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BOSITRA LIMESTONES – A STEP TOWARDS RADIOLARITES: CASE STUDY FROM THE TATRA MOUNTAINS

Renata JACH

Institute of Geological Sciences, Jagiellonian University, Oleandry 2a, 30-063 Kraków, Poland;
e-mail: jach@ing.uj.edu.pl

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Abstract: *Bositra* limestones of Aalenian–Lower Bathonian age crop out in the Krížna unit in the Western Tatra Mountains (Poland). They are sandwiched between pelagic red limestones and radiolarites and display lateral facies variation. Four facies were distinguished: (i) *Bositra* packstones/grainstones, (ii) crinoidal packstones/grainstones, (iii) *Bositra*-crinoidal packstones, and (iv) *Bositra*-radiolarian wackestones. The *Bositra* packstones/grainstones were laid down in high-energy setting, while *Bositra*-radiolarian wackestones in calm condition. Crinoidal packstones/grainstones represent density current deposits. *Bositra*-crinoidal packstones resulted from intense bioturbation and mixing of crinoidal packstones/grainstones with background *Bositra*-rich deposits. Topographic gradient affected the lateral facies variation. Taphonomic factors strongly controlled by energy of the sedimentary environment, ecological factors which caused domination of *Bositra* bivalves in benthos assemblage and dissolution eliminating non-calcitic bioclasts could resulted in formation of the *Bositra* limestones. The eutrophication of water column and remodelling of the Krížna Basin, which finally led to deposition of radiolarites seem to be of considerable importance. Hence, *Bositra* limestones can be regarded as the record of the intermediate stage of the basin evolution towards radiolarite formation.

Key words: thin-shelled bivalves, Middle Jurassic, Krížna Basin, Carpathians, Western Tethys.

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INTRODUCTION

The Jurassic deposits commonly contain thin-shelled bivalves. These specific deposits are represented by various facies, such as organic-rich shells, carbonate turbidites or pelagic limestones. *Bositra buchii*, formerly known as *Posidonia* or regarded as algal filaments, commonly occur in deposits of the Toarcian–Oxfordian age. Thus, the thin-shelled bivalve bearing deposits are traditionally named as *Bositra*, *Posidonia* or filamentous facies. However, the preservation of thin-shelled bivalves often hinders their precise taxonomical position. Several detailed investigations of Jurassic thin-shelled bivalves led to recognize, besides widely known *Bositra buchii*, some new taxons (Kuhry, 1975; Conti & Monari, 1992).

Thin-shelled bivalve bearing deposits are worldwide distributed. They were noticed among others from the Tethyan domain, Southern Andes, Kenya and Canada (Jefferies & Minton, 1965; Bernoulli & Jenkyns, 1974; Clapham *et al.*, 2002). Apart from classical and famous Lower Toarcian black shales, another *Bositra*-bearing common facies are thin-shelled bivalve bearing limestones. They are characterized by patchy geometry and limited lateral range (Bernoulli & Jenkyns, 1974). In the classical section of the Trento plateau, where such limestones are called Lumachella a Posidonia alpina, they occur between shallow water limestones and red nodular limestones of the Rosso Ammonitico Veronese. These deposits fill neptunian dykes there (Sturani, 1971; Winterer *et al.*, 1991). *Bositra* limestones form also bioclastic intercalations within the Rosso Ammonitico Veronese (Martire, 1996). In the Umbria-Marche region the limestones with *Bositra*, called here Calcari a Posidonia, overlay red nodular limestones (Monaco & Morettini, 1997). Thin-shelled bivalve-bearing facies are often succeeded by radiolarites, for example in the Northern Alps, Central Apennines and Tatra Mountains (Lefeld *et al.*, 1985; Böhm, 1986; Galluzzo & Santantonio, 2002). Association of *Bositra* limestones with radiolarites demands detailed sedimentological analysis, which allows to recognize environmental relations of these two facies.

