Annales Societatis Geologorum Poloniae (2006), vol. 76: 321–325.

BIOSTRATIGRAPHY AND SEQUENCE STRATIGRAPHY OF THE LOWER CRETACEOUS IN CENTRAL AND SE POLAND – REPLY

Elżbieta GAŹDZICKA[1*], Piotr DZIADZIO[2], Izabela PLOCH[1] & Jolanta SMOLEŃ[1]

[1] *Polish Geological Institute, Rakowiecka 4, 00-975 Warszawa; *e-mail: egaz@pgi.waw.pl*
[2] *Pułaskiego 20, 38-300 Gorlice*

We welcome the opportunity to reply to the criticisms by S. Marek, A. Raczyńska and K. Leszczyński. We appreciate the authors' knowledge and experience in solving problems of Cretaceous stratigraphy, lithology and palaeogeography. During our studies upon the Lower Cretaceous sedimentary series within the Warsaw – Lublin Trough we referred to the results of their previous works (papers and maps), what is expressed in our publication. However, we did obtain some new biostratigraphic data, mostly from micro- and nannofossil analyses, that allowed us to revise the hitherto existing stratigraphic schemes. On the other hand, a detailed study of wire-line logs, first digitized and calibrated, allowed us to identify (maximum) flooding and transgressive surfaces, as well as sequence and parasequence boundaries. Finally, sedimentary sequences enabled us to correlate Lower Cretaceous deposits within the studied segment of sedimentary basin. Identifying sedimentary sequences is of particular importance to the understanding of stratigraphy. We believed that simultaneous application of these different methods allowed us to properly resolve problems of stratigraphy and correlation. We might have made some unavoidable mistakes. Nevertheless, the stratigraphic scheme hitherto used was no longer workable, particularly within the Jurassic–Cretaceous transition.

Marek *et al.* (discussion – this volume) argue for a stratigraphic scheme that we had proposed for the Białobrzegi IG 1 borehole section. They put forward two arguments against our interpretation: (1) regional gap including the Upper Jurassic, Berriasian and Lower Valanginian, that was caused by uplifting of the Radom – Magnuszew area at the Jurassic–Cretaceous boundary, as well as in the earliest Cretaceous, and (2) the evidence of Valanginian (and Hauterivian?) ammonites in the well cores. We will reply to their criticisms following the order in their discussion.

Regional context

According to our opponents, we changed the earlier accepted scenario of the geological evolution of the Radom – Magnuszew area, as well as that of the NE margin of the Holy Cross Mts. They stated: "*The Late Valanginian sea transgressed northeastwards onto a flat Upper Jurassic surface, reaching the line Wilga – Izdebno – Ciepielów*". According to their opinion, a next gap within the Cretaceous sedimentary series in this area includes the Upper Hauterivian, Barremian, Aptian, Lower and Middle Albian. Marek *et al.* (discussion – this volume) cited a number of publications dealing with both individual sections of deep boreholes or outcrops and with the regional interpretation of the sedimentary basins development. Simultaneously, the authors suggest that we had assumed a continuous sedimentation northward to the Lublin region during the Jurassic–Cretaceous transition and *"thus the lack of stronger diastrophism resulting in denudation processes affecting uppermost Kimmeridgian through Lower Valanginian rocks"*.

We believe that quite a different interpretation of sedimentary processes within the Polish Basin was actually presented in our paper. Correlation of sedimentary sequences along the SW slope of the East European Platform, between the sections of the Gostynin IG 4 and Narol IG 2 boreholes (Dziadzio *et al.*, 2004; fig. 43) shows evidence of many stratigraphical gaps of different time intervals. Sometimes they are clearly visible in the sections of the wells situated nearby. On the one hand, they indicate a tectonic activity of this zone, on the other – eustatic changes of sea level. Additionally, they reveal a differentiation of the sedimentary basin caused by tectonic activity of some NW–SE trending faults or fault zones, cut by SW–NE trending structures. But tectonic analysis of the Warsaw – Lublin swell was beyond the scope of our study. Diastrophic phenomena are obvious in every sedimentary basin, but we do not want to postulate any general regressions or transgressions during the Late Jurassic or Early Cretaceous, studying only a fragment of inner part of tectonically active sedimentary basin.

