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LITHOLOGY AND MORPHOLOGY OF UPPER JURASSIC CARBONATE BUILDUPS IN THE BĘDKOWSKA VALLEY, KRAKÓW REGION, SOUTHERN POLAND

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Abstract: Upper Jurassic limestones exposed in the Będkowska Valley form an extensive complex of carbonate buildups of microbolite-sponge and microbolite-*Tubiphytes* reef-like bioherms, in which the main rock-building material are packstone and grainstone bound by microbolite structures. Horizontal discontinuity surfaces locally found in massive limestones are of sedimentary origin and are related to sediment gravity flows from the higher parts of the buildups.

Two basic morphological types of carbonate buildups are distinguished in the vertical sequence of studied sediments: (i) one or a couple of large buildups forming a continuous biolitite cover with one type of sediment prevailing over a wide area in the lower part and passing upwards to (ii) numerous small buildups separated by depressions filled with packstone and grainstone formed from erosion of the buildups. The smaller, younger buildups were subject to early cementation which led to formation of extensive constructions.

Abstrakt: Górnojurajskie wapienie Doliny Będkowskiej tworzą rozległy kompleks budowli węglanowych typu bioherm mikrobolitowo-gąbkowych i mikrobolitowo-Tubiphytesowych bioherm rafopodobnych, w których podstawową rolę skałotwórczą odgrywają ziarnity wiązane przez struktury mikrobolitowe. Poziome powierzchnie nieciągłości obserwowane niekiedy w wapieniach masywnych posiadają genezę sedymentacyjną związaną z drobnodetrytycznymi spływami z wyższych partii budowli.

W badanych osadach można wydzielić dwa podstawowe typy morfologiczne budowli: (i) rozwinięte jako jedna lub kilka dużych budowli tworzących zwartą pokrywę biolitytową charakteryzującą się szerokim rozprzestrzenieniem jednego typu sedymentacji, (ii) oraz liczne ale niewielkie budowle, między którymi, w nieckach, osadzały się ziarnity pochodzące z erozji tych budowli. Budowle te wraz z otaczającymi je ziarnitami uległy wczesnej cementacji tworząc większe, złożone konstrukcje.

Key words: carbonate buildups, microfacies, Upper Jurassic, Kraków region, Southern Poland.

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INTRODUCTION

The Upper Jurassic sediments in the Kraków region, that is in the southern part of the Kraków–Wieluń Upland (Fig. 1), differ in their facies from those exposed farther to the north. They are thinner and dominated by massive limestone facies, so called rocky limestone. The reason for this difference is the relative elevation of the Kraków region with respect to the surrounding areas of deposition, attributed to the incomplete compensation of sedimentation by subsidence (Kutek, 1994). It is because of this elevated position that the Kraków region was especially favourable for the growth of carbonate buildups (Dżułyński, 1952; Matyszkiewicz & Krajewski, 1996; Matyszkiewicz, 1997a).

This paper presents the lithology, facies and microfacies of the Upper Jurassic carbonate buildups in the Będkowska Valley. It discusses also the origin of horizontal discontinuity surfaces in rocky limestones and a reconstruction of the changing sedimentary environment.

The studied area lies in the middle part of the valley, near Będkowice village (Fig. 2). Numerous crags and cliffs are present in this part of the valley and three of them have been selected for detailed study (Fig. 3, 4, 5). The first is Turnia Lipczyńskiej (22 m high and 15 wide) and the second is Dupa Słonia (25 m high and 74 m wide; names after Czajka, 1995; Drobot & Król, 1996), less known as Szeroka Turnia (J. Baryła, personal information, 1999). The third is Sokolica (70 m high and 250 m wide; name after Gradziński *et al.*, 1994; Czajka, 1995; Król, 1997).

METHODS

The study included field work, study of thin sections and polished sections under a microscope and semiquantita-

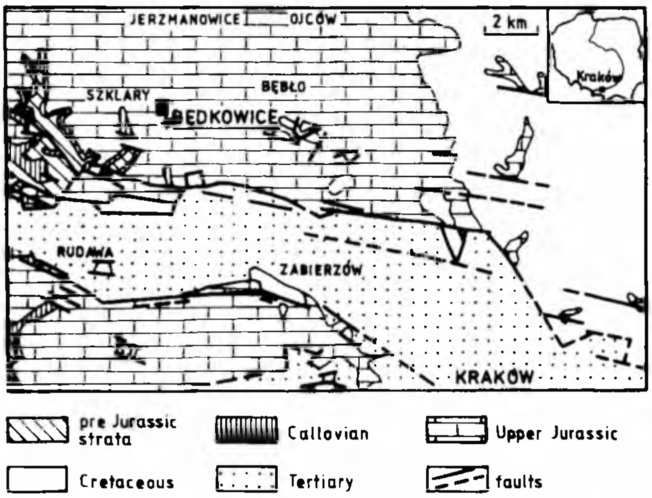

Fig. 1. Location of the study area (after Gradziński, 1972 and Rutkowski, 1989, simplified). The black rectangle shows location of Fig. 2

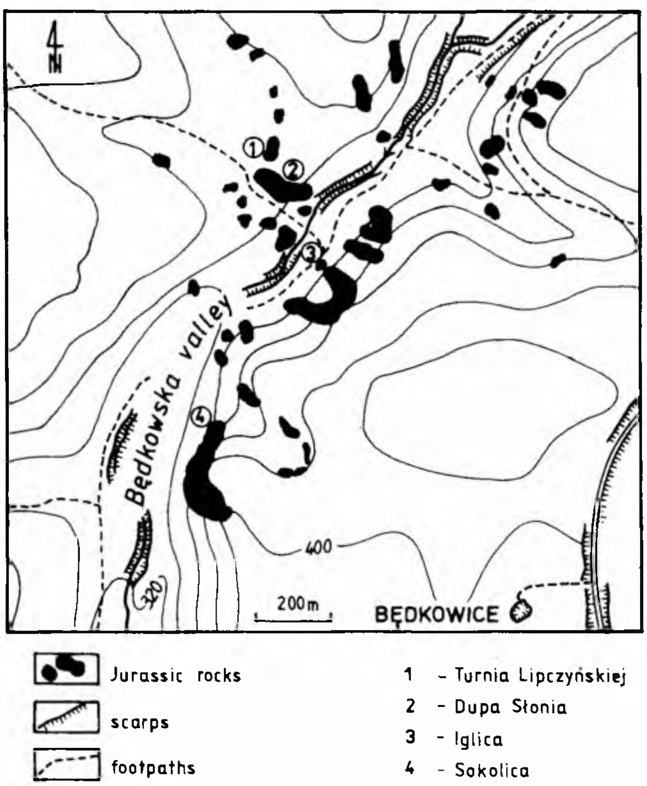

Fig. 2. Study area (names of crags after Gradziński *et al.*, 1994; Czajka, 1995; Drobot & Król, 1996; Król, 1997)

tive analysis of components in the crags of the Będkowska Valley. The field work included detailed study of vertical sections on the Turnia Lipczyńskiej, Dupa Słonia and Sokolica. A total of 72 oriented samples were collected: 14 from Turnia Lipczyńskiej, 15 from Dupa Słonia and 43 from Sokolica (Figs. 3, 4, 5). Fifty nine oriented thin sections were made from these samples and 49 polished sections. The laboratory studies included semiquantitative analysis of the frequency of each microfacies type according to Dunham (1962), with modifications by Embry & Klovan (1972) and Wright (1992). Other parts of the studied sections and crags and cliffs were studied macroscopically in detail. Numerous macroscopic observations have been also done on Iglica (Figs. 2, 6).

