Annales Societatis Geologorum Poloniae (2001), vol. 71: 43–51.

UPPER JURASSIC CHALKY LIMESTONES IN THE ZAKRZÓWEK HORST, KRAKÓW, KRAKÓW–WIELUŃ UPLAND (SOUTH POLAND)

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Krajewski, M., 2001. Upper Jurassic chalky limestones in the Zakrzówek Horst, Kraków, Kraków–Wieluń Upland (South Poland). *Annales Societatis Geologorum Poloniae*, 71: 43–51.

Abstract: Chalky limestones in the Zakrzówek Horst were laid down in small sponge-microbolite biostromes that provided stable foundation for the growth of extensive sponge-*"Tubiphytes"* biostromes forming the nodular limestones in the Zakrzówek area. The ammonites occurred in chalky limestones indicate that the studied deposits belong to the youngest palaeontologically documented Upper Jurassic limestones in the Kraków area (Planula zone). The vertical succession of fauna and facies characteristics indicate progressive shallowing of the environment at the end Oxfordian, from deeper shelf to shallower water.

Key words: Carbonate buildups, microfacies, background sedimentation rate, Upper Jurassic, Kraków, Southern Poland.

Manuscript received 28 February 2000, accepted 27 March 2001

INTRODUCTION

Chalky limestones are present in the Kraków Upland in only a few outcrops within the small tectonic element – the Zakrzówek Horst (Figs 1, 2). The rare occurrence of these limestones in the Kraków area is in clear contrast with the other areas of occurrence of Upper Jurassic rocks in Poland, where the chalky limestones are one of the dominant lithological varieties.

This paper presents the description of the lithology, facies and microfacies variation of the chalky limestones and their adjacent sediments. An attempt is also presented at the interpretation of the depositional environment of the chalky limestones.

GEOLOGICAL BACKGROUND

The studied area lies in the southern part of the Kraków–Wieluń Upland and from tectonic point of view it is a fragment of the Carpathian Foredeep (Rutkowski, 1993). Characteristic for the area are numerous horsts built mainly of Mesozoic rocks and surrounded by a system of faults; tectonic grabens are filled with Miocene clays (Fig. 1). The main faults in the Zakrzówek Horst are oriented SW–NE and NW–SE and have vertical displacements of ca. 200 m (Rutkowski, 1993). Besides the main faults the present author found smaller ones near Twardowski Rocks and Księża Hill; their amplitudes are from a few to nearly twenty metres (they are not shown in Figs 1, 2). Individual blocks between the faults are inclined at various angles, forming fault benches. So in the area of Twardowski Rocks the strata are inclined 3–5°, in the quarries Zakrzówek and Kapelanka they are nearly horizontal, while at Księża Hill, they dip at 20° SE (Gradziński, 1972). Moreover, Cretaceous abrasion surface and small tectonic grabens filled with Cretaceous marls are locally present.

The Zakrzówek Horst is built mainly of Oxfordian limestones which are up to 225 m thick. The limestones belong to the bedded facies (Dżułyński, 1952; Gradziński, 1972) and they include numerous nodules and flat lenses of chert. Four main lithological types may be distinguished in the exposed bedded limestones: micritic, chalky, nodular and dolomite-bearing granular ones; all these types form distinctive horizons in vertical sequence and their total thickness is ca. 40 m (Fig. 3). A part of the limestones was subject to early diagenetic dolomitization (Łaptaś, 1974) and to epigenetic silicification (Matyszkiewicz, 1987).

Chalky limestones are a subordinate lithological variety in the Kraków area, they belong to the facies variety of the bedded limestones, hence they are scarcely reported in publications (Krobicki, 1984; Matyszkiewicz, 1987, 1993). These papers, dealing with outcrops situated within the Zakrzówek Horst, are dedicated to other topics, hence they do not include a thorough discussion of the origin and depositional environment of the chalky limestones. The most complete description of these outcrops is included in the paper by Krobicki (1984) who found that the chalky lime-

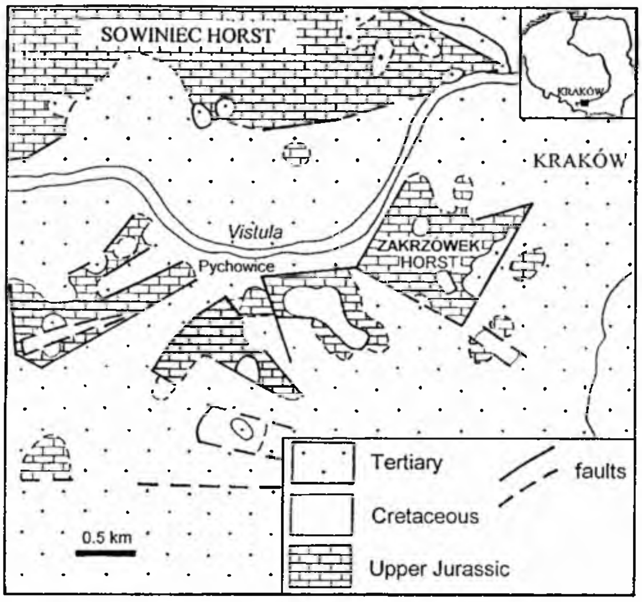

Fig. 1. Geological structure of the studied area (after Rutkowski, 1993, simplified)