The assumption about the presence of an elevation within the basin, including the Holy Cross Mts and the Lublin area, with a rising trend since the Berriasian (Late Volgian) to early Valanginian is difficult to confirm. The Holy Cross Mts were then in the axial zone of the Polish Trough which during the Early Cretaceous underwent extension, and thus subsidence (Kutek & Głazek, 1972; Pożaryski & Brochwicz-Lewiński, 1979; Dadlez *et al.*, 1994; Hakenberg & Świdrowska, 1997; Kutek, 2001). Both during the earlier Mesozoic and in the Cretaceous, the Gielniów Anticline formed simultaneously with inversion of the Polish Trough, was situated at its axis, and so in the zone of fastest subsidence (Dadlez, 2001). The area of Magnuszew, Białobrzegi and Radom was situated on the margin of the EEP, sloping to SW. This zone was probably cut by

NW–SE trending faults, with SW footwalls. Mesozoic sedimentary series, including the Lower Cretaceous strata, grow thicker towards the SW (eg., Marek, 1988). Several such faults are shown in a map, published by Marek *et al.* (1988; fig. 1).

Were the faults active during the Early Cretaceous? The answer is difficult due to very scarce data; little amounts of Lower Cretaceous deposits; few wells with limited cores data for that interval. Kutek (2001) claimed that the Early Cretaceous was among the extension periods and therefore increased subsidence of the Polish Trough. Dadlez *et al.* (1994), modeling the subsidence rate with backstripping method, interpreted the Early Cretaceous interval as a stage of slow, thermal subsidence of the basin floor. Hakenberg and Świdrowska (1997) (quoted by our critics) pointed to subsidence gradually increasing towards the trough axis during the Late Jurassic, but found no evidence for the activity of the Nowe Miasto – Iłża fault. The Early Cretaceous was not discussed in the cited paper. Therefore, it seems strange that the paper is cited in the context of the claim about rising "*margins of the Holy Cross Mts and the adjoining Lublin region (between Magnuszew and Radom)*", namely during the Early Cretaceous.

What geotectonic mechanism can be then invoked to explain "uplifting trends" of a fragment of a rift structure? Accepting an activity of the Nowe Miasto – Iłża Fault during the Late Jurassic and Early Cretaceous and treating it as a bounding fault, we can suppose that the Radom – Kraśnik uplift has formed an elevated flank of the rift. However, there is no evidence to prove this assumption. A total thickness of the Lower Cretaceous series within the Białobrzegi IG 1 section is bigger than those found in the wells located towards NE. It considerably increases from 34 m in Magnuszew IG 1 to more than 270 m in Białobrzegi IG 1, but this growth is gradual.

The unconformities, hiatuses and thickness variability in the Lower Cretaceous sedimentary series, as well as cyclic phenomena of different frequencies were caused, besides the tectonic activity of particular zones, by eustatic sea level oscillations. The shallow, epicontinental sedimentary basin of the Polish Lowlands was especially prone to such changes. Episodes of substantial drop of sea level occurred in the Latest Berriasian and Early Valanginian (Haq *et al.*, 1988; Hallam, 1992). These events were caused by a marked global climate cooling, resulting in glaciation and storing large amounts of water in ice caps (Kemper, 1987; Frakes & Francis, 1988). Lower Valanginian sequences within the Polish sedimentary basin, partially distinguished as Bodzanów Formation, also include shallowing-upward cycles (eg., Gostynin IG 1 and Łowicz IG 1 sections). Studies on calcareous nannoplankton assemblages led Mutterlose and Kessels (2000) to suggest, besides the Early Valanginian ice-age, also a cold period in Early Hauterivian. Middle and late Berriasian, as well as early and Middle Tithonian and Late Kimmeridgian were, on the other hand, times of high world ocean level (Haq *et al.*, 1988; Hallam, 1992). In the Polish Lowlands, a rise in sea level is evidenced by fine-grained siliciclastic deposits with bathyal fauna, ammonites, reach assemblages of foraminifers and calcareous nannoplankton, including Tethyan forms. Thus, it seems that a strong sea level drop in the Early Valanginian could have caused the local hiatuses (lack of accommodation space) as well as removal of some previously accumulated sedimentary sequences, including Berriasian and the uppermost Jurassic. With this model, there is no need to invoke problematic "*block uplifting trends*".