Fig. 3. Location of samples taken at Turnia Lipczyńskiej. The crag is 22 m high

MACROSCOPIC DESCRIPTION OF THE DESCRIBED EXPOSURES

Turnia Lipczyńskiej, Dupa Słonia, Iglica and Sokolica are built of strongly lithified massive limestone, light-cream in colour, of grainy or conchoidal fracture. Fauna in the limestone in Turnia Lipczyńskiej, Dupa Słonia and Iglica includes brachiopods, echinoderms, sponges with serpules and sporadic gastropods. The fauna are usually preserved complete or as large bioclasts. Most sponges are in form of calices. The most common among brachiopods are chaotically distributed thin-shelled forms. Stromatolithic are common and they occur in a variety of forms, from dome-like, columnar to planar. Common are intraclasts and small voids filled with internal sediment or sparite cement. Locally occurs packstone with small proportion of bioclasts, mainly fragments of brachiopods and echinoderm plates. Besides the vertical and inclined joints, typical of the massive limestone of the area, horizontal fractures resembling stratifica-

Fig. 4. Location of samples taken at Dupa Słonia. The crag is 25 m high. Arrows show locations of ammonite finds. The arrow at lower right corner shows location of photograph in Fig. 14

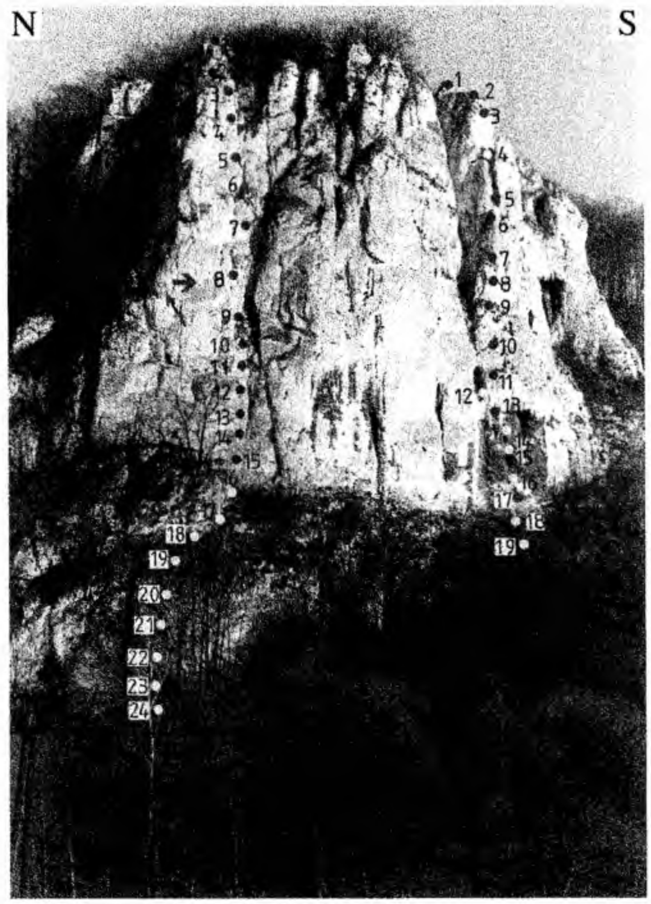

Fig. 5. Location of samples taken at Sokolica. The crag is 70 m high. The arrow shows where the determined ammonite was found

tion surfaces are present in Turnia Lipczyńskiej and Dupa Słonia. At Iglica, the fractures which are horizontal in Dupa Słonia and Turnia Lipczyńskiej, are bent upwards towards SE (towards Sokolica). At the same time they become less distinct and gradually disappear (Fig. 6).

The two sections in Sokolica are similar to each other. The northern one has more biolithite with numerous stromatolites which bind well sorted grains prevails in the lower parts of Sokolica. Bioclasts include small sponges and small brachiopods. The sediment in the middle part of the section is progressively less sorted. Thick-shelled brachiopods appear in masses. They are mostly terebratullids and rynchonellids. The grainstone practically lacks any depositional structures. Sponges and planar stromatolites have been sporadically observed.

The upper parts of the sections include increasing amounts of biolithites. Stromatolitic structures become dominant again, sponges are numerous. Common are borings and growth voids, in some cases filled with internal sediment.

MICROFACIES

The massive limestones of Będkowska Valley include depositional textures which are mud-supported (wackestone-floatstone), grain-supported (packstone-rudstone-grainstone), built of *in situ* organisms (boundstone-framestone) and diagenetic, obliterative structures (not shown in figures and descriptions; sparstone-microsparstone).

The studied rocky limestone is developed mainly as boundstone and packstone-rudstone, whose frequency in the sections is similar (Table 1). Less common are grainstone-rudstone and wackestone-floatstone. Both gradual and rapid lateral transitions between the microfacies types were observed.

Turnia Lipczyńskiej and Dupa Słonia

The parts of rock separated by horizontal fractures display repetitive sequences of sediments. The lower parts of the sequences consist of framestone. The main rock-building element are small siliceous sponges (Fig. 7e) covered on outer surfaces with cL-type leiolites (*clotted leiolites cf.* Schmid, 1996; Leinfelder *et al.*, 1996). Stromatolites of pS type (Fig. 7c) are also numerous (*peloidal stromatolite*; *cf* Schmid, 1996; Leinfelder *et al.*, 1996); so are fragments of brachiopods, benthic foraminifers and gastropods.