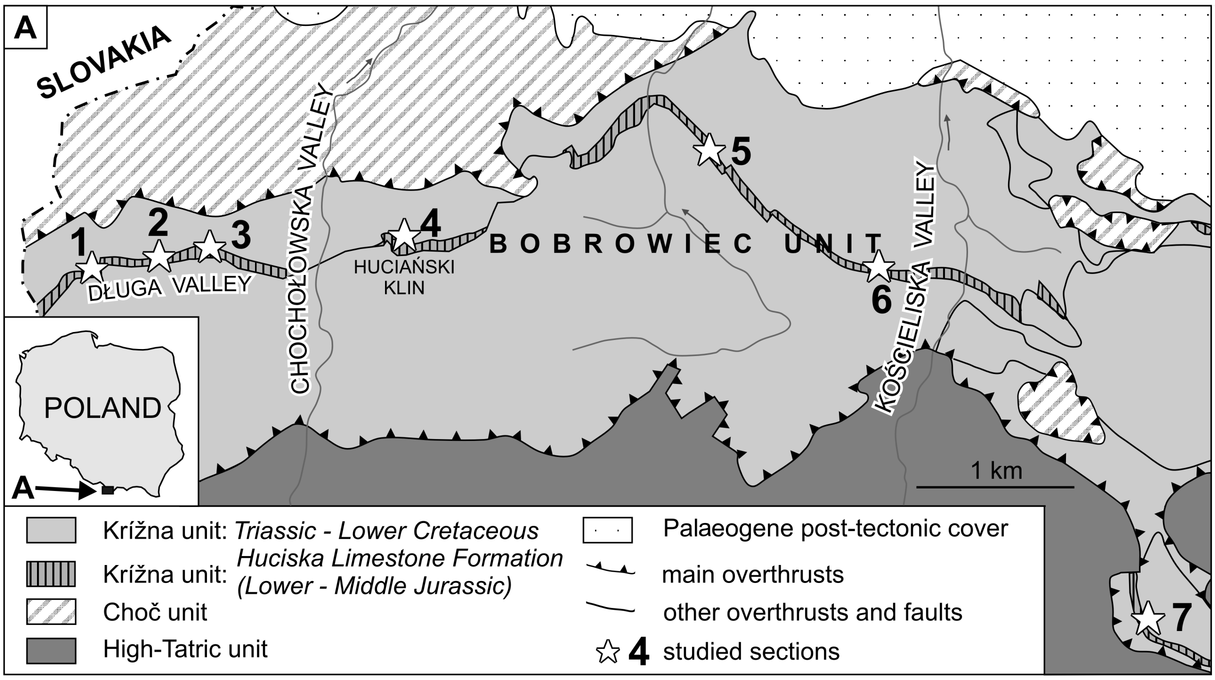

Fig. 1. Geological sketch map of the Polish part of the Western Tatra Mountains (after Bac-Moszaszwili *et al.*, 1979; simplified) showing location of studied sections; symbols of the sections explained in the text

The main purpose of this paper is to discuss the origin of the thin-shelled bivalve-bearing facies from the Jurassic deposits of the Western Tatra Mountains, and to define their significance in the reconstruction of the Krížna Basin development in the early Middle Jurassic times. Concentrations of thin-shelled bivalve shells can be a useful tool in facies analysis, especially in an integrated approach combining sedimentological and palaeoecological data. Since this kind of skeletal concentration is relatively frequent in the Middle Jurassic deposits of the Western Tethys, the present results would have implications for understanding depositional processes and the evolution of other Jurassic basins of the Tethyan domain.

GEOLOGICAL SETTING

The Middle Jurassic thin-shelled bivalve-bearing limestones, hereafter called *Bositra* limestones, crop out in the Polish part of the Western Tatra Mountains. They belong to the Krížna unit, which in this part of the Tatra Mountains is represented by a large slab, called the Bobrowiec unit, homoclinally dipping to the north (Fig. 1; Bac-Moszaszwili *et al.*, 1979). The unit comprises Lower Triassic through Lower Cretaceous deposits.