The analysis of available material from the Kielce – Radom area indicates interpretation errors. Certainly, assuming a regression/erosion episode after the early Kimmeridgian, and a subsequent transgression of the Late Valanginian–Hauterivian sea is an oversimplification. If in the study area a regression occurred after the deposition of the Lower Kimmeridgian series, the strata would have been eroded. It seems logical that the regressive phase (or phases) occurred later instead, probably during the global low ocean stand at the Tithonian/Berriasian boundary or in the early Valanginian. The upper Kimmeridgian, documented by the ammonite assemblage, occurs in Krzyżanowice near Iłża (Dąbrowska, 1983); in Nowe Miasto on Pilica, near Radom it has been documented by microfaunal evidence. The upper part of Lower Tithonian has been also found there (Pożaryski *et al.*, 1958). The Białobrzegi IG 1 well section represents a deeper zone of the basin than the other logs we analysed, as indicated by facies characteristics of the Lower Cretaceous sedimentary sequences. Located closer to the basin axis, it shows analogies to the logs of such wells as the Raducz IG 1 and Mszczonów IG 2 or Bąkowa IG 1, rather than to the Warka IG 1 or Magnuszew IG 1. The analysis of well logs allows us to correlate some sedimentary sequences in the Białobrzegi IG 1 section, previously identified as Kimmeridgian, with ammonite-dated strata of Lower and Middle Tithonian of Raducz IG 1. The latter borehole has not been included into our original study because of the lack of well cores, which have been destroyed.

Another example of erroneous interpretation concerns the log of the Bąkowa IG 1 borehole, located east of Iłża. According to the original interpretation (Niemczycka, 1975), the Juraasic/Cretaceous boundary (precisely, the Kimmeridgian/Upper Valanginian boundary) was set at the 946.0 m depth. Further above, there should be Upper Hauterivian, Barremian–Middle and Upper Albian. However, in the dolomitic marls from the depth of 953.0 m there are Cretaceous nannoplankton species, such as *Repagulum parvidentatum* (Deflandre) known since the Hauterivian, *Eprolithus antiquus* Perch-Nielsen (upper part of the Lower Hauterivian) or *Farhania varolii* (Jakubowski) from the Lower Aptian, as well as *Tubodiscus* sp. (Lower Cretaceous). Because of the stratigraphic scheme assumed earlier, the deeper interval has not been sampled, even though the core samples could have provided information on the actual Jurassic/Cretaceous boundary in that well section. Organodetritic limestones with numerous spur shell fragments, serpulid colonies, and ferruginous ooids found at 942.5 m b.g.l., regarded as the Upper Valanginian (Marek, 1975), contain abundant calcareous nannoplankton with Tethyan species known since the Hauterivian or Barremian. We find that palaeontological and facies evidence gathered during our study indicates a possibility of errors in previous stratigraphic interpretation of at least some well sections from the Holy Cross Mts, *i.e.* the Radom – Białobrzegi area.

Thus, assuming a uniform stratigraphic scheme for the whole region with a universal stratigraphic gap spanning the Upper Kimmeridgian, Tithonian, Berriasian and Lower Valanginian seems unjustified. A review of documentation of wells located near Białobrzegi (not included in our study because of lack of preserved cores or insufficient samples) indicates marked differences in lithofacies development and thicknesses of particular successions, even though the stratigraphic scheme assumed years ago was always the same: Kimmeridgian – Upper Valanginian – Lower Hauterivian – Albian. The nearby boreholes, including: Bąkowa IG 1, Ciepielów IG 1 or, more to the north, Magnuszew IG 1, Mszczonów IG 1, IG 2, Raducz IG 1, and Nadarzyn IG 1 can be cited here. In Korabiewice IG 1 (between Warka and Łowicz) there is no Valanginian and the Upper Hauterivian directly overlies the Berriasian. A detailed analysis of stratigraphic gaps in particular sections, a correlation of depositional sequences, and a comparison between these pieces of information and the eustatic curve (Haq *et al.*, 1988), allows us to precisely indicate the timing of tectonic activity in particular zones/blocks.