The texture of sediments gradually changes upwards in the middle part of the sequences. The main component becomes boundstone built mainly of pS-type (Fig. 7a, f) less

Fig. 6. Iglica. Numerous surfaces of depositional discontinuity are visible, slightly rising toward SE. The surfaces are not discernible in the crag on the right. The crag is 20 m high

Fig. 7. Microfacies observed at Turnia Lipczyńskiej and Dupa Słonia. **a.** Boundstone. Planar pS-type stromatolite (peloidal stromatolite). Turnia Lipczyńskiej; thin section, sample number 4; scale bar = 2 mm; **b.** Boundstone and wackestone passing upwards to packstone. Sample collected near a horizontal surface of sedimentary discontinuity. The packstone is a gravity-flow deposit whose material is derived from higher-lying buildups. Dupa Słonia; thin section; sample number 6; scale bar = 2 mm; **c.** Boundstone. Type pS stromatolite (peloidal stromatolite) (St) on the right, encrusted by serpules (S). Dupa Słonia; thin section; sample number 14, scale bar = 1 mm; **d.** Packstone. Sediment-flow deposit derived from erosion of higher-lying fragments of buildups, built mainly of oncoids and ooids. Turnia Lipczyńskiej; thin section; sample number 1; scale bar = 2 mm; **e.** Framestone. Spicules of completely calcified siliceous sponge. Turnia Lipczyńskiej; thin section; sample number 5; scale bar = 1 mm; **f.** Boundstone, locally packstone. Type mS (micritic stromatolite) and pS (peloidal stromatolite) stromatolites (St). A SC-type stromatactis cavity with geopetal fill in the centre. Dupa Słonia; thin section; sample number 7; scale bar = 1 mm

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Table 1

The most common microfacies in thin sections from samples collected in the Będkowska Valley. Sample numbers same as in Figs. 3, 4 and 5

(In the printed table each cell holds a symbol; here the symbols are written as the percentage they stand for.)

Turnia Lipczyńskiej

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Wackestone	25%					25%	25%			25%	25%		25%	50%
Packstone	75%	75%	25%	25%	25%	25%	25%	25%			25%			
Boundstone		25%	75%	75%	75%	50%	50%	75%	100%	75%	50%	100%	75%	50%

- 25% of thin-section or polished slab area
- 50% of thin-section or polished slab area
- 75% of thin-section or polished slab area
- 100% of thin-section or polished slab area

Dupa Słonia

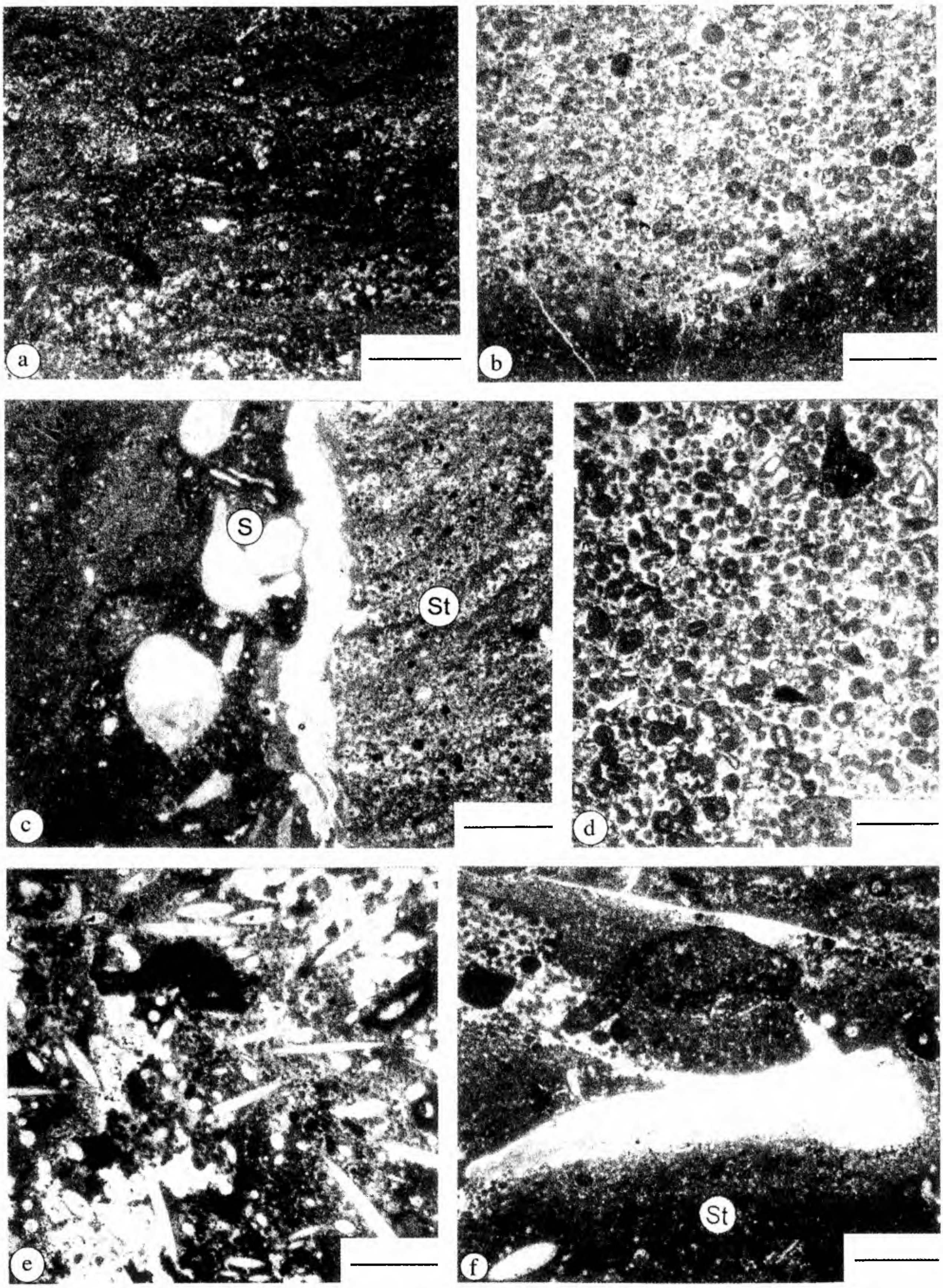
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Wackestone	25%		25%	25%		25%			25%	25%	25%	50%	50%		50%
Packstone	75%	75%	25%	25%	50%	50%	25%		25%	25%	25%			25%	25%
Boundstone		25%	50%	50%	50%	25%	75%	100%	50%	50%	50%	50%	50%	75%	25%

Sokolica, section 2

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Wackestone			25%		25%		25%												
Packstone	50%	50%	75%	50%	50%	25%	25%	50%	25%	50%	50%	50%	75%	75%	100%	50%	75%	50%	75%
Grainstone				25%	25%	25%		50%	75%	25%		25%							
Boundstone	50%	50%		25%		50%	50%			25%	50%	25%	25%	25%		50%	25%	50%	25%

