from the Lower Cretaceous indicates that the sea had open connections with the Tethys as well as with the epicontinental sea of the Polish Lowlands. The Sędziszów–Pilzno region was situated on the western slope of that basin.

Abstrakt: Epikontynentalne utwory dolnokredowe stwierdzono w rejonie Sędziszowa Małopolskiego–Dębicy–Pilzna, w kilku otworach wiertniczych. Są to morskie utwory walanżynu, wykształcone w facji ilasto węglanowej. Występują one wyłącznie w strefie o największej miąższości utworów górnojurajskich, w kontakcie z najmłodszymi utworami kimerydu. Osady dolnokredowe leżą pod utworami górnokredowymi (cenoman–turon), tworząc na powierzchni górnojurajskiej niewielkie wystąpienia w formie ograniczonych płatów. Pierwotnie obszar ten przykryty był całkowicie utworami dolnokredowymi, gdyż w dolnej kredzie był w całości zalany morzem. Liczna fauna alpejska stwierdzona w tych osadach świadczy, że przez obszar ten dochodziło do połączenia oceanu Tetydy z epikontynentalnym morzem Niżu Polskiego. Obszar Sędziszowa–Pilzna znajdował się na zachodnim skłonie tego basenu.

Key words: Carpathian Foredeep, epicontinental Lower Cretaceous, stratigraphy, structure of the pre-Miocene substratum.

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INTRODUCTION

Epicontinental Lower Cretaceous deposits in the southern sector of the Carpathian Foredeep have been discovered in the Dębica–Pilzno region in the Stasiówka-1 well (Geroch *et al.*, 1972), and in the Wola Wielka-2 well (Kijakowa & Moryc, 1991). In the latter study, the probable occurrence of Lower Cretaceous was also reported from the Pilzno-21 and Żarówka-1 wells. In these two wells, the Lower Cretaceous was not properly documented because the interval was not cored, but similarities in the log profiles allow comparisons to be made.

In all the above wells, the Lower Cretaceous occurs beneath sediments of Cenomanian to Turonian age, forming small localised caps which under favourable circumstances survived the middle Cretaceous and post-Late Cretaceous erosion. The Lower Cretaceous sediments are developed in a clayey-carbonate facies, and correlate with the upper Valanginian. These sediments rest upon Kimmeridgian limestones, and are associated with areas where the Upper Jurassic deposits reach their maximum thickness.

The most recent drilling results reveal that the Lower Cretaceous is present in at least two additional wells: Nawsie-1 and Zagórzyce-6 (Fig. 1). As in the Stasiówka-1 and Wola Wielka-2 wells, they occupy a similar structural position between the Upper Cretaceous and the Kimmeridgian, and again occur as isolated erosional caps. The occurrence and shape of these deposits was mentioned by Moryc (1995, 1996), who also pointed out that they are found further toward the east than had previously been mentioned. Both these wells were drilled as part of a new hydrocarbon exploration programme carried out in the Rzeszów–Sędziszów–Szufnarowa–Pilzno region.

The wells are located 10–15 km south of Sędziszów

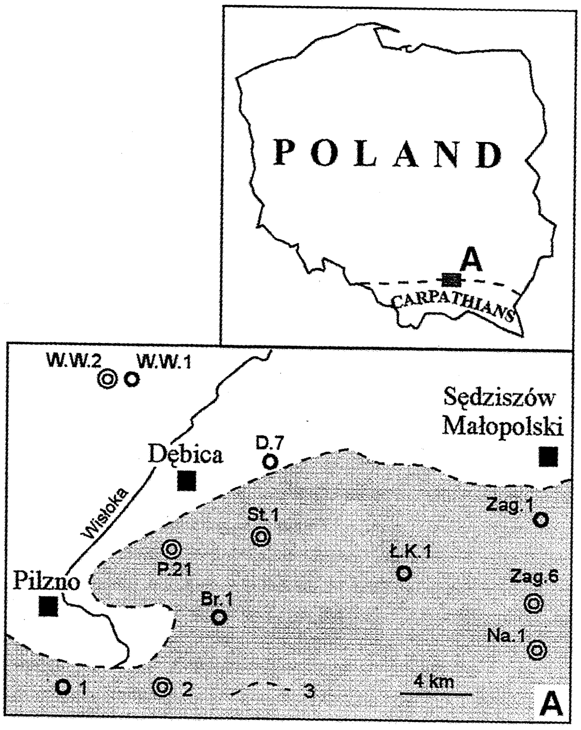


Fig. 1. Sketch map showing the locations of boreholes with Lower Cretaceous epicontinental deposits in the Pilzno–Rzeszów region: *1* – boreholes; *2* – boreholes with Lower Cretaceous deposits; *3* – boundary of the Carpathian overthrust. Names of the boreholes are given in Figure 7

Małopolski, and 20–22 km southeast of Dębica (Fig. 1). They were drilled on the Skole Unit of the Carpathian flysch in the northern part of the Strzyżów Depression. In both wells, after drilling through the flysch and the thin Miocene cover, an interesting profile of Mesozoic and Paleozoic sediments was documented which extends downwards into the Silurian graptolitic shales. The geological structure of the Miocene was the subject of a separate publication (Moryc, 1996), presenting the geology of the entire region between Pilzno and Sędziszów Małopolski. This study presents a summary of the Cretaceous of that area. The general geological relationships in the pre-Miocene substratum in the study area is illustrated using examples from two selected wells.

The task of reconstructing the stratigraphy of the Cretaceous deposits (especially the Lower Cretaceous) in the two exploration wells is an exceptionally difficult one. The problem stems from the sparse sampling from the two key wells, as well as from the limited occurrence of index fauna. It was unusually difficult to determine the base of the Cretaceous, as it occurs within an uncored interval that possessed a poorly differentiated geophysical log signature. As a consequence of this and the spot coring, estimates of the depth of the Upper Jurassic surface and the thickness of the Cretaceous are subject to some degree of uncertainty.

THE CREATACEOUS PROFILE IN THE ZAGÓRZYCE-6 WELL

The Zagórzyce-6 well drilled an outlier of Cretaceous sediments found south of Sędziszów Małopolski (Fig. 1). The Cretaceous was driled in the interval between 2690 and 2788 m. The portion of the interval between 2690 and 2750 m consists of the Upper Cretaceous deposits, and 2750–2788 m was assigned to the Lower Cretaceous (Fig. 2). Mechanical coring has been severely limited, and as a result the Cretaceous stratigraphy of the well is based on geophysical log interpretation and the study of drill cuttings. Additionally, the downhole logs from the Wola Wielka-2 well (Kijakowa & Moryc, 1991), which documented Lower Cretaceous sediments resting directly on Upper Jurassic limestones, were used for comparison.

Beneath the Carpathian flysch deposits in the Zagórzyce-6 well, a 7-m-thick layer of clayey sediments was found. By analogy to the Nawsie-1 well, this horizon was correlated to the Miocene (Badenian).