We think that it is not worth to argue about uplifting or downwarping of the Radom area during the Early Cretaceous. Having so a few cores with stratigraphic evidence for sedimentary series due to pure core recovery from the wells, the discussion seems to be theoretical. Still we can obtain much more data from geophysical logs. The interpretation of the entire studied succession permitted the recognition of tectostratigraphic units that are signature of superimposed effects of tectonics and long-term eustasy. On the basis of wireline logs it is possible to identify sedimentary sequences and unconformities within the questioned interval of Białobrzegi IG 1, which might have been caused by different regional events. Within the cored interval (of that well) two sequence boundaries were distinguished, that both may equate to the unconformities. The first of them is visible at a depth of 952 m, the second one – at 922 m. According to our opinion, there are not arguments for determination of the boundary between Kimmeridgian and Valanginian sedimentary series, including such a great stratigraphic gap, just at the base of the core, at a depth of 958 m (Marek *et al.*, discussion – this volume; fig. 2). The spontaneous potential log shows no deflection at this interval, what may suggest a continuous sedimentation rather than an unconformity (compare figs. 38 and 43 in Dziadzio *et al.*, 2004). The lowest part of drillcore, including claystone and marly mudstone (bioclastic claystone), may correspond to the highstand system tract of underlying member. Sequence boundary (type 1), clearly developed on the logs at 952 m (lower gamma ray) is characterized by sedimentary change. Above this surface, a gradual increase of quartz sand and contents of limestone clasts are observed in fossiliferous marly mudstones and sandstones. It was interpreted as a lowstand system tract that includes abundant faunal remains on secondary deposit. To the top of the drillcore, there appears ooid grainstone with common authigenic minerals (glauconite) that would confirm a transgressive systems tract. Depositional sequences and their boundaries distinguished in the Białobrzegi IG 1 section correspond to those identified in the other well sections that are clearly visible and correlative. Barremian deposits have the same and characteristic log response within the whole studied area (compare with Gostynin IG 4 and Żychlin IG 3 sections; Dziadzio *et al.*, 2004; fig. 43). Because the interpretation of depositional sequences and boundaries using only log patterns is not accurate enough, we would like to present palaeontological evidence obtained during our studies that have inclined us to such an interpretation.

Stratigraphy of the Białobrzegi IG 1 section

We believe the comments by Marek *et al.* (discussion – this volume) about the ammonite fragments from the Białobrzegi IG 1 well cores allegedly misidentified as *Deshayesites* sp. are unfounded. The specimen has sigmoidally curved ribs (Dziadzio *et al.* 2004: fig. 7F), which is a diagnostic feature of that genus (Wright *et al.*, 1996). The ventral side is missing, so no inferences can be made about its morphology in the specimen in question. Therefore, it seems that there are no reasons to question the validity of its attribution to *Deshayesites* sp. Fragmentary *Dichotomites* ammonites from the depth of 952.1–952.9 m co-occur with such bivalves as: *Exogyra virgula* Defrance, *Cucullaea contracta* (Philips), labeled by Karczewski (1977) as Upper Jurassic species and treated as such also by the authors of the discussion paper. Because assemblages of microfossils and calcareous nannoplankton younger than the upper Valanginian occur in these strata, we assumed that the *Dichotomites* sp. has also been redeposited. Micropalaeontological samples were collected from the same rock fragments that contained *Dichotomites*, precluding the possibility of accidentally misplaced younger core fragments sampled. Occurrence of *Saynoceras verrucosum* and *Prodichotomites complanatus* in Krzyżanowice near Iłża is not a proof that similarly developed Upper Valanginian is present in the Białobrzegi IG 1 section.