Sokolica, section 1

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Wackestone																				25%			25%	
Packstone	50%	50%	75%	100%	50%	25%		25%	75%	75%	50%	50%	75%	50%	50%	25%	50%	50%	50%		50%	25%		50%
Grainstone									25%		25%		25%											
Boundstone	50%	50%	25%		25%	[illegible]	100%	75%	25%	25%	25%	50%		50%	50%	75%	50%	50%	50%	75%	50%	75%	75%	50%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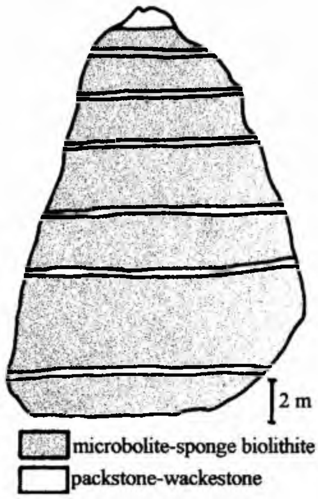


Fig. 8. Simplified scheme of the structure of Turnia Lipczyńskiej

commonly mS-type stromatolites (*micritic stromatolite cf* Schmid, 1996; Leinfelder *et al.*, 1996) which bind numerous poorly sorted, type I and II oncoids according to the Dahanayake's (1977) classification. Sponges, brachiopods and gastropods occur in small amounts. Common are voids up to 2 cm wide (Fig. 7f), resembling the stromatactis voids of SCs type (*stromatactis cavities cf.* Matyszkiewicz, 1997a, b).

Boundstone disappears in the upper part of the sequence. The sediment there is mostly packstone whose sorting increases upwards (Fig. 7b). At the top of the sequences the sediment is fine-grained, very well sorted, built mainly of type I oncoids (Fig. 7b, d) and rare echinoderm plates.

A similar sequence of sediments, with only minor departures, is observed in all studied parts of Turnia Lipczyńskiej and Dupa Słonia (Fig. 8). The thicknesses of individual sequences vary from 1 to 3 m. The sequences disappear towards the top parts of the studied sections and the sediment is mainly packstone and wackestone (Fig. 8) built mainly of type I and II oncoids, echinoderm plates and small *Tubiphytes* (*cf.* Riding & Guo, 1992) in which the thickness of the microbolite (term after Riding, 1991) walls attains 0.7 mm (Fig. 8d).

Sokolica

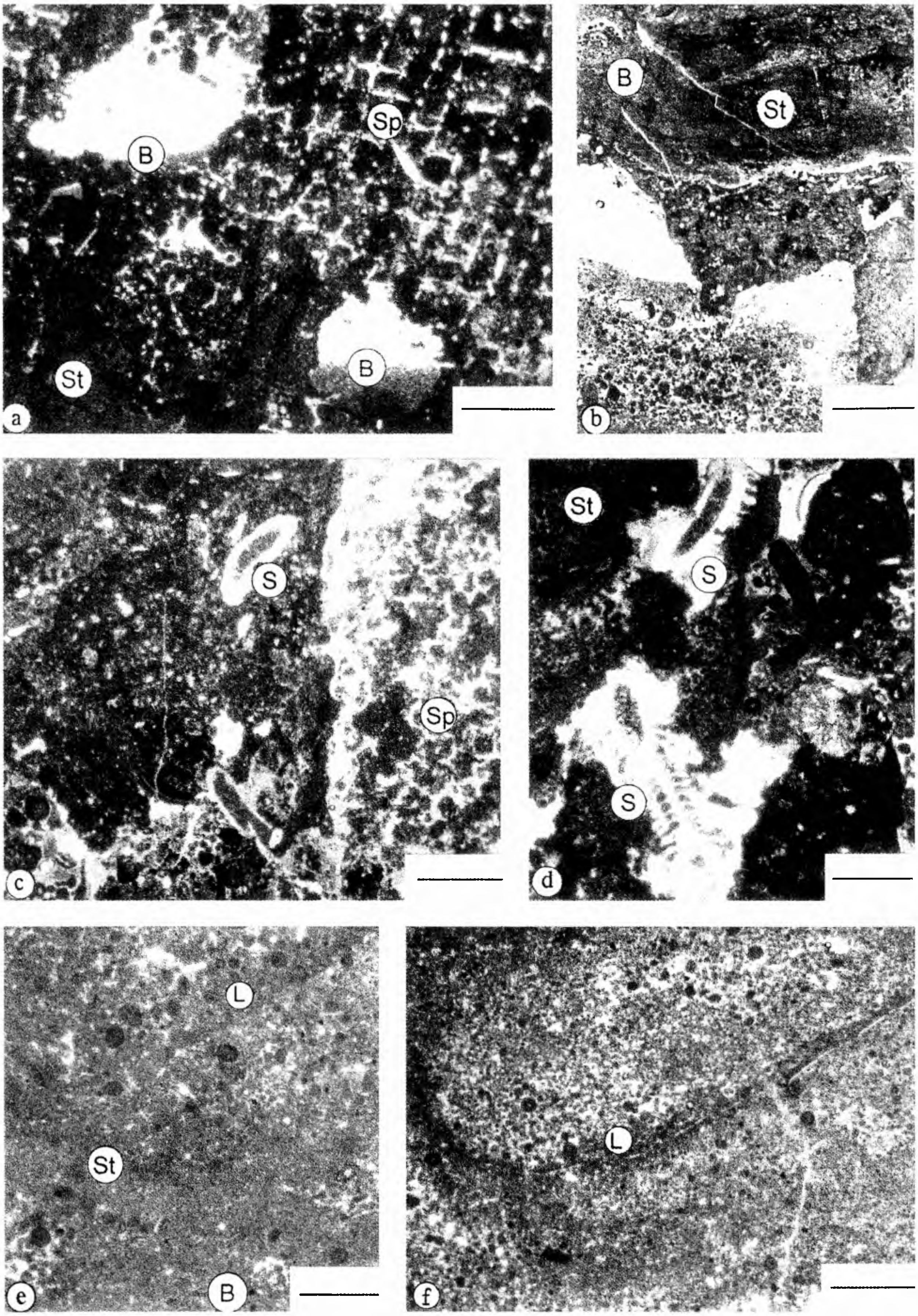
The most common microfacies type in the lowest parts of the sections on Sokolica is framestone (Fig. 10), gradually replaced upward by boundstone (Table 1; Fig. 9) with common stromatolites, usually occurring as coatings on larger bioclasts (Fig. 9b) and leiolites (term after Braga *et al.*, 1995) of cL type (*clotted leiolite cf.* Schmid, 1996; Leinfelder *et al.*, 1996) which bind the sediment composed of peloids and oncoids (Fig. 9e, f). Numerous are sponges (Fig. 9a) and polychetes, of which the most common are epifaunal serpules (Fig. 9c, d). They usually encrust lower parts of sponges and stromatolites or occur loose in sediment, in some cases as nuclei of larger oncoids.