Below this level, Upper Cretaceous marly limestones were found at a depth of 2690 to 2750 m. Two cores were cut from the upper portion of these deposits (2695–2701 m and 2704–2705 m), and one core was taken from the lower

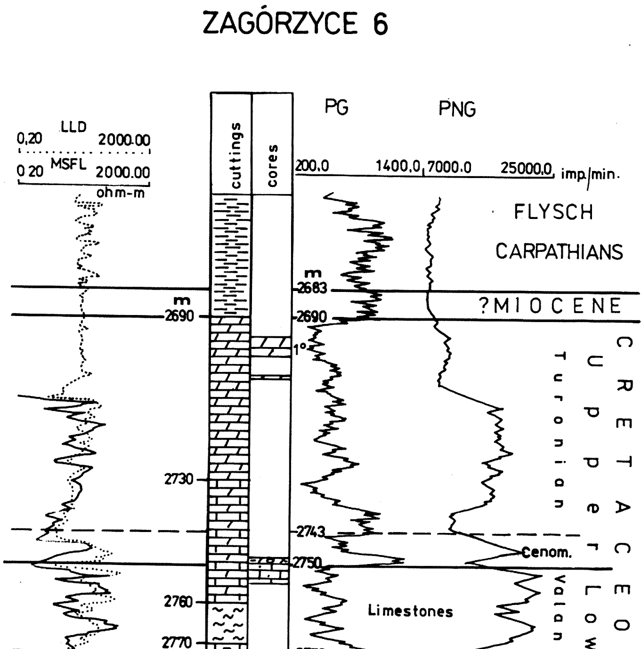


Fig. 2. Stratigraphical profile in the Zagórzyce-6 borehole: *1* – clays and claystones; *2* – marls; *3* – claystones with fragments of spongiolites; *4* – limestones; *5* – mudstones; *6* – downhole geophysical logs; *7* – dip of beds; LLD – Laterolog Deep Resistivity; MSFL – Micro-Spherically Focused Log; PG – Gamma Ray; PNG – Compensated Neutron Log

part (2749–2755 m). The upper 1.3 m of this core recovered Upper Cretaceous, while the lower part sampled Neocomian deposits.

In the two upper cores, greyish-beige hard marls, often brecciated, with opoka and fragments of inoceramids were recovered. The brecciated part of the marls is cemented with a greyish-green ilastic substance.

Both the microfaunal analyses and the lithological characteristics of these marls indicate a Turonian age. The microfaunal assemblage (determined by B. Olszewska) contains *Marginotruncana* cf. *marginata* (Reuss), *M.* aff. *bulloides* (Vogler), *Whiteinella baltica* Douglas et Rankin, *Guembelitria* cf. *cretacea* Cushman, *Globigerinelloides* sp., *Pyramidina* sp., *Hedbergella*? sp., *Spiroplectammina* sp., *Lenticulina* sp., *Gerochammina* sp., and calcispheres, including *Calcisphaerulina innominata* Bonnet, *Pithonella ovalis* (Kaufmann). Additionally, numerous sponge spicules and rare radiolarians were found.

The underlying deposits (to a depth of 2749 m) were not cored, but cuttings samples indicate the occurrence of typical Upper Cretaceous sediments. In the cuttings, light-grey marly limestones with opoka were recovered to a depth of 2730 m, and below this to a depth of 2760 m greyish-green marls and marly limestones were found which are similar to the ones occurring higher in the hole.

The next core was cut from a depth of 2749–2755 m, with full recovery from the cored interval. In the upper part, 130 cm of greyish-green noncalcareous claystone with stringers of quartz sand was recovered. In places scattered, dark grains of quartz 1–2 mm to 1 cm in diameter were found. In this material, numerous fragments of white noncalcareous highly porous rocks were observed that resemble sponges with irregularly smooth surfaces. According to preliminary investigations of A. Kranc, these are probably spongiolites. Altogether, the lithology appears to be a sponge conglomerate containing numerous fragments of a white rock of similar type, probably derived from the mechanical destruction of larger elements. The small fragments are of various size to 1 cm, and larger fragments are up to 3–5 cm. Their surfaces display a pattern of irregularly smoothened bumps, suggesting an organic origin.

Micropaleontological analyses of the claystones were carried out by J. Godawska, and reveal a foraminiferal assemblage with *Rotalipora cushmani* (Morrow), *Rotalipora* cf. *reicheli* Mornod, *Hedbergella brittonensis* Loeblich et Tappan, *H. delrioensis* (Plummer), *H. simplissima* (Magne & Sigal), *Gavelinella* cf. *cenomanica* (Brotzen), *Lingulogavelinella globosa* (Brotzen), *Valvulineria lotterlei* (Tappan), *V. lenticula* (Reuss), *Globorotalites* cf. *multisepta* (Brotzen), *Praeglobotruncana* cf. *stephani* (Gandolfi), *Dicarinella* cf. *imbricata* (Mornod). In addition, there are unidentified species of the genera: *Heterohelix*, *Marssonella*, *Marginotruncana*, and *Schackoina* as well as numerous coprolites, sponge spicules, and a mass occurrence of radiolarians. This assemblage indicates a Cenomanian age.

Previous micropalaeontological investigations carried out by Heller (Heller & Moryc, 1984) have noted that the occurrence of coprolites is a characteristic feature of Cenomanian sediments from the Carpathian Foredeep. Quartz pebbles and conglomeritic material occurring in these claystones provide further evidence that these basal sediments were formed during the Cenomanian transgression.

Below the noncalcareous greyish-green fossiliferous claystones (Core at 2749–2755 m), calcareous sediments were recovered. These consist of approximatelly 4 m of grey limestones, greyish-green in places, finely detritic, with scattered fine oolites and rather common crinoid fragments. Streaks of greenish clays were observed in places. Within these limestones, fissures were found which are infilled with material similar to the overlying sediments.

Beneath the 4 m-thick limestone layer to the bottom of the core, a light-grey, pelitic limestone of the opoka type with, fine interbeds of dark-grey and dark greenish-grey clays was recovered. In this unit, small almost vertical fissures were observed, that are infilled with a dark-grey marly clay material.

The lower part of the profile in Zagórzyce-6 from a depth of 2755 to 2791 m was not cored. This section was documented on the basis of cuttings samples and downhole logging. At a depth of 2760–2770 m (Fig. 2), the cuttings contain dark marly clay(stone), almost black in colour, and below this to 2780 m similar claystones are observed among pieces of grey limestones. Deeper in the well, similar limestones without clays were recovered.

The cuttings samples from 2760–2770 m were given to Prof. Geroch with the hope of verifying the correlations based on lithological characteristics. Prof. Geroch found the occurrence of common, but rather poorly preserved foraminifera belonging mainly to the epistominid and lenticulinid groups. In this assemblage the following forms were identified: *Epistomina caracolla* (Roemer), *Lenticulina nodosa* (Reuss), *L.* cf. *cultrata* (Montfort), *L.* cf. *muensteri* (Roemer). This assemblage confirmed the Early Cretaceous (probably Late Valanginian) age of the deposits. Additionally, Prof. Geroch remarked that the assemblage is rather poor in comparison to assemblages recovered from the Stasiówka-1 borehole (Geroch *et al.*, 1972). In fulfillment of a request for further samples submitted by Prof. Geroch, some additional material from the 2760–2770 m interval in the well was provided, as well as samples from the core collected from 2749–2755 m.

I delivered the samples to Prof. Geroch, but the sudden and unfortunate loss of our dear colleague meant that the investigation could not be completed. Samples were later investigated by S. Kijakowa, who was unable to find any additional species from the dark mudstones described above.