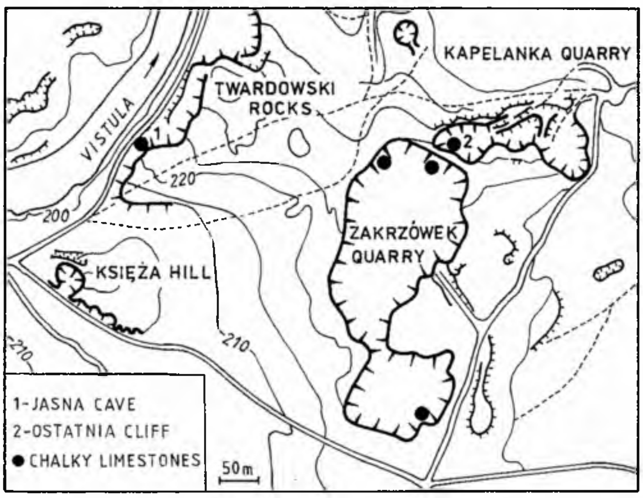

Fig. 2. Location sketch of the study area (names of exposures after Szelerewicz & Górny, 1986 and Król & Barabasz, 1997)

stones occur as lenses 4.0–4.5 m thick and ca. 4 m long. They are embedded in hard and compact bedded limestones. They include rich fauna, mostly sponges. Numerous are also brachipods, small ammonites, casts of pelecypods, crabs and gastropods. The bedding partly disappears within the lenses due to the nodular nature of the limestone. Bedding is marked by horizons of chert nodules and flat lenses. Krobicki (1984) distinguished three horizons of the chalky limestones in his generalised profile and described their lithology only in the lowest horizon. The two lowest horizons lie at the altitudes 168 and 190 m above sea level (calculated from an unpublished profile by M. Krobicki, 1984). They were exposed in the Zakrzówek Quarry which is now abandoned and its lower part is now flooded, together with the exposures of the two lowest horizons of the chalky limestones. The highest of the three horizons lies at an altitude of 210–220 m and this is described here.

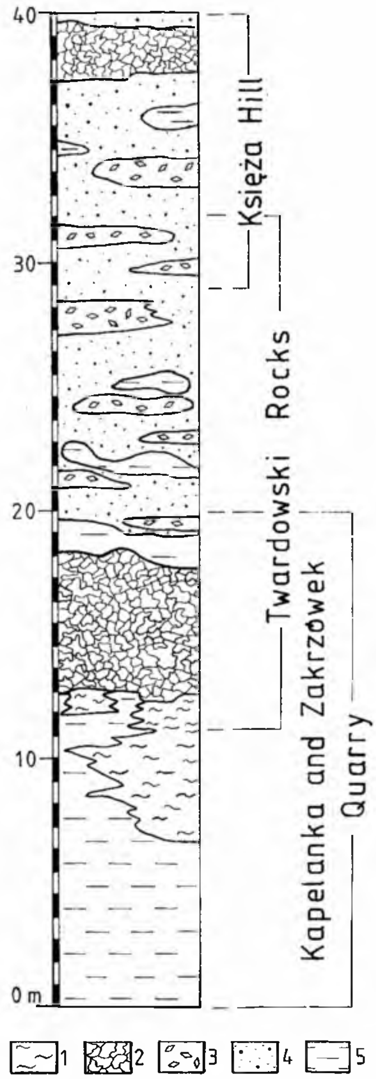

Fig. 3. Synthetic section of the sediments in the Zakrzówek Horst (without the older sediments, now under water). *1* – chalky limestones; *2* – nodular limestones; *3* – dolomites; *4* – granular limestones; *5* – micritic limestones

Matyszkiewicz (1987, 1993) in short comments on the chalky limestones from Zakrzówek points to the chaotic arrangement of cherts, as contrasted with their arrangement in parallel horizons in the bedded limestones. This author also suggests that the chalky limestones could correspond to local inhomogenities on the basin bottom, possibly related to the dense colonisation by benthos.

METHODS AND TERMINOLOGY

This study included field work and observation of thin sections under a polarising microscope. The field work included detailed mesoscopic study, vertically and laterally, of the chalky limestones and the compact limestones near the Jasna nad Wisłą Cave (Jasna Cave in short; name after Szelerewicz & Górny, 1986; Figs 2, 4), in Ostatnia Cliff (Figs 2, 5; name after Król & Barabasz, 1997) and the Zakrzówek Quarry (Fig. 2). The observations were also car-

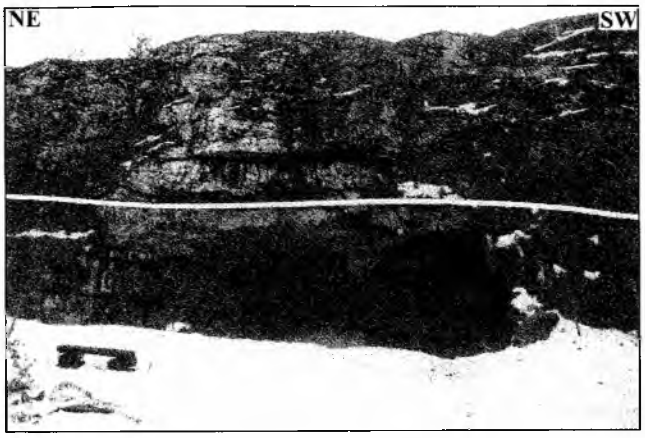

Fig. 4. Jasna Cave. The entrance is situated in chalky limestones passing upwards to nodular limestones; the white line shows chalky/nodular limestones boundary