In the lower parts of Sokolica there occurs also wackestone-floatstone, usually together with framestone. The granular components make up more than 10 percent in this microfacies and are mostly represented by oncoids, peloids and bioclasts embedded in micritic matrix. The bioclasts are mainly brachiopods, echinoderms and foraminifers. The larger bioclasts are usually encrusted by microbolitic structures. Sponge fragments and polychetes occurr sporadically.

The lower and middle parts of the sections include common packstone, often replaced upwards by matrix-supported rudstone with micritic matrix (Table 1; Fig. 9). Numerous intraclasts, brachipods, tuberoids, oncoids and less common ooids and gastropods were found in this microfacies type. *Tubiphytes* with diameters 0.5–0.8 mm are numerous in the middle parts of the sections.

Numerous stromatolites, sponges, growth voids, borings (Figs. 9a, b, e) and SICs-type stromatactis (*stromatactis-like cavities cf.* Matyszkiewicz, 1997a, b) are present in biolithites in the higher parts of the sections. Most voids are partly filled with geopetal internal sediments, some of which are size graded. Components of the internal sediments include peloids, oncoids (type I *cf* Dahanayake, 1977) and fine bioclasts (Fig. 9a, b, e). Frequently occur grainstones-rudstones (Table1; Figs. 10, 11) in which large intraclasts and *Tubiphytes* structures 1–1.2 mm in diameter are the main components. Irregular-shaped intraclasts (from elongated to ovate forms) are mostly built of small oncoids, peloids and bioclasts.

Fig. 9. Microfacies observed at Sokolica. Section numbers same as in Table 1. **a.** Framestone and boundstone. Within calcified siliceous sponge (Sp) visible borings (B) with geopetal fills and microbolite structures (St). Sokolica; section 1; thin section; sample number 7; scale bar = 2 mm; **b.** Packstone passing upward into boundstone. Type SIC stromatactis-like cavities visible in the central part. Type mS micritic stromatolite (St) with geopetally filled boring (B) in the upper part. Sokolica; section 2; thin section; sample number 2; scale bar = 4 mm; **c.** Framestone passing to the left to wackestone. In the right a calcified siliceous sponge (Sp) encrusted with serpules (S). Sokolica; section 1; thin section; sample number 20; scale bar = 2 mm; **d.** Boundstone. Type mS (micritic stromatolite) and pS (peloidal stromatolite) stromatolites encrusted by serpules (S). Sokolica; section 1; thin section; sample number 16; scale bar = 1 mm; **e.** Boundstone passing upwards into wackestone. Type pS (peloidal stromatolite) stromatolite and type cL (clotted leiolite) leiolite bounding loose peloids and oncoids. Boring (B) with geopetal fill is visible. Sokolica; section 1; thin section; sample number 23; scale bar = 2 mm; **f.** Packstone and boundstone. Microbolite crusts of leiolite type (L), cL (clotted leiolite) bounding the oncoid-peloid sediment. Sokolica; section 1; thin section; sample number 21; scale bar = 2 mm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STRATIGRAPHY

Stratigraphic position of the studied sediments was established on the base of ammonite fauna. The ammonites found at Dupa Słonia (Fig. 4) indicate the higher part of the *transversarium* Zone or the lower part of the *bifurcatus* Zone (A. Wierzbowski, personal information 1998). An ammonite *Perisphinctes (Dichotomoceras) cf. bifurcatoides* Enay, which indicates the higher part of the *bifurcatus* Zone, *stenocycloides* Subzone (B. A. Matyja, personal information 1998) was found in the central part of Sokolica (Fig. 5), ca. 40 m above the base of the cliff.

Stratigraphical relations between the described outcrops were established taking into account lithological data related to the vertical facies changes. Basing on ammonites, those parts of the Dupa Słonia and Turnia Lipczyńskiej sections in which the described above sediment sequences occur and the lower parts of Sokolica have been accepted as coeval. Also the top parts of the Dupa Słonia and Turnia Lipczyńskiej sections, developed as packstone and wackestone, and the middle parts of the Sokolica sections have been accepted as coeval.

EVOLUTION OF SEDIMENTATION IN THE CARBONATE BUILDUPS IN THE BĘDKOWSKA VALLEY

Pelitic carbonate sediments were being laid down in the studied area in the Early and Middle Oxfordian. It was in these sediments that the first carbonate buildups of sponge bioherm type (*sensu* Trammer, 1989) grew, described from the nearby locality Szklary (Matyszkiewicz, 1997a). Such bioherms are referred to in the literature as embryonic (Hammes, 1995) or initial buildups (Matyszkiewicz, 1997a), lacking a rigid framework. Those initially lithified bioherms occurred within less lithified carbonate mud. Younger bioherms already had a rigid framework which is the basic criterion for distinguishing carbonate buildups. During the early *bifurcatus* time the sponge bioherms grew upward into an extensive complex of microbolite and microbolite-sponge buildups represented in the studied area at Turnia Lipczyńskiej, Dupa Słonia, Iglica and the lower parts of Sokolica. The main rock-forming elements were sponges and stromatolites which bound the loose sediment. The development of some lower lying fragments of the buildups was temporarily interrupted by deposition of fine clastics, in some cases graded, which terminate the sedimentary sequences described at Turnia Lipczyńskiej and Dupa Słonia.