However, from the calcareous sediments sampled in the upper portion of the core collected from 2749–2755 m, S. Kijakowa was able to find a number of additional Lower Cretaceous forms, including *Trocholina burlini* Gorbatchik, *T. paucigranulata* Moullade, *T.* cf. *paucigranulata*, *Trocholina* sp., *Lenticulina* sp., *Patellina* cf. *subcretacea* Cushman et Alexander, *Patellina* sp., *Spirillina* sp., *Planularia* sp., echinoderm spines, and numerous fragments of macrofauna. The age of this unit fits within the interval from Valanginian to Hauterivian, but the correlation with the Stasiówka-1 well (Geroch *et al.*, 1972) and the Wola Wielka-2 well (Kijakowa & Moryc, 1991) suggests a Valanginian, and most probably a Late Valanginian age. In thin sections made from these limestones, B. Olszewska identified the following taxa: *Haplophragmium* sp., *Haplophragmoides* sp. *Trochammina* sp., *Recurvoides* sp., *Trocholina* sp., *Dorothia* sp., *Lenticulina* sp., as well as fragments of crinoids, bryozoans, blue-green algal lumps, and oolites.

The above analyses in combination with the downhole logging data enable us to place the depth of the contact between the Cenomanian and Valanginian deposits in the Zagórzyce-6 well at 2750 m. The infillings observed in the fissures in the upper part of the Lower Cretaceous limestone unit are interpreted as representing traces of the basal Upper Cretaceous deposits formed by the encroaching Cenomanian sea.

The lower boundary of the Lower Cretaceous in this well was determined based on the occurrence of Upper Jurassic deposits recovered from a core cut at 2791–2795 m (Fig. 2), as well as from the downhole logging results.

In the core, 3 m of rusty-yellow, beige, detritic, oolitic, crinoidal limestone was recovered. This contains rare clasts or rounded fragments (1–2 cm) of pelitic, beige limestone that was probably redeposited. In these limestones, fissures infilled with a micritic calcareous material are observed. These may have been derived from the Lower Cretaceous transgressive deposits. A Late Jurassic age for these detritic-oolitic limestones has been assigned based on the occurrence of corals of the family Latomeandridae (determined by E. Morycowa). In thin sections, B. Olszewska determined unidentified species belonging to the genera *Haplophragmoides*, *Recurvoides*, and *Trocholina*, which were unfortunately unable to provide a more precise age for the unit.

My identification of the contact between Jurassic (Kimmeridgian) and the Cretaceous (Valanginian) at 2788 m is based upon correlation with the Wola Wielka-2 well (Kijakowa & Moryc, 1991), and esspecially the similarity between the downhole logging results. In the latter well, the Lower Cretaceous limestones are also in direct contact with Upper Jurassic limestones.

Therefore, the Lower Cretaceous (Valanginian) deposits in the Zagórzyce-6 well occur between 2750 and 2788 m, although their lower boundary may actually extend a little deeper. However, this does not present an major problem for the purpose of this discussion.

Within the Lower Cretaceous calcareous-ilastic lithofacies (Fig. 2), it is possible to separate two units that are dominated by calcareous rocks (2750–2772 m and 2777–2788 m) separated by a 5 m thick mudstone layer.

THE CRETACEOUS PROFILE IN THE NAWSIE-1 WELL

Cretaceous deposits in the Nawsie-1 well were distinguished at a depth of 3003–3101 m. The Upper Cretaceous occurs to a depth of 3069 m, and below this to 3101 m the Lower Cretaceous was found (Fig. 3). The Cretaceous was only spot cored, and as a result drill cuttings and downhole logging was used to additionally subdivide the sequence.

Only three cores were recovered from the Upper Cretaceous sequence, from depths of 3020–3021 m, 3032–3034 m, and 3040–3042 m. Each core recovered about 1 m of sediment. These consist of beige, often marly, limestone of the opoka type, as well as grey and creamy-grey brecciated marls containing clasts of hard beige limestone. The clasts appear to be redeposited in the marly-clay matrix, which is characterised by its greenish and pinkish colours. In the two lower cores, nodules of brown cherts were found. These are commonly observed in sediments of Turonian age in numerous boreholes drilled throughout the region (Pilzno–Dębica–Dąbrowa Tarnowska, among others). The lithological features of these sediments are fully analogous to the Turonian deposits of the region which have also been documented biostratigraphically in numerous boreholes. The only macrofauna found in the Nawsie-1 well consists of inoceramian fragments.

Micropalaeontological

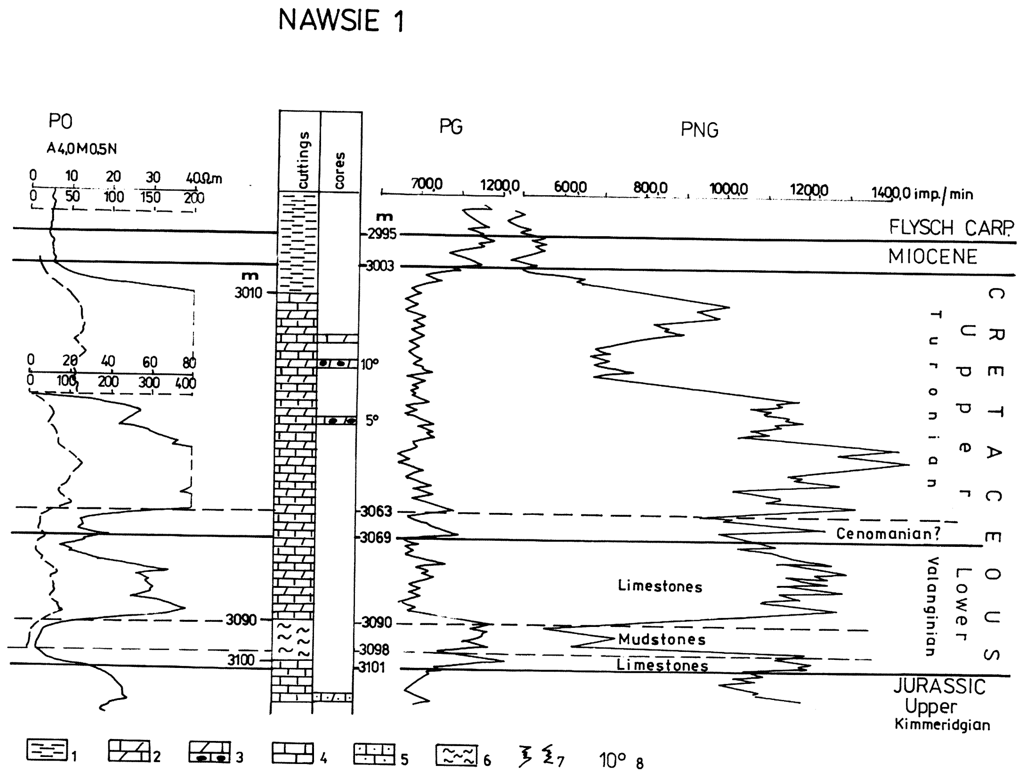


Fig. 3. 3. Stratigraphical profile in the Nawsie-1 borehole: *1* – clays and claystones; *2* – marls and limestones; *3* – marls and limestones with chert nodules; *4* – limestones; *5* – oolitic, detritic limestones; *6* – mudstones; *7* – downhole geophysical logs; *8* – dip of beds; PO – Electrical Logging. Other explanation as in Fig. 2