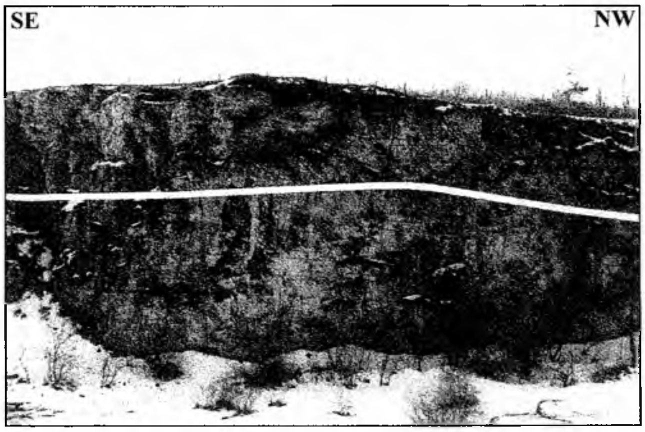

Fig. 5. Ostatnia Cliff. Lenses of chalky limestones are present in the central part and they pass upwards to nodular limestones; the white line shows chalky/nodular limestones boundary

ried out within the massif in numerous caves whose total length attains ca. 1 km (A. Górny pers. commun., 1999). Because of the monotonous lithology of the chalky limestones and the difficult access to the outcrops, the detailed descriptions are provided only for the exposure in the Jasna Cave and in Ostatnia Cliff. A tentative name "chalky limestone horizon" has been accepted for the chalky limestones and other sediments at the same stratigraphical level. A total of 130 samples were collected and thin sections for microscopic study were made of them. The other parts of the studied outcrops were studied in detail mesoscopically. The study included also the limestones directly below and above the chalky limestones horizon. During the laboratory study, microfacies types were described according to the classification and terminology by Wright (1992) which in turn is based on that by Dunham (1962) and its later modification (Embry & Klovan, 1972).

CHALKY LIMESTONES

A total of eight exposures of chalky limestones have been found; four in the western, northwestern and southern walls of abandoned and partly drowned Zakrzówek Quarry (Fig. 2), three in abandoned Kapelanka Quarry in its fragment known as Ostatnia Ścianka (Figs 2, 5) and one at the entrance to the Jasna Cave (Figs 2, 4). All outcrops are situated at similar altitudes (210–220 m) and they make up the highest horizon of the chalky limestones.

Jasna Cave

The cave is situated in the Twardowski Rocks park, in a wall of an old quarry facing the Vistula River (Figs 2, 4). The exposed chalky limestones form a lens within hard, bedded limestones. The height and width of the lens are from a few to nearly twenty metres and its precise boundary is difficult to delineate. Laterally, the chalky limestones pass gradually into the harder, bedded limestones. They are light cream in colour; they smear fingers when touched. The bedding surfaces are not as distinct as in typical bedded limestones; they locally disappear and are marked only by the arrangement of cherts. Some of the cherts are arranged chaotically. Most of them do not exceed 8 cm in diameter. Their nuclei often include fragments of sponges and brachiopods. Fauna is abundant, represented mainly by sponges, brachiopods, gastropods, ammonites (see also section Stratigraphy) and belemnites. Among the brachipods the most common are *Dictyothyropsis* cf. *loricata*, *Sellithyris* sp., *Lacunosella cracoviensis* (Quenstedt) and *Septaliphoria* cf. *astieriana* (d'Orbigny), (M. Krobicki, pers. commun., 1999; cf. Müller *et al.*, 2000). The interiors of some brachiopod shells are not completely filled with sediment. Sponges occur in life position as well as redeposited. In the lower and middle parts of the lens they are hexactinellids with widely varying forms – from calices to narrow tubes. The sponge diameters vary from 2 to 10 cm.

Microfacies in the lower parts of the lens are boundstone and wackestone (Figs 6, 7). The boundstone is composed of numerous pure clotted thrombolite (cf. Schmid, 1996; Leinfelder *et al.*, 1996) encrusted with abundant serpules. Numerous growth voids and burrows are present, geopetally filled with internal sediment composed exclusively of peloids. The voids are less than 3 mm across. Fragments of siliceous sponges and echinoderm plates are also present.

Wackestone and boundstone (Figs 6, 7) predominate in the middle part of the lens. They are strongly differentiated and are mainly pure leiolite, layered leiolite (term after Braga *et al.*, 1995; cf. Leinfelder *et al.*, 1996; Riding, 2000) and micritic stromatolites, developed on sponge surfaces and poorly structured thrombolites. Fragments of siliceous sponges encrusted with serpules are also common.

In the upper parts of the lens, hexactinellids spoges are partly replaced by lithistids sponges, densely packed in sediment. They are accompanied by nektonic fauna, mainly ammonites and belemnite fragments. The ammonites include specimens 4–12 cm in diameter, preserved complete or in large fragments, many of them incompletely filled with sediment. The fossils do not display important deformations. All fossils are strongly lithified and embedded in soft sediment. The degree of compactness of the sediments and