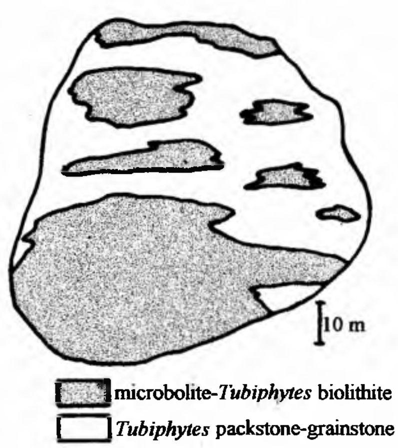


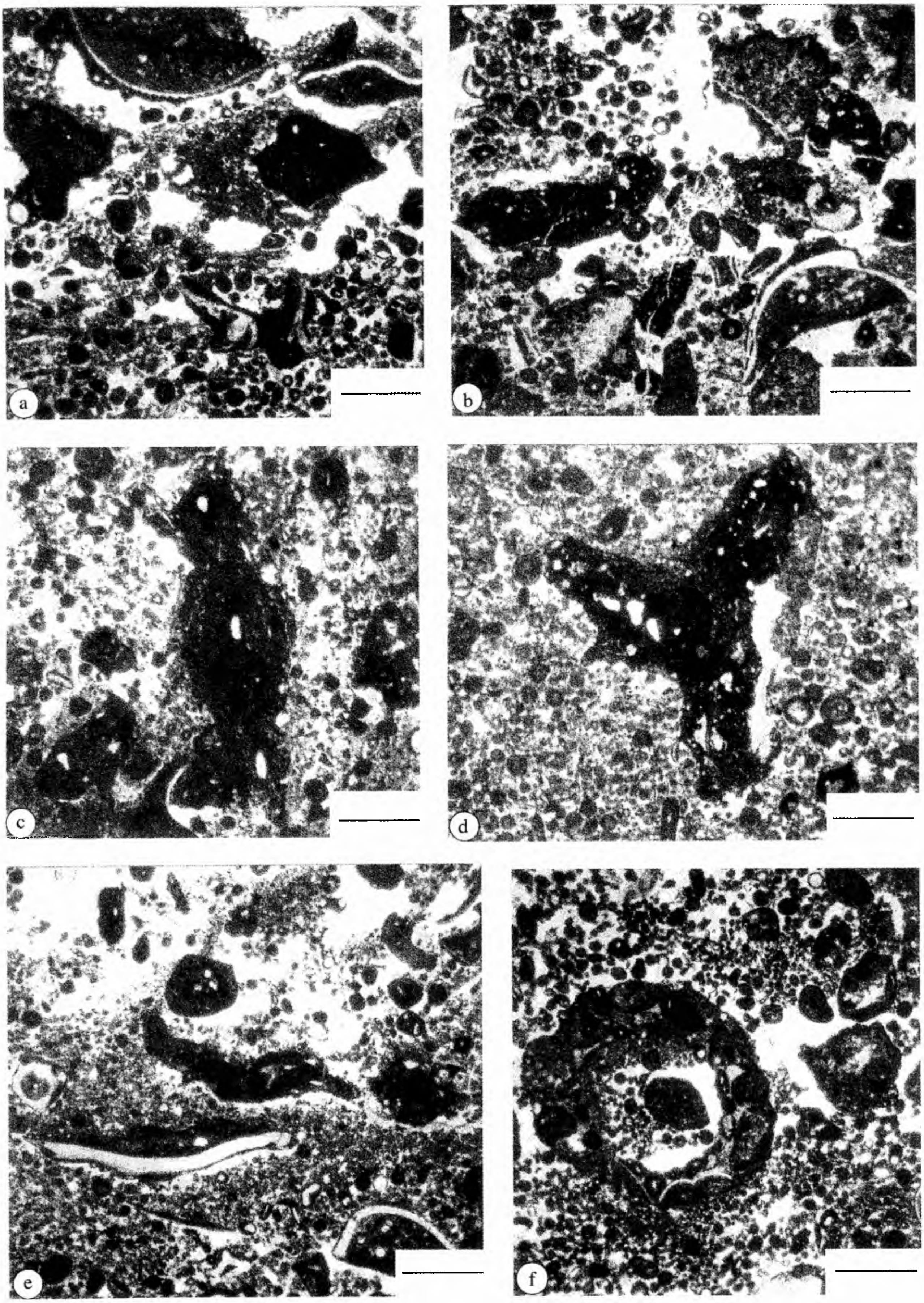
Fig. 10. Simplified scheme of the structure of Sokolica

The uneven growth of the buildups was an indirect cause of the fine clastics deposition. Insufficient lithification led to the failure of unstable constructs, so that particles from collapsing top parts of the buildups (to which Sokolica belongs) were transported as sediment flows downslope to the lower parts of the buildups, resulting in their burial and consequently a break in their growth (Fig. 12). Each sequence at Turnia Lipczyńskiej and Dupa Słonia corresponds thus to a cycle of the buildup growth up to a break caused by temporary burial.

The sediment flow deposits are in some cases preserved as packstone horizons between the sequences (Fig. 13). The occurrence of the sediment flows is also confirmed by SCs-type stromatactis cavities (*cf.* Matyszkiewicz, 1997a, b), frequently observed close to the discontinuity surfaces. During sediment flows turbulence occurred also in the water filling primary growth voids, resulting in their internal erosion and origin of stromatactis. The surfaces along which the sediment flow deposits were laid down are in some cases marked as horizontal fractures (Figs. 3, 4, 6).

The existence of moderate relief within the complex of buildups during the early *bifurcatus* time is indirectly corroborated by the fractures observed at Sokolica, that rise and disappear at the contact with some parts of the buildups (Fig. 6). Moreover, no grainstone horizons are present in the crags where no horizontal fractures are visible. As the fragments of typical buildups, as well as of the buildups in which the sediment sequences occur, are built of massive limestones which were subject to early lithification, we may assume that the angle of slope of the fractures at Iglica is the

Fig. 11. Microfacies observed at Sokolica. Section numbers same as in Table 1. **a.** Packstone, locally wackestone. Among poorly sorted grains there are numerous oncoids, *Tubiphytes* and intraclasts with brachiopod fragments. Sokolica; section 2; thin section; sample number 12; scale bar = 1 mm; **b.** Packstone passing upwards into grainstone. Note poor sorting and rounding of grains, which are mainly oncoids, *Tubiphytes* and intraclasts. Sokolica; section 2; thin section; sample number 8; scale bar = 1mm; **c.** Packstone. *Tubiphytes* is visible in the central part. Sokolica; section 2; thin section; sample number 8; scale bar = 1 mm; **d.** Packstone. A composite form of *Tubiphytes* is visible in the central part. Sokolica; section 2; thin section; sample number 14; scale bar = 1mm; **e.** Packstone, locally wackestone and grainstone with abundant *Tubiphytes*. Sokolica; section 2; thin section; sample number 5; scale bar = 1 mm; **f.** Packstone, locally wackestone. Poorly sorted grains include mainly oncoids and intraclasts. Sokolica; section 2; thin section; sample number 12; scale bar = 1 mm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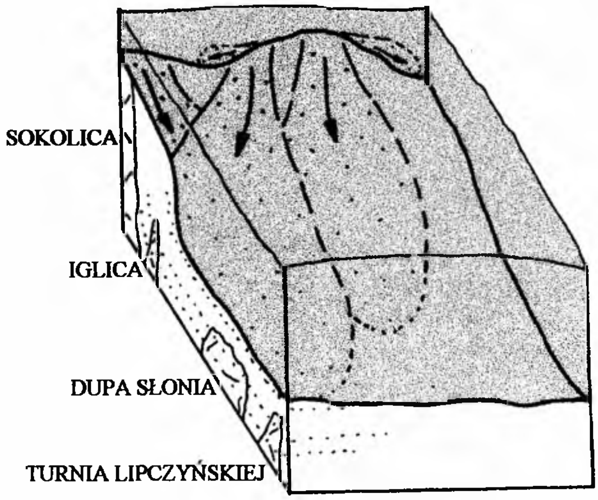

Fig. 12. Idealised model of sedimentation in the Będkowska Valley with actual exposures marked (not to scale). Sediments derived from erosion of the higher parts, represented by Sokolica, were transported downslope to the lower parts, forming horizontal surfaces of discontinuity visible at Turnia Lipczyńskiej and Dupa Słonia. Dots mark the gravity-flow deposits

Fig. 13. Horizontal fractures at Dupa Słonia with preserved gravity-flow deposits derived from erosion of the higher parts of the buildups. The location of the part shown in the photographs is indicated by arrow in Fig. 4

approximate angle of the buildup slope over which the sediment flows descended.