A 100 m thick complex of spotted limestones and marls (Fleckenmergel) of the Late Sinemurian–Early Pliensbachian age occurs in the lower part of the sections (Fig. 2; Uchman & Myczyński, 2006). This complex is covered by up to 20 m thick Domerian spiculites (Jach, 2002). In the eastern part of the studied region, spiculites are covered by Lower Toarcian crinoidal grainstones, while in the western part by alternated limestones and marls (Jach, 2005). Locally, manganese deposits of hydrothermal origin occur above crinoidal grainstones (Jach & Dudek, 2005). The overlying 1–4 m thick suite is composed of red nodular Adnet type limestones and marls belonging to the lower part of the Kliny Limestones Member of the Huciska Limestone Formation (Fig. 2; Lefeld *et al.*, 1985). Red deposits comprise diagnostic ammonites for *Bifrons* zone (Myczyński & Lefeld, 2003; Jach & Myczyński, 2006). *Bositra* limestones belong to the upper part of the Kliny Limestones Member (Lefeld *et al.*, 1985). Their age is not precisely determined due to lack of diagnostic fauna, however they are usually ascribed to Aalenian (Bujnovský & Polák, 1979; Lefeld *et al.*, 1985). *Bositra* limestones are covered with red, pinkish layered radiolarian limestones and radiolarites of the Late Bathonian–Early Kimmeridian age (Polák *et al.*, 1998). Average thickness of these deposits is estimated as 15–25 m (Lefeld, 1974).

METHODS

Nine sections have been studied in the western part of the Krížna unit in the Western Tatra Mountains (Fig. 2). For the sake of simplicity, sections are numbered as follows: 1 – section located in the upper parts of the Długa Valley (Dolina Długa), 2 – section on the northern slopes of the Długa Valley, 3 – section at Grześ hill in the Długa Valley, 4 – section on the south-western slopes of the Huciański Klin crest, 5 – section at slopes of Pośrednia Kopka, 6 – section at Świńska Turnia, and 7 – section on the western slopes of Gładkie Upłaziańskie. Facies and sedimentary