analyses carried out independently in two laboratories have confirmed the Turonian age of the recovered sediments. According to B. Olszewska, the microfauna observed in this section contains *Textularia* sp., *Dicarinella* sp., *Heterohelix* sp., *Hedbergella* aff. *delrioensis* (Carsey), *H. planispira* Tappan, ?*Rotalipora* sp. (recrystallized), and the calcispheres *Calcisphaerula innominata* Bonnet (common) and *Pithonella ovalis* (Kaufmann). In washed samples, J. Godawska identified *Lingulogavelinella* cf. *globosa* (Brotzen) and *Dicarinella* sp. Owing to the lack of further cores, the cuttings samples and downhole logs were used to determine the boundaries of the unit. In the cuttings, material from the Carpathian flysch was found to a depth of 3010 m (Fig. 3), below this to 3090 m chips of marl and limestone of the Upper Cretaceous variety were found. In the lowermost samples containing material from the flysch (with an abundant Upper Cretaceous flysch-type fauna), J. Godawska also found a lower Badenian microfauna that contains *Orbulina suturalis*, *"Biorbulina" bilobata*, *Globigerinoides bisphaericus*, *G. trilobus*, *Globigerina diplostoma*, *G. concinna*, *Turborotalia mayeri*, *T. bykovae*, among others. This indicates that traces of the Miocene sediments occur between the Flysch and the underlying Upper Cretaceous. According to the logs, this Miocene is probably about 8 m thick in the interval between 2995 m and 3003 m. They are probably tectonically disturbed.

Based on the results from the Zagórzyce-6 well and the similarities between the downhole logs, the lower boundary of the Upper Cretaceous deposits has been placed at 3069 m. In the Zagórzyce-6 well, Cenomanian sediments were documented in their lower part by means of microfauna (Fig. 2). Similar sediments have been determined in the 3063–3069 m interval in the Nawsie-1 well based on similarities between the downhole logs (Fig. 3). Unfortunately no cores were collected from this interval, and the cuttings do not provide us with unambiguous information.

While the hole was being drilled, I carried out core descriptions and collected cuttings samples. I noted the occurrence of black (dark) marly claystones and mudstones in the cuttings from a depth of 3090–3100 m which suggested Lower Cretaceous lithologies. The cuttings were delivered to Prof. Geroch, who found a foraminiferal assemblage that was quite abundant, though low in diversity. The assemblage contained *Epistomina* cf. *caracolla* (Roemer), *Lenticulina* cf. *nodosa* (Reuss), and rare indeterminate species of *Trocholina*. The assemblage indicates an Early Cretaceous age, and probably more precisely correlats with the upper Valanginian (Bartenstein & Bettenstaedt, 1962; Riegraf & Luterbacher, 1989; Bartenstein, 1977).

Samples of the claystones given to J. Jamiński for palynological analysis revealed that the organic material is comprised of about 75% amorphic material and 25% woody fragments. Rare dinocysts belonging to the genera *Avelloidinium*, *Surculosphaeridium*, and *Spiniferites* suggested a probable Early Cretaceous age.

Cuttings samples from the same interval were independently analyzed in the Micropalaeontological Laboratory of Polish Oil and Gas Company in Jasło, by J. Godawska. A Lower Cretaceous foraminiferal assemblage with *Lenticulina nodosa* (Reuss), *L. munsteri* (Roemer), *Epistomina* cf. *caracolla* (Roemer), *Trocholina* cf. *infragranulata* Noth, *Astacolus* sp., and one Lower Cretaceous ostracod species, *Mandocythere frankei* (Triebel) was determined. Although the assemblage is poor in species, it compares well with the assemblage from the Wola Wielka-2 well (Kijakowa & Moryc, 1991) and Stasiówka-1 (Geroch *et al.*, 1972).

The Gamma ray and N-gamma logs (Fig. 3) allow us to more precisely determine the depth of the claystone unit from which the cuttings samples were derived. This was observed between 3090 m and 3098 m. The unit correlates with the claystone observed between 2772 m and 2777 m in the Zagórzyce-6 well. As in the previous well, it separates two calcareous units: the first occurring between 3069 m and 3090 m and, the second between 3098 m and 3101 m. The 2.5 m of oolitic detritic limestone recovered in the core cut at 3108–3111 m was assigned to the Upper Jurassic, based on its lithology.

The micropalaeontological analyses carried out by Prof. Geroch revealed rare *Trocholina,* Miliolidae and other calcareous benthic foraminifera, but index forms were lacking.

The analyses carried out on both of these wells revealed important similarities between the Lower Cretaceous deposits.

DISTRIBUTION OF LOWER CRETACEOUS DEPOSITS

The epicontinental Lower Cretaceous deposits in the southern part of the Carpathian Foredeep are preserved as small caps, preserved on the Upper Jurassic erosional surface (Fig. 4). The caps are generally small, as their areal distribution is delimited by boreholes in which the Lower Cretaceous is absent. The caps do not reflect the original extent of Lower Cretaceous sediments in the study area, as the whole region was once covered by the Early Cretaceous sea. Their present-day distribution only reflects those areas that were sheltered from erosion. Perhaps the erosional remnants were preserved in depressions, or in somewhat higher areas that were later isolated by erosion.

In the study area, the Valanginian was documented in the boreholes Stasiówka-1 (Geroch *et al.*, 1972), Wola Wielka-2 (Kijakowa & Moryc, 1991) as well as in the Nawsie-1 and Zagórzyce-6 wells (Fig. 4). Additionally, the probable occurrence of Lower Cretaceous deposits has been determined in the Żarówka-1 and Pilzno-21 wells. There is a questionable occurrence of Lower Cretaceous in the Pilzno-20 and Pilzno-40 wells, since at the (uncored) Jurassic–Cretaceous contact the downhole logging registered a thin claystone unit, similar to the ones from the Pilzno-21 and Żarówka-1 wells.

It is noteworthy that the Lower Cretaceous deposits were only preserved in the areas with the thickest Upper Jurassic sediments, and at the same time in areas with the youngest Jurassic deposits (Kimmeridgian age) (Fig. 4). This indicates that the pre-Valanginian erosion of the Upper Jurassic was not as great in these areas, but it was nevertheless present. A striking example is the difference in the thickness of the Malm (about 140 m) between two wells