Another cause of the gravity flows could be synsedimentary tectonic movements, earlier described from the Kraków region (Kutek, 1994; Wieczorek & Krobicki, 1994; Matyszkiewicz, 1997a, b). No evidence that would support such origin of the horizontal discontinuity surfaces has been

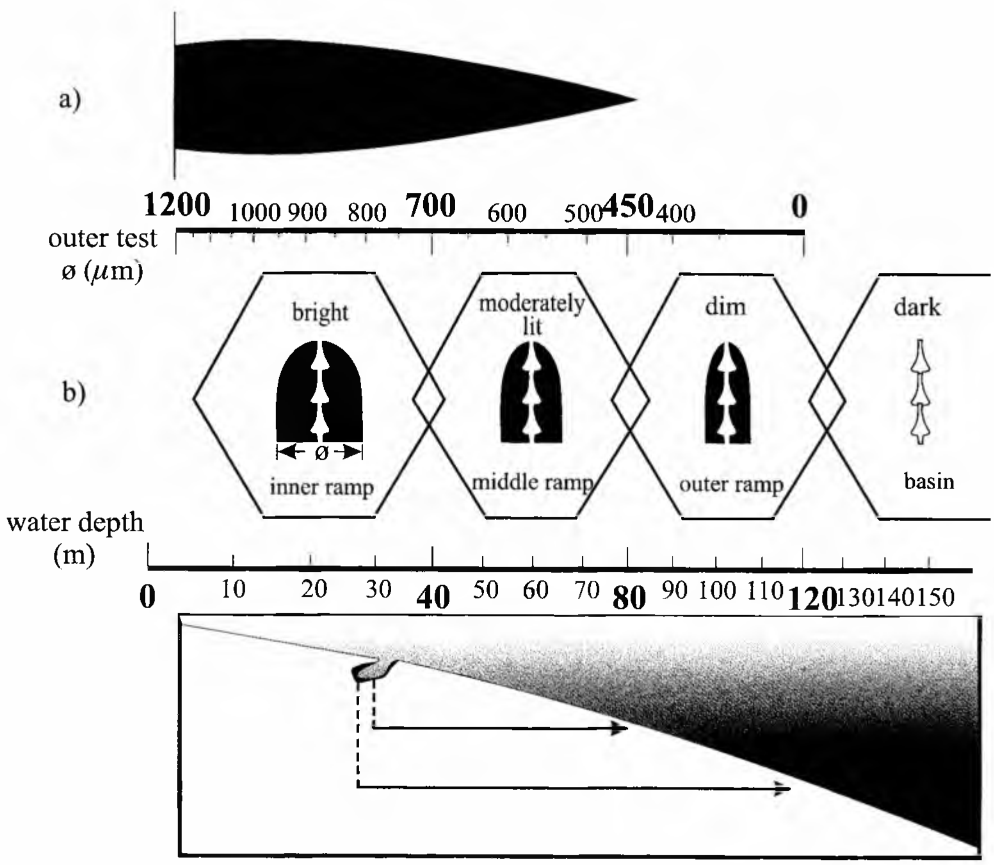

Fig. 14. a. Frequency of occurrence of *Tubiphytes* at Sokolica in relation to the thickness of microbolite crusts; **b.** Relationship between *Tubiphytes* shape and photic zone. The thickness of microbolite crusts is ca. 1 mm in a shallow environment and it decreases with depth (after Schmid 1995 and Leinfelder *et al.*, 1996; simplified)

hitherto found in the studied area.

The fragments of buildups situated in the depressions between the elevations gave way upwards to deposition of bedded limestones (Fig. 8). The microfacies of the top parts of Turnia Lipczyńskiej and Dupa Słonia are similar to those of typical bedded limestones (*cf.* Matyszkiewicz, 1989). Taking into account the features of the sediment and the lack of fauna typical of shallow environments, the environment of deposition of the limestones exposed at Turnia Lipczyńskiej, Dupa Słonia, Iglica and the lower part of Sokolica may be interpreted as one situated below the wave base.

Shapes of the buildups change upsection. One or a few large microbolite-sponge bioherms gave way to numerous but small reef-like microbolite-*Tubiphytes* bioherms (Fig. 10; *cf.* Pomoni-Pappaioannou *et al.*, 1989) represented in the middle and upper parts of Sokolica. Poorly sorted grainstone-rudstone originating from the erosion of nearby buildups was laid down in the depressions between them. The characteristics of the grainstones indicate that the buildups grew at that time in a shallow environment under a permanent influence of waves. The clastic sediments were subject to early cementation due to constant flushing (*cf.* Matyszkiewicz, 1996) and coalesced with neighbouring buildups into greater complex constructs (Fig. 10). Progressive shallowing of the environment of deposition and changes in the internal structure of the buildups are documented in both sections at Sokolica. Coarse-grained sediments appear in abundance, as well as thick-shelled brachiopods and SIC-type stromatactis (*stromatactis-like cavities cf.* Matyszkiewicz, 1997a, b) formed by cavitational erosion related to intense action of wave movements in the intertidal zone. Shallowing of the environment is also indicated by the *Tubiphytes* structures (Fig. 14). Forms 0.8–1.2 mm in diameters dominate in the described sediments, which indicates a shallow environment (*cf.* Schmid, 1995, 1996; Leinfelder *et al.*, 1996; Fig. 14). Smaller forms also occur, formed probably in those places within the buildups where amount of light was smaller, for instance in bigger voids.

CONCLUSIONS

The Upper Jurassic limestones of the studied part of the Będkowska Valley form an extensive complex of carbonate buildups of microbolite-sponge type and reef-like microbolite-*Tubiphytes* bioherms belonging to the *bifurcatus* Zone. The main rock-forming component of the rock is packstone bound by microbolite structures. The lower parts of the section of sediments in the Będkowska Valley are developed as one or a few large buildups, forming a coherent biolithite cover with wide lateral extent of one facies. The fragments of the buildups in which horizontal discontinuity surfaces occur have been laid down in depressions or marginal parts of the biohermal complex.