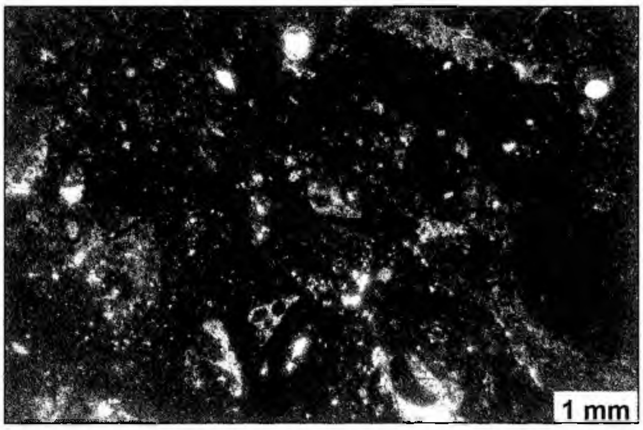

Fig. 6. Thrombolitic boundstone; chalky limestones, Jasna Cave

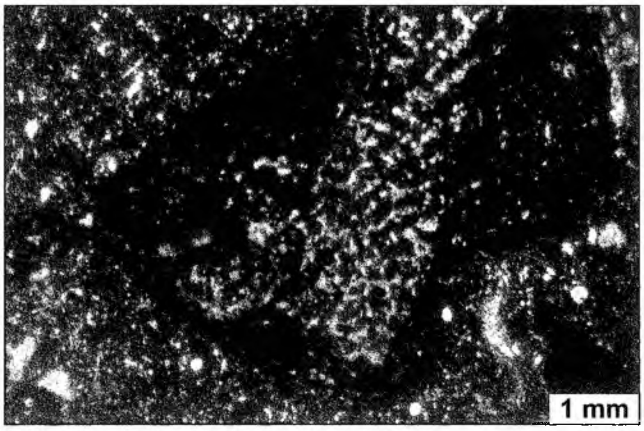

Fig. 7. Boundstone. Siliceous sponge overgrown with microbolites; chalky limestones, Jasna Cave

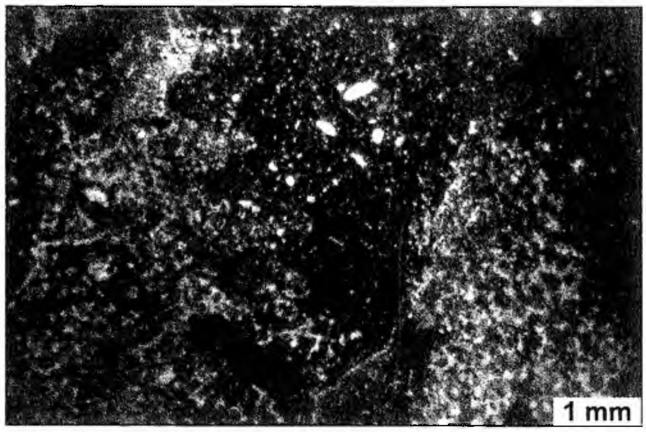

Fig. 8. Boundstone-bafflestone, locally wackestone. A fragment of siliceous sponge with numerous leiolites; nodular limestones, Ostatnia Cliff

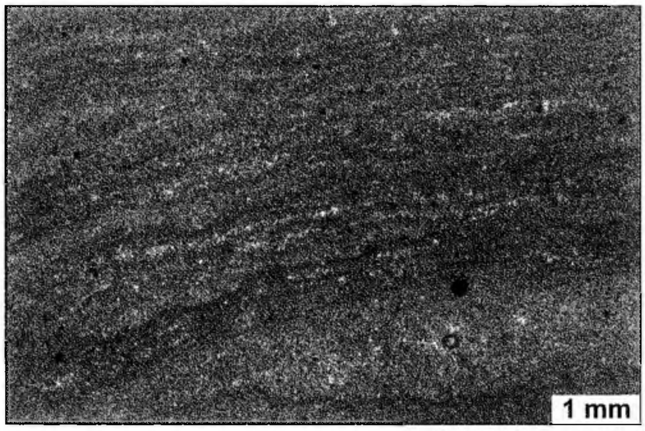

Fig. 9. Boundstone micritic stromatolites. Zakrzówek Quarry

the abundance and diversity of fauna increase from the assumed centre of the lens towards its margins.

Microbolites are less common in the upper part of the lens and these are mainly single pure leiolites on sponge outer surfaces. The sediment is mainly bafflestone-boundstone and wackestone-floatstone, less commonly packstone. The main components are fragments of calcareous and siliceous sponges and *"Tubiphytes" morronensis* (cf. Schmid, 1995, 1996) who are up to 0.8 mm across. The other components include gastropods, echinoderms, brachiopods, *Terebella lapilloides* and numerous unidentifiable bioclasts.

Ostatnia Cliff

This exposure is situated at the western end of the abandoned quarry Kapelanka (Figs 2, 5). Ostatnia Cliff is 20 m high and 35 m long. The chalky limestones are exposed here in yellowish lenses a few metres thick and long. They are best visible in places from which rocks have fallen recently. In other places the chalky limestones are similar at surface to the typical hard, bedded limestones and only when struck with hammer they disintegrate into soft debris. They smear fingers upon touching, but are somewhat harder then the chalky limestones from the Jasna Cave. They include cherts only sporadically, and these do not exceed 6 cm in size. Fauna is frequent but less diversified than in the Jasna Cave.

Among the mesoscopically discernible faunal components, the most common are lithistid sponges, less common are hexactinellide sponges, brachiopods (mainly terebratulids).

The microfacies is mostly wackestone and bafflestone-boundstone. The lower parts of the lenses contain numerous poorly structured thrombolites and single pure leiolites on surfaces of numerous tuberoids built of fragmented siliceous sponges. The upper parts of the lenses include numerous *"Tubiphytes" morronensis* with diameters of 0.8 mm and calcareous sponges, while the numbers of leiolites and thrombolites decrease.

ENCOMPASSING SEDIMENTS OF THE CHALKY LIMESTONES

In the exposures in the Jasna Cave and in Ostatnia Cliff the chalky limestones pass laterally into compact bedded limestones (Figs 4, 5) whose microfacies is wackestone. Fauna includes small bioclasts of undetermined nature and fragments of echinoderms, brachiopods and *"Tubiphytes"*