A detailed revision of microfauna from the well Białobrzegi IG 1 pertained to the foraminiferal and ostracod assemblages occurring in sediments from the well preserved cores from the depth 958.5–924.0 m. This interval consists of marly, locally sandy mudstones and siltstones containing abundant macro- and microfossils. Micropalaeontological samples were thoroughly disaggregated and washed on nest of sieves (the finest one of which had a 75 μm mesh) allowing to retrieve more specimens, especially those with smaller shells. Species yet unnoticed and not recorded by Sztejn (1977) in the documentation of this well were obtained owing to this method. The documentation list of species presented by this author and considered as an index for the Valanginian and Lower Hauterivian include cosmopolitan foraminifers with wider stratigraphic ranges. Such species, as *Epistomina cretosa* Ten Dam, *Epistomina caracolla caracolla* (Koehen), *Lenticulina nodosa* (Reuss) and others are known also from the Barremian and Aptian. Thus, first occurrences of new species are crucial stratigraphic markers. The microfaunal assemblages from that core section, described in the paper discussed, contain index species for upper stages of the Lower Cretaceous. At a depth of 958.5 m there appears *Praedorothia* cf. *praeoxycona* (Moullade), recorded in the literature from Late Hauterivian, as well as

Barremian and Aptian (Holbourn & Kamiński, 1977). As mentioned in the discussed paper, a foraminiferal assemblage occurs in the 953.5–924.0 m depth range, clearly indicating the Upper Barremian–Lower Aptian. The index species include: *Gavelinella barremiana* Bettenstaedt, *Gyroidinoides* aff. *infracretaceus* Morozova, *Hedbergella infracretacea* (Glaessner), *Meandrospira washitensis* Loeblich & Tappan, *M. bancilai* Neagu, *Praedorothia* cf. *praeoxycona* (Moullade), and *Falsogaudryinella scherlocki* Bettenstaedt. The same age is suggested by the presence of *Verneuilinoides subfiliformis* Bartenstein (Dziadzio *et al.*, 2004; fig. 19J), that was also described from the deposits of the Gopło Member (Mogilno Formation) in Central Poland (Sztejn, 1984), as well as from the Barremian and Aptian strata in the Outer Carpathians (Geroch, 1966).

It should be noted that microfaunal assemblages similar to those from the Białobrzegi IG 1 cores, have been described from siliciclastic and carbonate deposits from the south-eastern part of the Lublin Upland. Olszewska (in: Gaździcka *et al.*, 2002) recognized the foraminiferal assemblages with *Heterohelix* and *Hedbergella* in thin sections of limestone assigned to the Cieszanów Formation. She interpreted this sequence as younger than the Hauterivian, and representing the stratigraphic interval including the Barremian or Aptian. Presence of planktonic foraminifers in marine sediments of the Early Aptian was also found in NW Germany (Rückheim & Mutterlose, 2001). The Early Aptian assemblages with small Tethyan hedbergellids, including *Hedbergella infracretacea* (Glaessner), indicate the first pulses of transgression of warm Tethyan waters into the epicontinental basins of Northern Europe. The Early Aptian foraminifers of Tethyan origin, identified in the sedimentary series within the Białobrzegi IG 1 section, can suggest their migration pathways.

Another challenge for the stratigraphy of the Białobrzegi IG 1 section is posed by the finding in samples from a depth of 1062.5 m (regarded by our opponents as definitely Kimmeridgian) of calcareous nannoplankton assemblages bearing such species, as: *Polycostella senaria* Thierstein, known from the Upper Tithonian and Berriasian of the Tethys (Bown & Cooper, 1999), and *Haqius circumradiatus* (Stover), appearing only as late as Berriasian (Bown *et al.*, 1999). This corroborates the conclusions achieved from the analysis of wire-line logs, namely that the interval 1107.0–958.0 m deep in the Białobrzegi IG1 section includes also sequences younger than the Kimmeridgian.