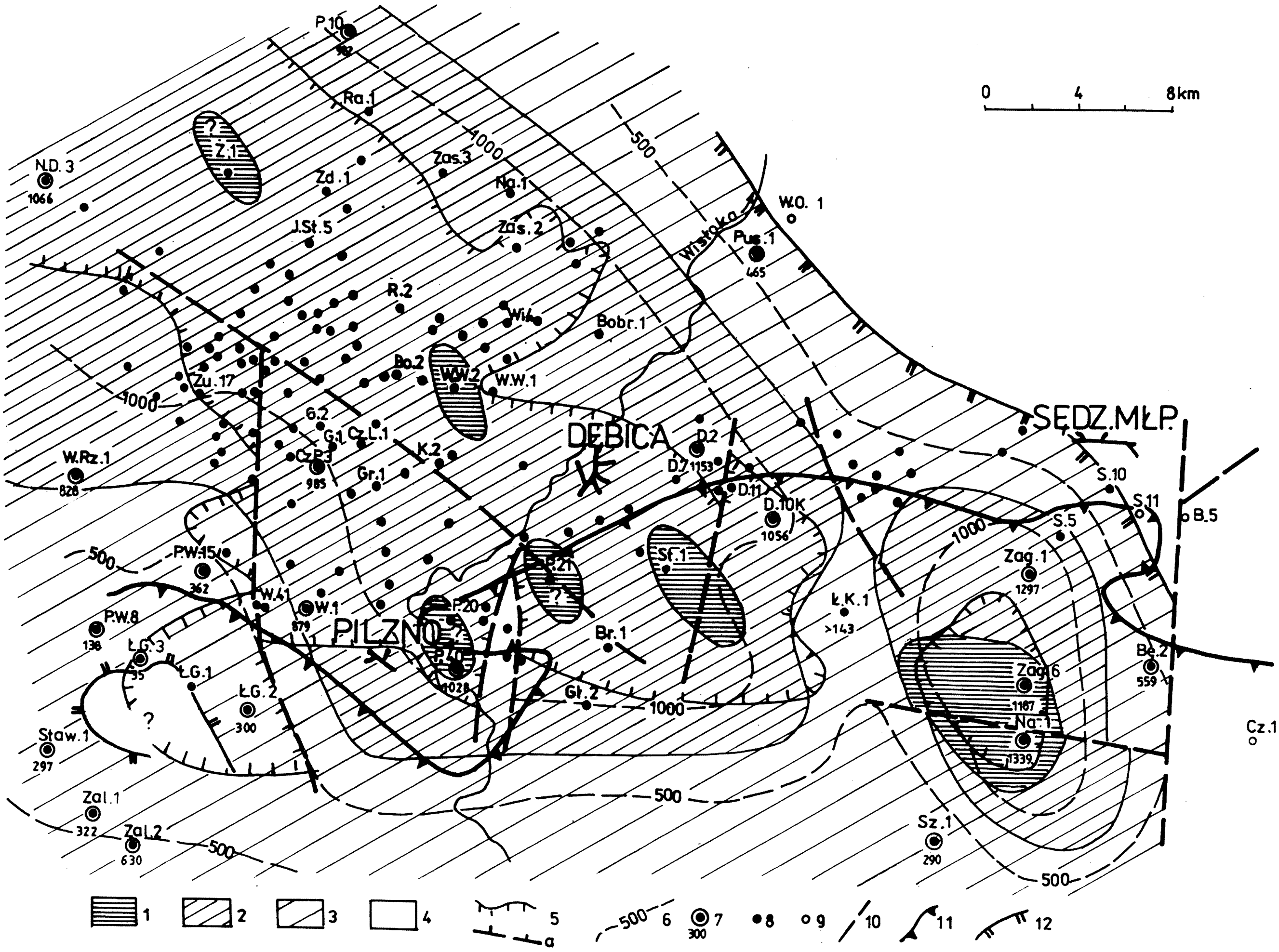


Fig. 4. Sub-Miocene map of the occurrence of Lower Cretaceous epicontinental deposits in the Pilzno–Dębica–Sędziszów Małopolski region, with thickness of Upper Jurassic deposits: *1* – Lower Cretaceous; *2* – Kimmeridgian; *3* – Oxfordian; *4* – pre-Upper Jurassic deposits; *5* – extent of the Upper Cretaceous deposits: *a* – boundary fault delimited; *6* – isopachs of Upper Jurassic deposits, in metres; *7* – boreholes that completely penetrated the Upper Jurassic, with thickness; *8* – boreholes that drilled into the Upper Jurassic; *9* – boreholes lacking Upper Jurassic; *10* – faults; *11* – boundary of the Carpathian overthrust; *12* – current extent of the Upper Jurassic deposits (Zero isopach). Explanations to boreholes are given in Figure 7

drilled not far from one another, the Nawsie-1 and Zagórzyce-6 wells.

However, at the time of the Early Cretaceous transgression, the region must not have been morphologically differentiated to any great extent, as the Lower Cretaceous in all the boreholes is generally of similar age and thickness.

The above relationships suggest that the Early Cretaceous history of the basin was linked with that of the pre-existing Late Jurassic basin (Niemczycka & Brochwicz-Lewiński, 1988), preserved most probably in the Lower San Anticlinorium, which was the southeastern extension of the Mid-Polish Trough. This area was transitional between the epicontinental seas and the southern seas that were influenced by Mediterranean environmental conditions. This is suggested by the influence of alpine fauna in the Lower Cretaceous of Dębica, Lubaczów, and many other localities in the Polish Lowlands (Marek, 1988).

The Dębica–Pilzno region was located in the western, marginal part of the Lower Cretaceous basin. In this area, the transgression did not occur until the Valanginian, and most probably the Late Valanginian, and formed clayey, muddy, and carbonate sediments. In the region, no sediments of Hauterivian age were encountered. These may have been removed by the pre-Late Cretaceous erosion. At this time, some parts of the Lower Cretaceous (Valanginian) erosional remnants preserved beneath the Cenomanian and Turonian deposits must have assumed their present-day form.

However, the Lower Cretaceous deposits were also eroded during a later stage. A striking example is the pre-Badenian palaeovalley (Figs. 4, 7) drilled in the Łączki Kucharskie-1 well, which completely cuts through the Cretaceous and Kimmeridgian deposits and bottoms in the upper part of the Oxfordian. Such erosion resulted in the isolation of the (originally continuous) Cretaceous of the Stasiówka region from that of the Nawsie–Zagórzyce area. It is also possible that, in contrast to the results presented in Figures 4 and 7, the Lower Cretaceous of the two areas may once have been continuous.

GEOLOGICAL STRUCTURE OF THE PRE-MIOCENE SUBSTRATUM

The structure of the Palaeozoic–Mesozoic basement in the Pilzno–Dębica–Sędziszów region is rather complicated. This has been the subject of a separate study (Moryc, 1996), which covered the material in greater detail. To provide a general overview of the geological structure, several typical profiles from deep boreholes in the region are presented in Figures 5 and 6. These illustrate the general mutual relationships between the geological systems.

The oldest deposits in the region are Precambrian clayey metaargilites drilled in the Dębica-2 and Zagórzyce-1 wells (Fig. 6) and in the Wola Ociecka-1 well (Fig. 7).

Cambrian deposits are not known from the area, and probably do not occur. The oldest paleozoic rocks are of Ordovician and Silurian age, which form a separate, differentiated, sedimentary-structural unit (Figs. 5, 6).

Devonian deposits have not been encountered in the study area. There are reasons to believe that Devonian sediments were originally present over the region, but these have been completely removed by the subsequent post-Bretonian erosion (Moryc, 1992). The Carboniferous sea probably encroached on the area comparatively late. In the northern region, the transgression was of a Tournaisian and early Visean age, whereas the southern region was elevated for a longer period of time, and the transgression did not take place until the mid to late Visean. At that time carbonates were deposited, and later the more clastic Kulm facies developed.