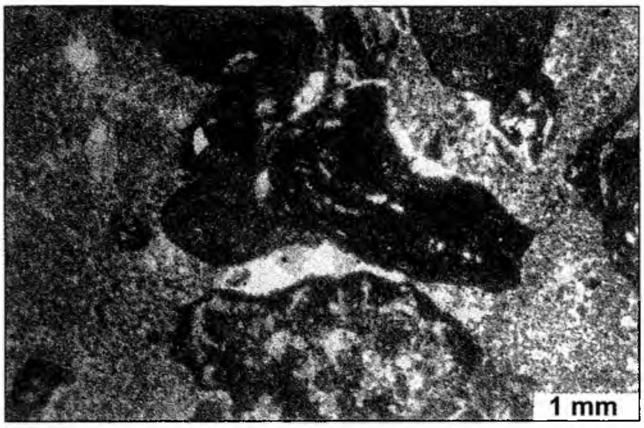

Fig. 10. Wackestone – floatstone with *"Tubiphytes" morronensis*; Księża Hill

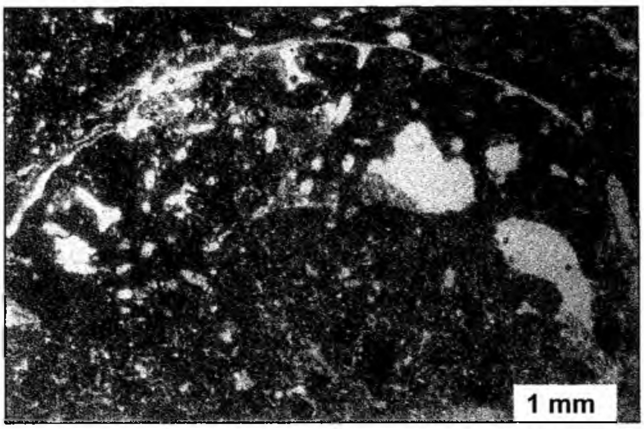

Fig. 11. Wackestone – floatstone with *Lithocodium aggregatum*; Księża Hill

morronensis embedded in micritic matrix. *"Tubiphytes" morronensis* occur as branching and ovate forms, 0.5–0.8 mm across. Common are siliceous sponges up to 15 cm across and poorly structured thrombolites binding the sediment.

Below the chalky limestones horizon lies a horizon of micritic limestones with scarce fauna (cf. Peszat, 1991). They are more compact than the sediment in the chalky limestone horizon. The dominant microfacies is wackestone, sporadically mudstone built of predominant peloids, few tuberoids and less numerous boundstones, those built mainly micritic stromatolites, forming flat and dome-like forms, and of few layered leiolites.

The micritic limestones are overlain with the described chalky limestone horizon. The proportion of microbolites in the sediment increases in the transitional zone between the two horizons. These are mainly poorly structured thrombolites, less commonly micritic stromatolites. The chalky limestone horizon is 7 m thick on average and it is distinguished by the abundance of benthic and nektonic fauna. The horizon includes the chalky limestone lenses described above. The chalky limestone lenses usually pass upwards into nodular limestones (Figs 3, 8), sponge-microbolite and sponge-*"Tubiphytes" morronensis*, build mostly of siliceous and calcareous lithistid sponges successively overgrown upwards. Microfacies of the nodular limestones are mostly boundstone-bafflestone and wackestone and in most parts have the same lithology as the chalky limestones. These limestones include common peloidal stromatolites and less common micritic ones which include small growth voids and poorly structured thrombolites. Common are *"Tubiphytes" morronensis* 1 mm across and *Terebella lapilloides*, brachiopods (mostly terebratulids) and numerous unidentifiable bioclasts.

Fig. 12. Nodular biostromes with columnar stromatolites. Księża Hill

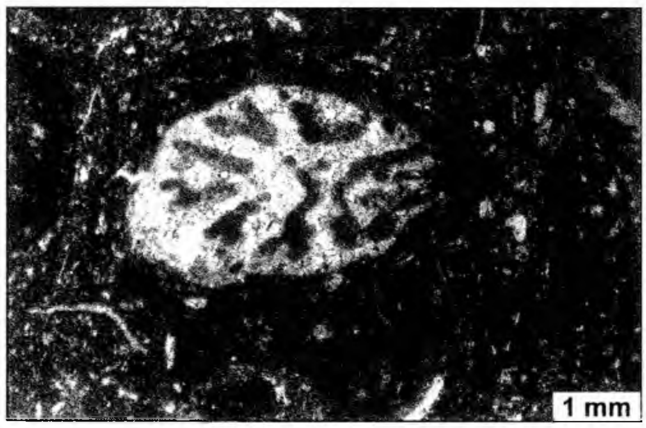

Fig. 13. Floatstone – wackestone with scleractinian coral (fragment of colony? pers. commun. E. Morycowa, B. Kołodziej, 2001); Księża Hill

Above the horizon of nodular limestone lies a horizon built mainly of stromatolites (Fig. 9) which is ca. 1 m thick in Zakrzówek Quarry. Mesoscopically these are hard limestones with conchoidal fracture, resembling micritic limestones. The forms and internal structures of these stromatolites differ from those described earlier from Zakrzówek. In