The calcareous nannoplankton assemblages from the sandy mudstones with *Dichotomites* ammonites, includes numerous warm-climate species common in the Tethyan province. Among them are nannoconids (*Nannoconus circularis*, *N. elongatus, N. inormatus* – species known since the Barremian), genus *Micrantholithus*, and *Watznaueria barnesae* (Black). They clearly indicate the directions of marine palaeocurrents which transported these planktonic organisms. Presence of *Farhania varolii* (Jakubowski) (known worldwide from the Lower Aptian; Bown *et al.*, 1999) in the same sample, suggests such an interpretation of the stratigraphic position of the discussed sequence. Even if this form was misidentified due to its resemblance to the *Eprolithus antiquus* Perch-Nielsen, known worldwide from the Hauterivian, there still remains the discrepancy with ammonites occurring in the same layer. Very abundant calcareous nannoplankton assemblages occur in sediments from a depth of 949.0 m, thus 3 m above the layer with *Dichotomites* ammonites, in the interval interpreted by Marek *et al.* as the Upper Valanginian. The taxonomic content of these assemblages differs from those associated with the ammonites. Even greater number of Tethyan species is notable, and appearance of the *Eprolithus floralis* (Stradner) and *E. apertior* Black, known from the Lower Aptian. This may document another transgression (cf. Dziadzio et al., 2004; fig. 44). Unfortunately, calcareous nannoplankton is missing from the uppermost part of the core.

We should stress that we do not question the orthostratigraphic importance of ammonites and in our published report they received priority treatment. However, regarding the comments about the importance of Tethyan (thermophilous) zoo- and phytoplankton species, we should assume that they appeared in the Polish Lowlands Basin rather later than earlier, compared to the Tethyan province. They indicate an opening of the basin towards the Tethys and reflect directions of palaeocurrents carrying these planktonic organisms.

REFERENCES

Bown, P. R., Rutledge, D. C., Crux, J. A. & Gallagher, L. T., 1999. Lower Cretaceous. In: Bown, P. R. (ed.), *Calcareous nannofossil biostratigraphy*. Kluver Academic Publishers, pp. 86–131.

Bown, P. R. & Cooper, M. K. E., 1999. Jurassic. In: Bown, P. R. (ed.), *Calcareous nannofossil biostratigraphy*. Kluver Academic Publishers, pp. 34–85.

Dadlez, R., 2001. Mid-Polish trough – geological cross-sections, 1:200 000. Państwowy Instytut Geologiczny. Warszawa.

Dadlez, R., Narkiewicz, M., Stephenson, R. A. & Visser, M. T., 1994. Subsydencja bruzdy śródpolskiej w permie i mezozoiku. (In Polish). *Przegląd Geologiczny*, 42: 715–720.

Dąbrowska, Z., 1983. Jura okolic Iłży. Paleontologia i stratygrafia jury i kredy okolic Iłży. *Materiały VII Krajowej Konferencji Paleontologów.* Iłża, 7-9 październik 1983, pp. 32–36.

Dziadzio, P., Gaździcka, E., Ploch, I. & Smoleń, J., 2004. Biostratigraphy and sequence stratigraphy of the Lower Cretaceous in Central and SE Poland. *Annales Societatis Geologorum Poloniae*, 74: 125–196.

Frakes, L. A. & Francis, J. E., 1988. A guide to Phanerozoic cold polar climates from high latitude ice-rafting in the Cretaceous. *Nature*, 333: 547–549.

Gaździcka E., Olszewska B., Smoleń J. & Połońska M., 2002. Wczesnokredowe baseny sedymentacyjne na Niżu Polskim; stratygrafia, paleogeografia i paleoekologia na podstawie badań mikropaleontologicznych i mikrofacjalnych. (In Polish). Centralne Archiwum Geologiczne, Warszawa, pp. 1–76

Geroch, S., 1966. Lower Cretaceous small Foraminifera of the Silesian series, Polish Carpathians. *Annales Societatis Geologorum Poloniae*, 36: 413–480.

Hakenberg, M. & Świdrowska, J., 1998. Evolution of the Holy Cross segment of the Mid-Polish Trough during the Cretaceous. *Geological Quarterly*, 42: 239–262.