During the long sedimentary hiatus, which lasted from the later part of the early Carboniferous, through the entire Permian, until the Bunter times, the region was subjected to intense erosion of the Paleozoic cover. The Carboniferous deposits were especially removed. In many areas the Kulm facies was removed completely, and even the lower Carboniferous carbonates may be missing (e.g., the Pustków-1 and Wola Ociecka-1 wells; Fig. 7). As a result, the Triassic and Jurassic deposits (and partly even Miocene sediments deposited after the Alpine erosion) rest upon Paleozoic deposits of various age, or partly even lie directly upon the Precambrian metamorphics.

The Triassic of the region is developed either as a Bunter sandstone facies, or in the western part of the study area, as lower Muschelkalk (e.g., in the Nieczajna Dolna-3 well).

The Jurassic deposits are represented by clastic Dogger sediments (Bajocian to Callovian) with a maximum thickness of 200–250 m. Upon this, a limestone unit comprising the Oxfordian to Kimmeridgian is developed. In the study area this unit reaches a thickness of 1330 m (e.g., the Nawsie-1 well).

The Cretaceous facies are most interesting in light of the Early Cretaceous history of the area. As mentioned above, they are found in the areas of the thickest Upper Jurassic deposits (Fig. 4). In addition, the overlying Upper Cretaceous deposits played an important role in preserving these deposits (Fig. 7). These shielded the Lower Cretaceous from ero-

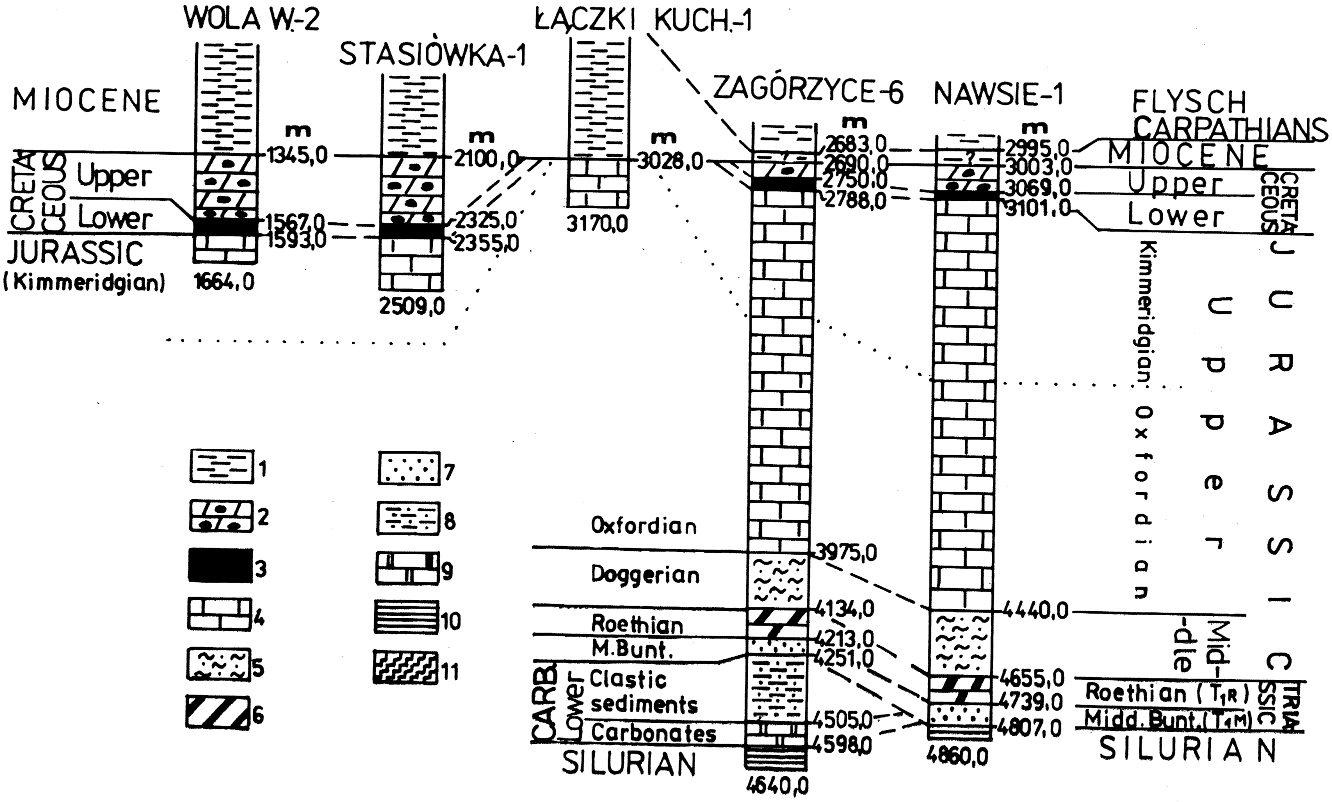


Fig. 5. Correlation of sub-Miocene sediments in the Wola Wielka–Zagórzyce–Nawsie region: *1* – Miocene; *2* – Upper Cretaceous; *3* – Lower Cretaceous; *4* – Upper Jurassic; *5* – Middle Jurassic; *6* – Rhetian; *7* – Middle Bunter; *8* – Lower Carboniferous, Kulm; *9* – Lower Carboniferous, carbonates; *10* – Silurian + Ordovician; *11* – Precambrian