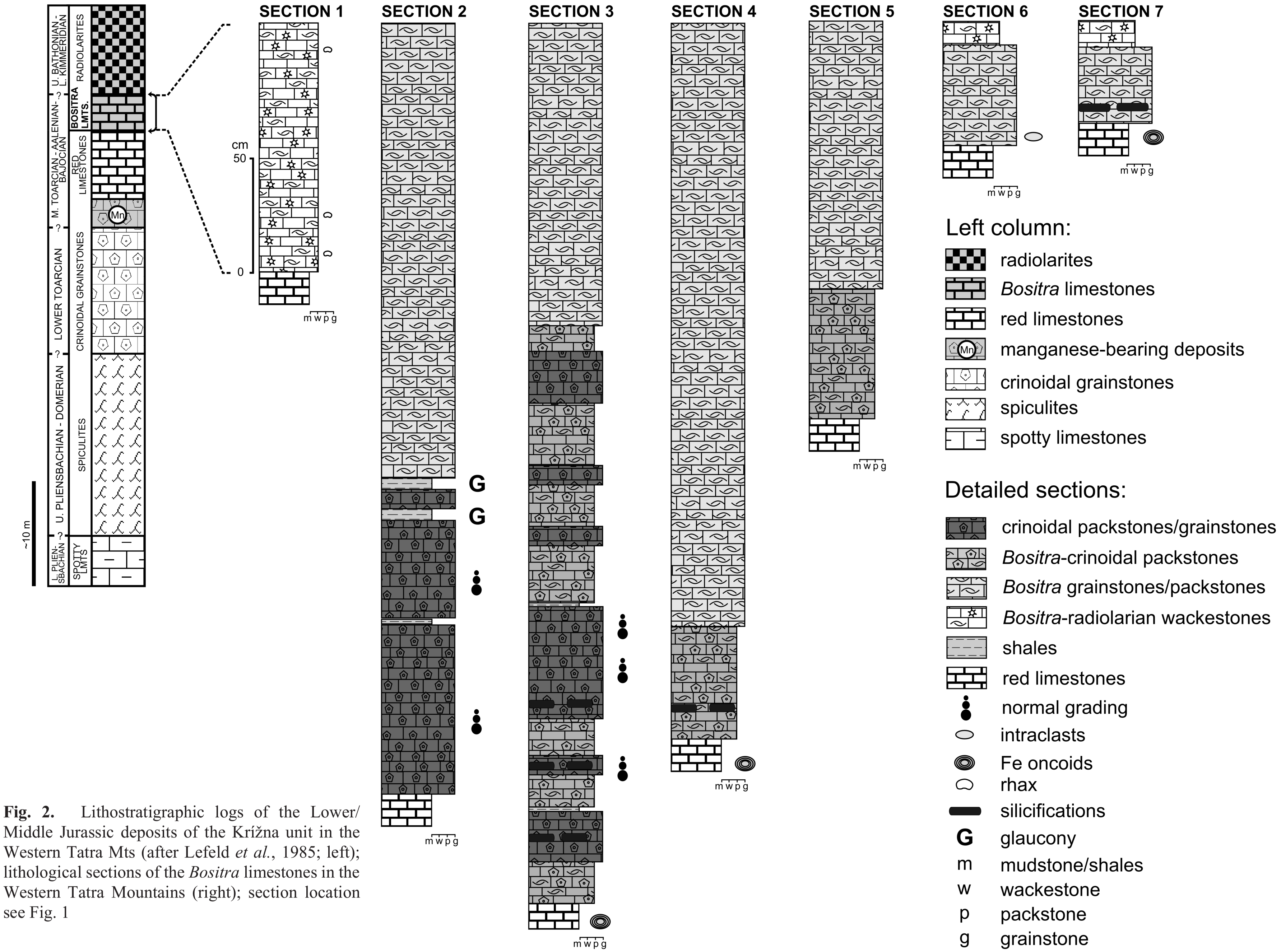

Fig. 2. Lithostratigraphic logs of the Lower/Middle Jurassic deposits of the Krížna unit in the Western Tatra Mts (after Lefeld *et al.*, 1985; left); lithological sections of the *Bositra* limestones in the Western Tatra Mountains (right); section location see Fig. 1

structures were studied and distinguished in the field. The sections were analysed bed-by-bed with detailed sampling. The observations were supplemented by rock slabs and microfacies analysis.

RESULTS

Bositra limestones are grey and well bedded, only at the base they are more grey-pinkish and more cherty. Dominating components are disarticulated *Bositra* shells. Elongated siliceous lenses up to a few centimetres thick occur in the lower part of the sections. The thickness of *Bositra* limestones ranges usually from 0.5 to 4 m (Fig. 2). However, one may assume that their total thickness is slightly greater because outcrops are not complete. The contact of *Bositra* limestones with underlying red limestones is very sharp and marked by change in colour and decrease in a fine fraction content. The contact most probably displays character of an omission surface. Four facies types are distinguished mainly by means of thin section analysis: (i) *Bositra* packstones/grainstones, (ii) crinoidal packstones/grainstones, (iii) *Bositra*-crinoidal packstones, and (iv) *Bositra*-radiolarian wackestones. The facies distribution is presented in Fig. 2.

Facies description and interpretation

Bositra packstones/grainstones contain *Bositra* shells and rare crinoid fragments. Shells are very thin (30–40 µm) and approximately 3.5 mm in length, but maximally reach 6 mm. They are flattened and horizontally oriented (Fig. 3A, E). The distinctive feature of this facies is a grain-supported texture. Shells are usually so densely packed that the rock exhibits fitted fabric (Fig. 3E). Only locally, shells are reoriented due to bioturbations (Fig. 3F). Bioclasts are very well selected and recrystallized. *Bositra* grainstones display common stylolites (Fig. 3E).