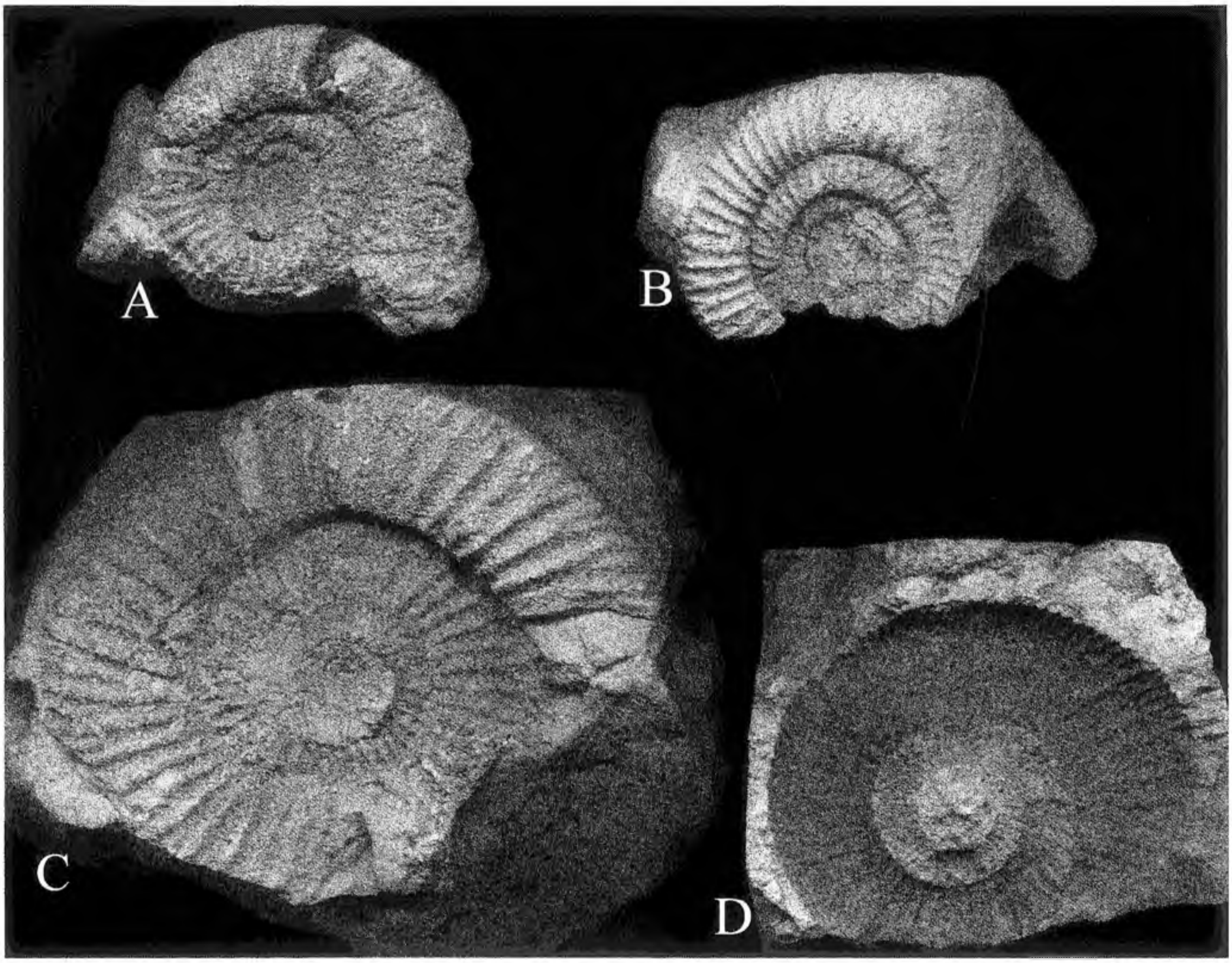

Fig. 14. Ammonites collected in the Jasna Cave and used for biostratigraphy. A, B – *Idoceras (Subnebrodites)* sp., C – *Idoceras (Subnebroidites) proteron* Nitzopoulos, D – *Orthosphinctes* sp. (imprint); (personal communication by B. A. Matyja, 1999). All specimens in natural size

the Zakrzówek quarry these are micritic stromatolites with darker and lighter bands. The stromatolites are up to 10 cm thick and extend laterally up to several tens of centimetres.

Above the "stromatolite" horizon, there appear numerous horizons of grainstones (packstone-grainstone-rudstone) which in some parts were partly or even completely dolomitized. The sediments between the grainstones are developed as wackestones and floatstones with numerous *"Tubiphytes" morronensis* up to 1.2 mm across (Fig. 10), *Lithocodium aggregatum* (Fig. 11; cf. Schmid & Leinfelder, 1996; Kołodziej, 1997), calcareous sponges, agglutinating and peloidal stromatolites. The stromatolites have columnar forms, up to 5 cm across and up to 15 cm high (Fig. 12). Scleractinian corals (Fig. 13; fragment of colony?; E. Morycowa, B. Kołodziej, pers. commun., 2001) occur sporadically.

The same sediments at Księża Hill include forms resembling erosional channels filled with grainstones (rudstone-grainstone), built mainly of ooids and oncoids of II and IV type (cf. Dahanayake, 1977) and intraclasts, often with graded bedding. The grainstones are in places bound by single pure leiolites.

STRATIGRAPHY

Biostratigraphic attribution of the studied deposits was established on the base of ammonites collected in the Jasna Cave, i.e. in the lower part of the Zakrzówek Horst section (Fig. 3), ca. 190–200 m above the base of the Oxfordian. Twenty fragments of ammonites were collected, of which four were determined as *Orthosphinctes* sp., *Idoceras (Subnebrodites) proteron* Nitzopoulos and two as *Idoceras (Subnebrodites)* sp. (Fig. 14). They indicate that the studied deposits belong to the Planula zone, Planula subzone, proteron horizon (B. A. Matyja, pers. commun., 1999), hence these are the youngest palaeontologically documented Upper Jurassic deposits in the Kraków area. Taking into account the minimal sedimentation rate of the chalky limestones and the stratigraphical condensation of the Upper Jurassic deposits in the Kraków area, relative to the areas of the Upland situated farther to the north, it seems likely that the deposits in the middle and upper parts of the Zakrzówek section belong to still younger zones of the Upper Jurassic (Krajewski & Bajda, in press; cf. Matyszkiewicz, 1997)[1].

DEPOSITIONAL ENVIRONMENT

The chalky limestones differ markedly from the surrounding typical compact bedded limestones. The differences consist mainly in greater diversity of benthic and nektonic fauna and lower compactness in the chalky limestones.