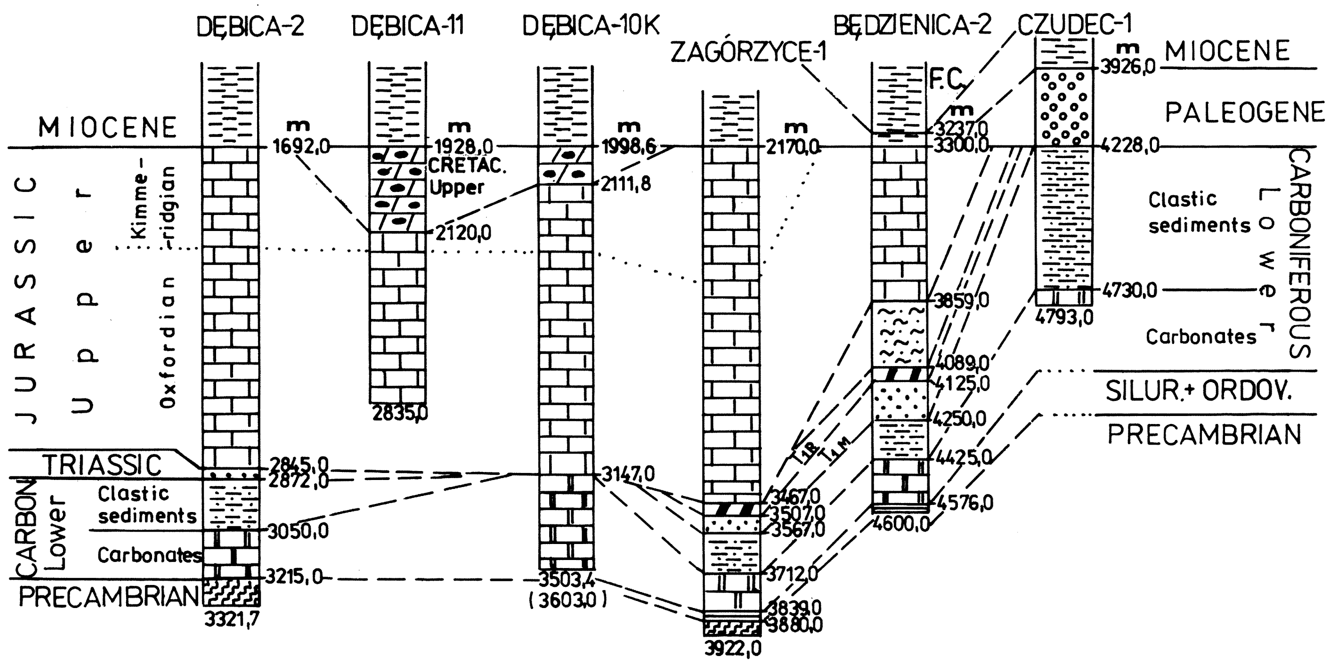
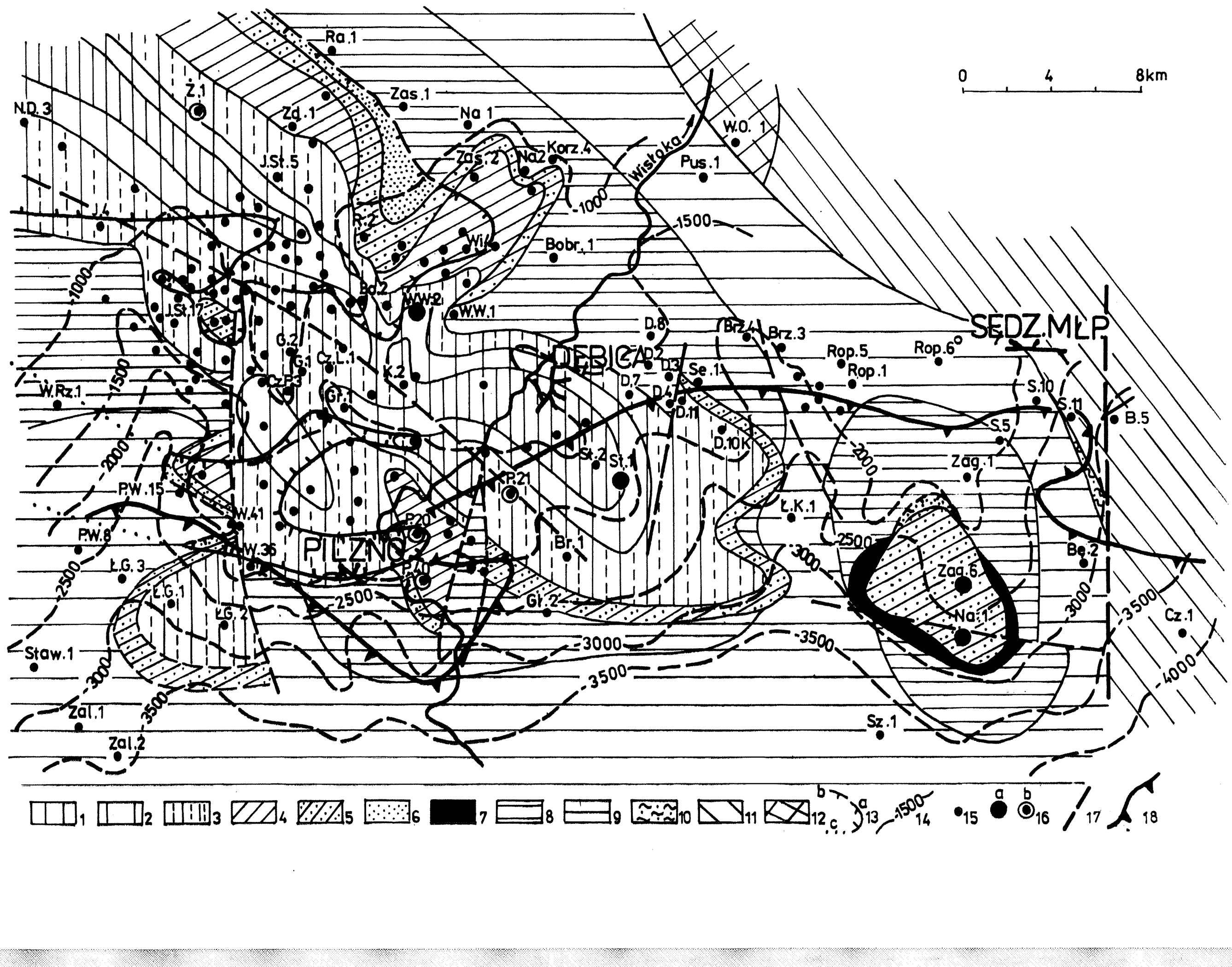


Fig. 6. Correlation of sub-Miocene sediments in the Dębica–Będzienica–Czudec region; F. C. – flysch Carpathians; U. Cretaceous – Upper Cretaceous. Other explanation as in Fig. 5

sion. We observe this in the Pilzno–Dębica area, as well as in the Nawsie–Zagórzyce cap (Figs. 5–7). The Łączki Kucharskie-1 well is situated between these two areas with Cretaceous deposits, which must have originally formed a laterally continuous cover on the Upper Jurassic limestones.

Until the Nawsie-1 and Zagórzyce-6 wells were drilled, the eastern limit of the Cretaceous deposits was believed to be located southeast of the Stasiówka-1 well, but west of the



Łączki Kucharskie-1 well. The current results significantly extend the known areal occurrence of the Cretaceous towards the east, and also document their occurrence as isolated erosional outliers that are separated from the main body of Cretaceous deposits (in the Dębica–Pilzno–Nieczajna Dolna region) by small incised valleys. In the study area, it is quite possible that additional erosional remnants of Cretaceous deposits exist which have not yet been documented by drilling.

The lithological development of the Lower Cretaceous deposits has been described in the preceding section. Upper Cretaceous deposits are developed in a facies that is typical of the whole Carpathian Foredeep region (Heller & Moryc, 1984). These are (from their base) Cenomanian sandstones and Turonian–Coniacian marls, opokas, and limestones formed during the early transgression of the Late Cretaceous sea; and Santonian–Maastrichtian marly limestones of the later Late Cretaceous marine transgression. These display transgressive and unconformable nature with respect to the underlying Jurassic and lower part of Upper Cretaceous deposits. The Santonian is itself transgressive, and partly lies directly upon various Jurassic sediments (e.g., in the Wygoda-36, -41, and Dębica-7 wells). The transgressive nature of the Turonian is also observed with respect to the Cenomanian sandstones, which are only found within depressions and in the incised valleys. One of these links the Cenomanian of Smęgorzów–Swarzów in the Dąbrowa Tarnowska region, with the deeply incised valley filled with Cenomanian at Krzyż–Szczurowa–Łąkta area (Heller & Moryc, 1984). It is possible that the occurrence of Cenomanian in the Zagórzyce-6 well was in some way connected with the Cenomanian of the Smęgorzów–Swarzów valley, but this presumed connection developed towards the north was located in an area where Cretaceous sediments were subsequently eroded.

The Cretaceous facies in the Pilzno–Dębica–Sędziszów region (Fig. 7) are completely analogous to the coeval sediments that are found in the whole southern part of the Carpathian Foredeep, and its eastern extension into the Miechów Trough.