Bositra packstones/grainstones displaying a good selection of bioclasts were laid down in relatively high-energy settings. However, the *Bositra* shells were not crushed completely, what indicates rather moderate current action. Fitted fabric within *Bositra* grainstones suggests that early cementation was insignificant (see Clari & Martire, 1996).

Crinoidal packstones/grainstones contain, besides crinoidal fragments, rare foraminifer tests and crushed *Bositra* shells (Fig. 3B, C). Crinoids show overgrowth of syntaxial cements. Normal grading and good sorting of material are common in this type of sediment. In some sections this facies is interlayered with thin layers of marls. Fragments of crinoids, fish teeth, rare foraminifer tests (*Lenticulina* sp.) and glaucony dominate in these marls. In such beds the crinoidal fragments are often filled with glaucony. Crinoidal packstones/grainstones occur usually in the lower part of the studied sections (sections 2, 3; Fig. 2). These beds are several centimetres thick, whereas marls are few centimetres thick.

This type of facies forms intercalations within *Bositra* limestones. These intercalations suggest the transport of crinoidal material by density currents, probably of turbiditic character. Primary porosity of crinoidal material determines its hydrodynamic behaviour and makes the transport possible on long distances, even by weak currents (Blyth Cain, 1968). Thin marls with glaucony overlaying crinoidal intercalations, seem to represent background pelagic sediment with some admixture of fine material of tail of gravity flows.

***Bositra*-crinoidal packstones** are characterized by high content of crinoidal debris and crushed *Bositra* shells (Fig. 3D). This type of facies occurs in lower parts of the sections. Foraminifer tests and sponge spicules occur sporadically. Selection of bioclasts is low. Bioclasts are reorientated due to bioturbation. Traces of dissolution in the form of stylolites and dissolution seams occur commonly within these facies.

Bositra-crinoidal packstones represent bioturbated turbidites mixed with background *Bositra*-bearing deposits. Crinoidal debris and probably majority of *Bositra* shells were transported. Bioturbations indicate oxic conditions within the bottom sediment.

***Bositra*-radiolarian wackestones** are fine-grained and structureless sediments (Fig. 3G). Locally they contain sponge spicules of rhax type. *Bositra* shells up to 1 mm in length are crushed and do not display sorting. Radiolarian tests are calcified. Locally the *Bositra*-radiolarian wackestones display dissolution seams.

Bositra-radiolarian wackestones were deposited in lower-energy settings. It is proved by the occurrence of large amount of micrite as well as numerous radiolarians. Probably radiolarians, as the element easily put in motion, were replaced by currents from elevated parts of the basins and accumulated in adjacent, calm depressions (Baumgartner, 1987). Thus, this facies were laid down in local depressions.

Lateral facies variation

Bositra limestones exhibit distinct lateral facies variation. *Bositra*-radiolarian wackestones occur in the section 1 and 7, but only in the first one they contain common sponge