The described lenses of chalky limestones were laid down as small sponge-microbolite biostromes (cf. Leinfelder *et al.*, 1996) passing upwards into sponge biostromes (autoparabiostrome - autobiostrome; cf. Kershow, 1994; Figs 3, 4, 5) with numerous *"Tubiphytes" morronensis* and microbolites, forming nodular limestones in the area of Zakrzówek.

The environment of deposition of the sponge-microbolite biostromes remains open to discussion. The sponge-microbolite bioconstruction are usually related to deep shelf environment with minimal rate of deposition, variable or small supply of nutrients in the marginal parts of the so called "reef window" (Leinfelder *et al.*, 1996; Leinfelder & Nose, 1999). The main components of sediments at Zakrzówek are thrombolites, subordinate are stromatolites and leiolites, siliceous and calcareous sponges and *"Tubiphytes" morronensis*.

The chalky limestones include a broad variety of sponges. Their frequency and diversity are at maximum in the central parts of the chalky lenses. Hexactinellids dominate in the lower parts of the lenses, gradually replaced upwards by lithistids. Calcareous sponges appear in great numbers in the upper parts. The studies in other areas indicate that such a sequence reflects a shallowing trend (cf. Trammer, 1982, 1989; Leinfelder *et al.*, 1993, 1994, 1996; Keupp *et al.*, 1996). The depositional environment of the buildups made up of hexactinellids and lithistids with thrombolites was one of lower shelf, ca. 100 m deep (cf. Pratt, 1995; Leinfelder *et al.*, 1994, 1996) or deeper (cf. Pisera, 1998).

Microbolites are common in the limestones in Zakrzówek Horst. However, they are not very useful for interpretation of depositional environment. Microbolites could form at various depths, levels of water energy, salinities and degrees of aeration. The studied sediments commonly include thrombolites and micritic stromatolites which indicate a low-energy environment with low sedimentation rate (cf. Keupp *et al.*, 1993; Leinfelder *et al.*, 1993, 1996; Schmid, 1995, 1996; Dupraz & Strasser, 1999; Leinfelder & Schmid, 2000; Riding, 2000).

"Tubiphytes" morronensis are common in the Zakrzówek area in the middle and upper parts of the section. They occur in various forms, mostly ovate, less commonly branching, depending on the firmness of substratum (cf. Schmid, 1995). The diameter of the outer tests of *"Tubiphytes" morronensis* increase in thickness upwards in the section. This indicates changes in availability of light, related to either shallowing or decreasing turbidity (cf. Leinfelder *et al.*, 1996; Krajewski, 2000). In the case of the limestones observed at Zakrzówek both factors seem important. In the upper parts of the section *"Tubiphytes" morronensis* often occur together with *Terebella lapilloides* in the *Terebella-"Tubiphytes"* association, widely described in the literature (cf. Leinfelder *et al.*, 1993, 1996; Schmid, 1995, 1996; Dupraz & Strasser, 1999). According to them, the occurrence of this community in shallow water setting indicates poor oxygenation. The depth of deposition of this association was probable several tens of metres (cf. Leinfelder *et al.*, 1993, 1994, 1996) in a high mesotrophic environment (cf. Dupraz & Strasser, 1999). In the uppermost parts of the section at Zakrzówek *"Tubiphytes" morronensis* often occur together with *Lithocodium aggregatum* and the thickness of the *"Tubiphytes" morronensis* outer walls attains 1.2 mm, indicating low mesotrophic or oligotrophic environment of a few to less than twenty metres deep (cf. Schmid, 1995; Leinfelder *et al.*, 1996; Schmid & Leinfelder, 1996; Dupraz & Strasser, 1999; Krajewski, 2000).

CONCLUSION

The basic components and their succession indicate that in the initial stage of formation of the sponge-microbolite biostromes (chalky limestones), the depth was about 100 m or more, and that at the end of their deposition the depth could be of a few tens of metres. The sediments found higher in the section could be laid down in an even shallower environment.

The occurrence of relatively infirm sponge-microbolite biostromes (chalky limestones) beneath similar in structure but more compact sponge biostromes with numerous *"Tubiphytes" morronensis* and microbiolites (nodular limestones) reflects a change in depositional environment. The sponge-microbolite biostromes formed on deep shelf, below the storm wave base in a low-energy environment. Sponges growing loose in sediment (cf. Trammer, 1985) did not develop a rigid framework typical of carbonate buildups in the Kraków area (Matyszkiewicz & Krajewski, 1996; Matyszkiewicz, 1997), but only an initially lithified construction. On the other hand, the sponges in the biostromes with *"Tubiphytes" morronensis*, growing in a shallower environment, were overgrowing one another and formed a structure resistant to erosion.

Acknowledgements

The author thanks J. Matyszkiewicz and G. Haczewski for critical remarks on the earlier drafts of this paper, anonymous Reviewer and B. Kołodziej for theirs suggestions, B. A. Matyja for

1 After final preparation of the present paper an ammonite *Pictonia albinea* Oppel was found at the chalky/nodular limestones boundary (cf. Figs 3, 4), which indicates the lowermost Platynota zone (lowermost Kimmerydgian; G. Schweigert, pers. commun., 2001). The ammonite will be discussed in the next publication.

determination of the ammonites, M. Gradziński and A. Górny for discussion, M. Krobicki for providing access to his Master thesis and for discussion, E. Morycowa and B. Kołodziej for determinatoion of the coral and M. Kuśmierek and T. Bartuś for assistance in material collection. This work was funded as AGH project 11.140.54.