Hakenberg, M. & Świdrowska, J., 1997. Propagation of the south-eastern segment of the Polish Trough connected with bounding fault zones (from Permian to the Late Jurassic). *C. R. Acad. Sci. Paris*, T. 324, série IIa: 793–803.

Hallam, A., 1992. *Phanerozoic Sea-level Changes*. Columbia University Press, New York. 266 pp.

Haq, B. U., Hardenbol, J. & Vail, P., 1988. Mesozoic and Cenozoic chronostratigraphy and eustatic cycles. In: Wilgus C. K. *et al.* (eds), *Sea-level changes: an integrated approach. Society of Economic Paleontologists and Mineralogists Special Publication*, 42: 71–108.

Holbourn, A. E. L. & Kaminski, M. A., 1997. Lower Cretaceous deep-water benthic foraminifera of the Indian Ocean (a synthesis of DSDP 7 and ODP material). *Grzybowski Foundation Special Publication*, 4: 1–172.

Karczewski, L., 1977. Fauna kimerydu. Białobrzegi IG 1. (In Polish). In: Krassowska, A. (ed.), *Profile głębokich otworów wiertniczych Instytutu Geologicznego*, 38: 88–89.

Kemper, E., 1987. Das Klima der Kreide-Zeit. *Geologische Jahrbuch* A, 96: 5–185.

Kutek, J., 2001. The Polish Permo-Mesozoik rift basin. In: Ziegler, P. A., Cavazza, W., Robertson, A. H. F. & Crasquin-Soleau, S. (eds), *Peri-Tethys Memoir 6: Peri-Tethyan rift/wrench basins and passive margins*. *Mémoires Museum Histoire Naturelle*, 186: 213–236.

Kutek, J. & Głazek, J., 1972. The Holy Cross area, Central Poland, in the Alpine cycle. *Acta Geologica Polonica*, 22: 603–653.

Marek, S., 1975. Kreda dolna. Bąkowa IG1. (In Polish). In: Niemczycka, T. (ed.), *Profile głębokich otworów wiertniczych Instytutu Geologicznego*, 26: 22–23, 66–67.

Marek, S., 1988. Palaeothickness, lithofacies and palaeotectonics of the epicontinental Lower Cretaceous in Poland. (In Polish, English summary). *Kwartalnik Geologiczny*, 32: 157–174.

Mutterlose, J. & Kessels, K., 2000. Early Cretaceous calcareous nannofossils from high latitudes: implications for palaeobiogeography and palaeoclimate. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 160: 347–372.

Niemczycka, T., 1975. Jura górna. Bąkowa IG 1. (In Polish). In: Niemczycka, T. (ed.), *Profile głębokich otworów wiertniczych Instytutu Geologicznego*, 26: 23–34, 53–59.

Pożaryski, W. & Brochwicz-Lewiński, W., 1979. On the Mid-Polish Aulakogen. *Kwaralnik Geologiczny*, 23: 271–290.

Pożaryski, W., Bielecka, W. & Sztejn, J., 1958. Stratygrafia rejonu Przytyk – Dęba pod Radomiem. (In Polish). *Instytut Geologiczny Biuletyn*, 126: 155–173.

Rückheim, S. & Muterllose, J., 2001. The Early Aptian migration of planktonic foraminifera to NW Europe: the onset of the mid-Cretaceous plankton revolution in the Boreal Realm. *Cretaceous Research*, 23: 49–63

Sztejn, J., 1977. Wyniki badań mikrofaunistycznych kredy dolnej. Białobrzegi IG 1. (In Polish). In: Krassowska, A. (ed.), *Profile głębokich otworów wiertniczych Instytutu Geologicznego*, 38: 93–95.

Sztejn, J., 1984. Late Lower Cretaceous microfauna of Polish Lowlands. *Prace Instytutu Geologicznego*, 101: 1–64.

Wright, C. W., Callomon, J. H. & Horwarth, M. K., 1996. Cretaceous Ammonoidea. In: Kaesler, R. L. (ed.), *Treatise on Invertebrate Paleontology*, Vol. 4, 362 pp.