Numerous small reef-like bioherms dominate in the upper part of the section. Grainstones derived from their erosion were laid down in depressions between them. The buildups and the grainstone deposits among them were subject to early cementation forming larger composite constructs. The microfacies of the higher parts of the section indicate rapid shallowing of the environment (probably at the transition between early and late *bifurcatus* time), from deposition in the deeper part of a carbonate ramp much below the wave base to shallow-water deposition with permanent wave agitation.

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Streszczenie

LITOLOGIA I MORFOLOGIA GÓRNOJURAJSKICH BUDOWLI WĘGLANOWYCH W REJONIE DOLINY BĘDKOWSKIEJ, REGION KRAKOWSKI

Marcin Krajewski

W niniejszym opracowaniu przedstawiono wyniki badań wapieni górnojurajskich z badanej części Doliny Będkowskiej. Szczegółowe badania makroskopowe i mikrofacjalne objęły trzy grupy skalne znajdujące się w pobliżu miejscowości Będkowice (Fig. 1, 2). Pierwszą grupę stanowi Turnia Lipczyńskiej, drugą Dupa Słonia (Fig. 3, 4) trzecią Sokolica (Fig. 5). Obserwacje makroskopowe prowadzone były również na Iglicy (Fig. 2, 6). Stratygrafia ustalona została na podstawie amonitów (zebranych na Dupie Słonia i Sokolicy; Fig. 4, 5) wskazujących na przynależność wapieni do poziomu bifurcatus (inf. ustna B. A. Matyja,1998; inf. ustna A. Wierzbowski, 1998).

W oparciu obadania przeprowadzone na Turni Lipczyńskiej i Dupie Słonia stwierdzono iż, partie skały oddzielone od dołu i od góry poziomymi szczelinami wykazują pewne powtarzające się pionowe sekwencje sedymentacyjne.

W dole sekwencji występują najczęściej biolityty (framestone; Tabela 1; Fig. 7 e, c) przechodzące ku górze w biolityty (boundstone, Fig. 7 a). W szczycie sekwencji biolityty zanikają i osad jest wykształcony głównie jako ziarnit mikrytowy (packstone) charakteryzujący się niekiedy uziarnieniem frakcjonalnym (Fig. 7 b, d, 8).

Najczęściej spotykanym typem mikrofacjalnym w dolnych partiach Sokolicy są biolityty (framestone) ku górze przechodzące w biolityty (boundstone; Tabela 1; Fig. 10 a, c, d, 10). W środkowych i górnych partiach Sokolicy oprócz biolitytów licznie występują ziarnity mikrytowe (packstone-rudstone; Tabela 1; Fig. 10, 11) oraz ziarnity (grainstone-rudstone; Fig. 10, 11 b, e). Waki wapienne (wackstone-floatstone; Fig. 9 c, e) sporadycznie występują w opisywanych profilach.

Badane skałki stanowiły w oksfordzie fragment rozległego mikrobolitowego (nazewnictwo wg Riding, 1991) i mikrobolitowo-gąbkowego kompleksu biohermalnego. Podstawowe znaczenie skałotwórcze miały tu stromatolity wiążące luźny osad peloidowo-onkoidowy. Rozwój niektórych niżej położonych fragmentów budowli był okresowo przerywany przez sedymentację drobnodetrytycznych osadów kończących rozwój poszczególnych sekwencji sedymentacyjnych opisanych na Turni Lipczyńskiej i Dupie Słonia. Osady detrytyczne pochodziły z erozji szczytowych partii budowli, do których należy Sokolica i były transportowane w formie spływów w niższe partie budowli powodując ich zasypywanie i w efekcie przerwy w rozwoju (Fig. 12). Każda sekwencja na Turni Lipczyńskiej i Dupie Słonia odpowiada więc cyklowi rozwoju budowli do jej obumarcia na skutek zasypania.

Osady spływów zachowały się niekiedy w postaci horyzontów ziarnitów mikrytowych (packstone) oddzielających sekwencje (Fig. 13). Istnienie spływów mogą również potwierdzić kawerny stromatactis typu "SCs" (*stromatactis cavities cf.* Matyszkiewicz, 1997 a, b) obserwowane często w pobliżu powierzchni nieciągłości. Powierzchnie wzdłuż których deponowane były osady spływowe obecnie zaznaczają się w morfologii skałek w postaci horyzontów szczelin (Fig. 3, 4, 6).

Na istnienie niewielkiego reliefu w obrębie kompleksu budowli pośrednio wskazują szczeliny obserwowane na Iglicy, które na kontakcie z niektórymi fragmentami budowli podnoszą się i zanikają (Fig. 6). Ponadto w skałkach, gdzie nie występują poziome szczeliny również nie obserwuje się horyzontów ziarnitów. Po-

nieważ fragmenty typowych budowli, jak i budowli, w których obserwuje się sekwencje sedymentacyjne zbudowane są z wapieni masywnych podlegających wczesnej lityfikacji można przyjąć, iż kąt nachylenia szczelin na Iglicy jest przybliżonym kątem nachylenia stoku budowli wzdłuż których następowły spływy.

Biorąc pod uwagę wykształcenie osadu oraz fakt, iż nie występowała tu fauna typowa dla środowisk płytkich, środowisko sedymentacji Turni Lipczyńskiej, Dupy Słonia, Iglicy oraz niższej części Sokolicy można lokować w głębszej części rampy węglanowej poniżej podstawy falowania.

W górę profilu osadów zmienia się morfologia budowli. Z jednej lub kilku większych bioherm mikrobolitowo-gąbkowych rozwinęły się liczne ale niewielkie rafopodobne biohermy mikrobolitowo-Tubiphytesowe (Fig. 10; *cf.* Pomoni-Pappaioannou *et al.*, 1989) reprezentowane przez środkowe i górne partie Sokolicy. W nieckach między budowlami zachodziła sedymentacja słabo wysortowanych ziarnitów (grainstone–rudstone) pochodzących z erozji pobliskich budowli. Wykształcenie ziarnitów wskazuje, iż budowle rozwijały się wówczas w środowisku płytkim w stałym zasięgu falowania. Osady detrytyczne na skutek ciągłego przemywania ulegały wczesnej cementacji (*cf.* Matyszkiewicz, 1996) i wraz z sąsiadującymi budowlami tworzyły większe złożone konstrukcje (Fig. 10). Postępujące spłycanie środowiska sedymentacji i zmiany w budowie wewnętrznej dokumentują obydwa profile Sokolicy. Masowo pojawiają się osady grubodetrytyczne, gruboskorupowe ramienionogi oraz kawerny stromatactis typu “SlCs” (*stromatactis-like cavities cf.* Matyszkiewicz, 1997a, b) a także struktury *Tubiphytes* (Fig. 14; *cf.* Schmid, 1995, 1996; Leinfelder *et al.*, 1996).