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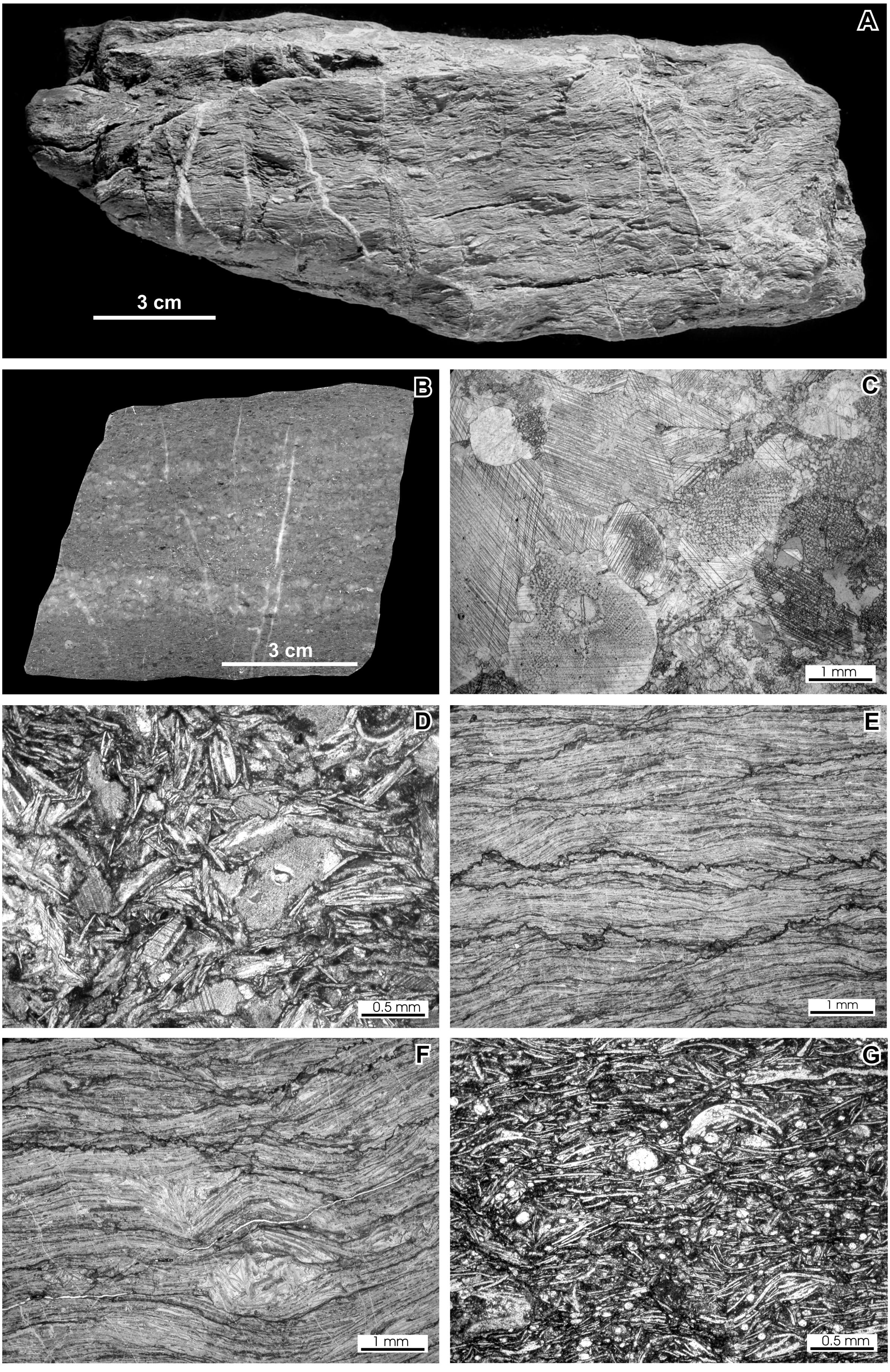
Fig. 3. Facies of the *Bositra* limestones: **A.** *Bositra* grainstone displaying densely packed flattened *Bositra* shells; weathered surface of the rock sample; section 3; **B.** Crinoidal grainstone with normal grading horizons; polished section; section 3; **C.** Crinoidal grainstone with syntaxial cement; thin section; section 3; **D.** *Bositra*-crinoidal packstone showing crushed bioclasts; thin section; section 3; **E.** Fitted fabric in *Bositra* grainstone; stylolite cutting the shells are visible; thin section; section 4; **F.** *Bositra* grainstone; locally reoriented shells of *Bositra* may be effect of bioturbation; thin section; section 4; **G.** *Bositra*-radiolarian wackestone; thin section; section 7