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Fig. 7. Structure of the pre-Miocene basement (in the Czudec–Będziemyśl area, the pre-Palaeogene basement) in the Pilzno–Dębica–Zagórzyce region: *1* – Maastrichtian; *2* – Campanian; *3* – Santonian; *4* – Coniacian; *5* – Turonian; *6* – Cenomanian; *7* – Lower Cretaceous (Valanginian); *8* – Kimmeridgian; *9* – Oxfordian; *10* – Dogger; *11* – Lower Carboniferous; *12* – Precambrian; *13* – limit of the Cenomanian: *a* – primary at the base of the Turonian, *b* – erosional, *c* – presumed in the area of complete removal by subsequent erosion; *14* – isobaths of the sub-Paleogene surface; *15* – boreholes in which the substratum was drilled; *16* – boreholes that drilled epicontinental Lower Cretaceous deposits: *a* – verified by faunal evidence, *b* – probable; *17* – faults; *18* – boundary of the Carpathian overthrust. Symbols of boreholes: B – Będziemyśl; Bę – Będzienica; Bobr. – Bobrowa; Bo. – Borowa; Br. – Braciejowa; Cz. P. – Czarna Pilzno; Cz. – Czudec; D. – Dębica; G. – Golemki; Gł. – Głobikowa; Gr. – Grabiec; J. – Jastrząbka; J. St. – Jastrząbka Stara; K. – Karolówka; Korz. – Korzeniów; Ł. K. – Łączki Kucharski; Ł. G. – Łęki Górne; Nag. – Nagoszyn; Na. – Nawsie; N. D. – Nieczajna Dolna; P. – Pilzno; Po. – Podborze; P. W. – Pogórska Wola; Pus. – Pustków; Ra. – Radomyśl; Rop. – Ropczyce; R. – Róża; Se. – Sepnica; S. – Sędziszów; St. – Stasiówka; Staw. – Stawiska; Sz. – Szufnarowa; Wi. – Wiewiórka; W. O. – Wola Ociecka; W. Rz. – Wola Rzędzińska; W. W. – Wola Wielka; W. – Wygoda; Zag. – Zagórzyce; Zal. – Zalasowa; Zas. – Zasów; Zd. – Zdziarzec; Ż. – Żarówka; Żu. – Żukowice. Arabical numbers following the symbols sign the number of the boreholes

Streszczenie

KREDA DOLNA W PODŁOŻU MIOCENU POŁUDNIOWEJ CZĘŚCI PRZEDGÓRZA KARPAT

Władysław Moryc

Epikontynentalne utwory dolnokredowe w południowej części przedgórza Karpat zostały dotychczas znalezione w rejonie Dębicy–Pilzna, w otworach wiertniczych Stasiówka-1 i Wola Wielka-2. Prawdopodobnie utwory tego wieku występują również w otworach Pilzno-21 i Żarówka-1 oraz Pilzno-20 i Pilzno-40. Jednakże z braku rdzeni nie zostały one udokumentowane fauną, a ich wiek został wyznaczony na podstawie podobieństwa wykresów geofizyki wiertniczej.

Najnowsze wyniki wierceń wykonanych w tym rejonie wykazały występowanie epikontynentalnych utworów dolnokredowych przynajmniej jeszcze w dwóch otworach wiertniczych, Zagórzyce-6 i Nawsie-1. Otwory te odwiercone zostały około 20 km na południe od Rzeszowa i około 20 km na południowy wschód od Dębicy (Fig. 1). Zlokalizowane one zostały na obszarze Karpat fliszowych w obrębie jednostki skolskiej, w północnej części depresji strzyżowskiej.

W obydwu otworach (Fig. 2 & 3), po przewierceniu osadów fliszowych i cienkiej pokrywy mioceńskiej stwierdzono utwory kredy górnej (cenoman–turon), a następnie morskie osady wykształcone w facji ilasto-węglanowej kredy dolnej. Występująca w tych osadach mikrofauna świadczy o ich walanżyńskim (? górnowalanżyńskim) wieku. Miąższość tych osadów wynosi 32–38 m. Pierwotna miąższość była zapewne większa, gdyż część osadów, w tym prawdopodobnie również utwory hoterywu, zostały przed cenomanem erozyjnie zredukowane.

Utwory dolnej kredy zachowały się wyłącznie w strefie największej miąższości osadów górnojurajskich i równocześnie w strefie występowania osadów najmłodszych tego podsystemu, utworów kimerydu (Fig. 4). Utwory dolnokredowe występują dziś w postaci niewielkich płatów, ograniczonych wierceniami, w których osadów tych brak. Pierwotnie jednak, cały ten obszar był zalany przez morze dolnokredowe i na całej jego powierzchni występowały utwory neokomskie. Późniejsza, przedgórnokredowa erozja doprowadziła do znacznego ich zniszczenia, a pojedynczo zachowane płaty stanowią ich niezerodowane resztki.

Przez obszar Pilzna–Dębicy, który we wczesnej kredzie zajmował zachodnią, brzeżną strefę basenu, przebiegało bezpośrednie połączenie morza południowego z morzem epikontynentalnym. Świadczy o tym fakt znacznego oddziaływania środowiska medyterańskiego, przejawiający się alpejskimi wpływami faunistycznymi w osadach dolnej kredy w rejonie Dębicy, Lubaczowa i wielu punktach Niżu Polskiego.

Utwory dolnokredowe były niszczone również w późniejszym okresie. Ulegały one erozji laramijskiej wraz z nadległymi osadami kredy górnej i niżejległą serią węglanową górnej jury. Jednym z przykładów takiego niszczenia jest przedbadeńska paleodolina przebiegająca przez otwór Łączki Kucharskie-1 (Fig. 4 & 7). Rozcina ona całkowicie utwory kredowe i kimerydu i wcina się w górne partie osadów oksfordu. Wcięcie to doprowadziło do izolacji łączących się pierwotnie utworów kredowych z rejonu Dębicy–Stasiówki, z utworami kredowymi w rejonie wierceń Nawsia-1 i Zagórzyc-6, zachowanymi tam w formie płatu.

Budowa geologiczna podmioceńskiej pokrywy mezo-paleozoicznej rejonu Pilzna–Sędziszowa Małopolskiego jest bardzo zróżnicowana i złożona. Ilustruje to korelacja utworów z kilku ważniejszych otworów wiertniczych (Fig. 5 & 6). Wskazuje ona na szereg niezgodności stratygraficznych poszczególnych systemów geologicznych. W wyniku szeregu postorogenicznych ścięć erozyjnych części, a nawet całości, utworów danego systemu, występuje na tym obszarze wiele luk stratygraficznych. Ujawniają się one również na mapie geologicznej przedmioceńskiej powierzchni erozyjnej (Fig. 7), nie tylko jako powierzchnia niezgodności utworów różnych systemów (np. spągu jury), ale również niezgodnym przebiegiem różnych utworów jednego systemu (np. niezgodność przedsantońska, ścinająca powierzchnię starszych utworów kredowych i jurajskich).

Wyniki wierceń Nawsie-1 i Zagórzyce-6 wykazały również znaczniejszy, niż dotychczas znano, wschodni zasięg utworów kredowych. Świadczy to zarazem o możliwości występowania tych utworów jako oddzielnych, izolowanych płatów, odciętych erozyjnie niewielkimi „przełomami" od zasadniczej pokrywy kredowej rejonu Dębicy–Nieczajny Dolnej.