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Streszczenie

GÓRNOJURAJSKIE WAPIENIE KREDOWATE ZRĘBU ZAKRZÓWKA W KRAKOWIE, WYŻYNA KRAKOWSKO-WIELUŃSKA, POŁUDNIOWA POLSKA

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W pracy przedstawiono wyniki badań górnojurajskich wapieni kredowatych zrębu Zakrzówka (Fig. 1, 2, 3). Szczegółowe badania makroskopowe, mikrofacjalne objęły dwa stanowiska. Pierwsze stanowisko znajduje się w otworze Jaskini Jasnej nad Wisłą (w skrócie Jasnej; Fig. 2, 4). Drugie stanowisko znajduje się we fragmencie ściany o nazwie Ostatnia Ścianka (Fig. 2, 5). Badania przeprowadzone zostały również w osadach sąsiadujących z wapieniami kredowatymi.

Stratygrafia została ustalona na podstawie amonitów zebranych w niższej części profilu Zakrzówka (Fig. 3) w jaskini Jasnej wskazujących na przynależność wapieni kredowatych do poziomu Planula, podpoziomu Planula horyzontu Proteron (Fig. 14; inf. ustna B. A. Matyja, 1999).

W Jaskini Jasnej (Fig. 2, 4) odsłaniające się wapienie kredowate tworzą soczewkę wśród twardych typowych wapieni uławiconych. Licznie występuje fauna, głównie gąbki, ramienionogi, ślimaki, oraz amonity i belemnity. W dolnych i środkowych partiach wapieni kredowatych obserwuje się Hexactinellida wykazujące duże zróżnicowanie w morfologii od form w kształcie kielichów do form w kształcie wąskich rurek. W wyższych partiach soczewki Hexactinellida zastępowane są przez Lithistida. Wszystkie skamieniałości są silnie zlityfikowane i tkwią w miękkim kredowatym osadzie.

Pod względem mikrofacjalnym dolne partie soczewki wykształcone są jako biolityty (boundstone) oraz waki (wackestone). W środkowych partiach soczewki dominują waki (wackestone) oraz biolityty (boundstone; Fig. 6, 7). W górnych partiach soczewki osad wykształcony jest głównie jako biolityt (bafflestone-boundstone) oraz waki (wackestone-floatstone), rzadziej jako mikrytowy ziarnit (packstone).

Na Ostatniej Ściance (Fig. 2, 5) najczęściej obserwuje się gąbki z rodzaju Lithistida rzadziej Hexactinellida, ramienionogi głównie terebratule. Pod względem mikrofacjalnym wykształcone są jako waki (wackestone), oraz biolityty (bafflestone-boundstone).

Lateralnie wapienie kredowate przechodzą płynnie w zwięzłe wapienie uławicone (Fig. 4, 5). Ku górze najczęściej soczewki wapieni kredowatych jak i inne wapienie z tego poziomu zastępowane są przez gruzłowate wapienie gąbkowo-tubiphytesowe zbudowane głównie z gąbek krzemionkowych i wapiennych Lithistida (boundstone - bafflestone - wackestone; Fig. 8) i w większości partii wykazują podobne wykształcenie strukturalne jak wapienie kredowate. Ponad wapieniami gruzłowatymi występuje poziom zbudowany głównie ze stromatolitów (Fig. 9) oraz poziom ziarnitów (packstone -grainstone - rudstone; Fig. 3), które w pewnych partiach uległy częściowej bądź całkowitej dolomityzacji. Pomiędzy ziarnitami osady wykształcone są jako waki (wackestone-floatstone) z *"Tubiphytes" morronensis* i *Lithocodium aggregatum* (cf. Schmid, 1995; Schmid & Leinfelder, 1996; Kołodziej, 1997; Fig. 10, 11).

Na podstawie przeprowadzonych badań stwierdzono, iż opisywane soczewki wapieni kredowatych są to niewielkie biostromy gąbkowo-mikrobolitowe (por. Leinfelder *et al.*, 1996) przechodzące ku górze w biostromy (por. Kershow, 1994; Fig. 3) gąbkowe z licznymi *"Tubiphytes" morronensis* i mikrobolitami tworzącymi w rejonie Zakrzówka wapienie gruzłowate.

Dyskusyjnym problemem jest środowisko sedymentacji biostrom gąbkowo-mikrobialnych i biostrom gąbkowych z *"Tubiphytes" morronensis* w których głównymi komponentami są trombolity, rzadziej stromatolity i leiolity, gąbki krzemionkowe oraz wapienne i *"Tubiphytes" morronensis*. Biorąc pod uwagę sukcesję fauny oraz niewielką miąższość wapieni kredowatych, można stwierdzić, iż środowisko sedymentacji wapieni ulegało zmianom, które były związane ze spłycaniem zbiornika na przełomie oksfordu i kimerydu. Podstawowe komponenty i ich następstwo wskazuje iż, w początkowej fazie tworzenia się wapieni kredowatych głębokość wynosiła około 100 m lub głębiej, a pod koniec ich sedymentacji mogła wynosić około kilkudziesięciu metrów.

Różnice w zwięzłości podobnie wykształconych kredowatych biostrom gąbkowo-mikrobolitowych i gąbkowych biostrom gruzłowatych z *"Tubiphytes" morronensis* prawdopodobnie mogą odzwierciedlać zmianę warunków środowiskowych. Biostromy kredowate rozwijały się w głębszym szelfie poniżej sztormowej podstawy falowania w środowisku spokojnym. Gąbki tkwiąc w stanie luźnym zagłębione w osadzie (por. Trammer, 1985) nie rozwinęły sztywnej konstrukcji typowej dla budowli węglanowych a jedynie konstrukcję inicjalnie zlityfikowaną. Natomiast gąbki biostrom gruzłowatych rozwijające się w środowisku płytszym narastały kolejno na sobie i tworzyły zwięzłą konstrukcję.