A
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spicules of rhax type (Fig. 2). Sections 2 and 3 are characterized by the occurrence of crinoidal grainstones/packstones in their lower parts. In sections 4 and 5 *Bositra*-crinoidal packstones dominate in their lower parts, which are gradually replaced upward by *Bositra* packstones/grainstones. Lower part of the section 6 contains 60 cm thick interval of slump conglomerates (Fig. 2), which comprise intraclasts of *Bositra* packstones/grainstones where the *Bositra* wackestones form the matrix. The spatial arrangement of *Bositra* limestone facies mirrors the facies variation of underlying deposits (Jach, 2003).

DISCUSSION

Factors controlling concentration of *Bositra* shells

The main characteristic of *Bositra* limestones is the great abundance of *Bositra* shells constituting the predominant rock-building component. There are several possible reasons of such concentration. One can list: (i) taphonomic factors, (ii) ecological factors, and (iii) dissolution factors. However, the above described distribution of bivalve shells is hardly explained only by one of the listed factors. Therefore, it seems that several factors affected sedimentation of *Bositra* limestones.

Taphonomic factors

After a long lasting discussion on the ecology of *Bositra* their benthic life has been finally proved (Etter, 1996; Röhl *et al.*, 2001). The above conclusion concerns also other Jurassic thin-shelled bivalves (Conti & Monari, 1992). Wignall (1993) and Röhl *et al.* (2001) claim that *Bositra* preferred soft muddy substrate. Thus, accumulation of *Bositra* shells in the form of grainstones and packstones as observed in the studied case may be a current or winnowed concentration (*sensu* Fürsich & Oschmann, 1993). The relatively good preservation of fragile *Bositra* shells let us rule out the former possibility (see Kuhry, 1975). The latter possibility depends on intense removal of fine-grained carbonate fraction and bioclasts characterized by the low proportion of weight to volume leading to the concentration of *Bositra* shells that, in consequence, became almost the only one autochthonous element (Martire, 1992; Fürsich & Oschmann, 1993). Winnowed concentrations can proceed in various ways. However, in the studied case the most probable one is the action of weak currents (cf. Fürsich & Oschmann, 1993).

Ecological factors

Another possible explanation of *Bositra* shell concentration invokes generally accepted facts that *Bositra* were oligotypic fauna. They were opportunistic organisms, representing extreme r-strategists, therefore they increased rapidly in number under favourable conditions. Hence, the concentration of the shells may be the effect of environmental stress. It is well known that *Bositra* tolerates low oxygen content (Oschmann, 1993; Röhl *et al.*, 2001). However, no proof for oxygen depletion has been given for the studied deposits. By contrast, some parts of *Bositra* limestones bear the evidence of intense bioturbation, which suggests that oxygen content in the pore water allowed infaunal colonization.

A close relationship exists between *Bositra* blooms and events of high organic productivity, since *Bositra*-bearing shales, especially those of Toarcian age, have high organic matter content (Röhl *et al.*, 2001 and references quoted herein). It may not be excluded that *Bositra* were able to tolerate toxic elements or assimilate nutrients in an unusual way (cf. Kauffmann, 1976). Extremely low biodiversity may reflect paleoenvironmental stress conditions owing to high input of nutrients (Bartolini & Cecca, 1999). High density of oligotypic fauna, in the studied case represented by *Bositra*, is often related to eutrophication (Bartolini & Cecca, 1999). This phenomenon affected the Western Tethys during Middle Jurassic time, which was reflected in sedimentation of radiolarites and in the crisis of carbonate production (Bartolini & Cecca, 1999). Hence, the concentration of *Bositra* in the studied deposits may be an effect of eutrophication of the water column.

Dissolution factors

Another reason of high concentration of *Bositra* shells could be dissolution of aragonite in the water column. This concept assumes that aragonite components were dissolved by aggressive bottom waters which led to relative enrichment in calcite components. Similar mechanism was commonly invoked to explain the deposition of Tethyan Jurassic radiolarites (Bosellini & Winterer, 1975; Winterer & Bosellini, 1981).

Although the studied limestones are composed almost exclusively of bivalve shells, it is difficult to state their primary mineralogy. *Bositra* shells were built of an outer calcitic-simple prismatic layer coupled to a nacreous-aragonitic one (Conti & Monari, 1992). However, the studied shells are presently heavy recrystallized, therefore no relics of primary structure are visible. Hence, it is difficult to find if these shells displayed single-layered or double-layered microstructure during burial. The *Bositra* limestones may be a concentration of calcite layers of the originally bi-mineralic shells owing to aragonite dissolution below the aragonite compensation depth (see also Böhm, 1986). In such a case they represent dissolution facies (*sensu* Bosellini & Winterer, 1975). However, dissolution alone cannot explain formation of *Bositra* limestones, because one can expect more other calcitic components, such as belemnite guards and aptychi which occur even in overlying radiolarites (Gąsiorowski, 1959).

Topography of the Krížna Basin during deposition of *Bositra* limestones

The deposition of *Bositra* limestones took place in the basin with considerable topographic gradient, what plausibly explains the distinct lateral facies variation of *Bositra* limestones as well as changes in their thickness. The Krížna

Basin comprised pelagic carbonate platforms (*sensu* Santantonio, 1993) and adjoining basins (Jach, 2003). Santantonio *et al.* (1996) and Galuzzo and Santantonio (2002), following the study of the drowned Pacific atolls (Winterer, 1991), have suggested that thickness of pelagic platform deposits decreases toward the edges, which is caused by the angle of repose and more intense current action at the marginal parts of the platform. Galuzzo and Santantonio (2002) compared such facies geometry of the pelagic carbonate platform to the famous Milanese cake *panettone*. The proposed model fits well for *Bositra* facies distribution in the Krížna unit. In the depressions and in the interior of the elevated horsts *Bositra*-radiolarian wackestones were deposited (sections 1, 5, 6), while at the margins of the elevated parts of the basin the deposition of well-sorted *Bositra* packstones/grainstones took place (sections 2, 3 and 4; Figs 2, 4). The best selected *Bositra*-bearing sediment formed along the margins of the pelagic carbonate platform (section 2, 3 and 4) due to more intense action of currents (cf. Galuzzo & Santantonio, 2002; cf. Baumgartner, 1987).

The thickness of the studied deposits differs from that of Galluzzo and Santantonio's (2002) model. *Bositra*-limestones reach the maximum thickness in section 3, whose position indicates location at the edge zone of the pelagic carbonate platform (Jach, 2003). It may be explained by the existence of a small depression of a perched basin type near the edge of the platform (see Santantonio, 1993). The accommodation space created there, enabled formation of a thick sequence of *Bositra* limestones.

Some evidence, like the occurrence of crinoidal turbidites, points to gravity transport and indicates a considerable topographic relief of the sea-bottom. This kind of deposition was limited only to margins of the submarine elevations (sections 2 and 3). However, some mass movements took place in the central parts of the elevations, which is evidenced by intraformational slump conglomerates, and might reflect synsedimentary tectonic activity (Jach, 2003).

Topographic gradient affecting the deposition of *Bositra* limestones was inherited from Early Toarcian time, since the spatial arrangement of the Lower Toarcian crinoidal tempestites and spotty limestones is concordant with the distribution of the discussed *Bositra* limestone facies (cf. Jach, 2003, 2005). The topographic gradient persisted during the deposition of radiolarites as well, and probably caused the diachronicity of their lower boundary, which was observed by Bąk (2001).

Significance of *Bositra* limestones for depositional history of the Krížna Basin

Progressing deepening of the Krížna Basin through the Middle Jurassic was traditionally accepted. This process commenced after the deposition of crinoidal tempestites (Jach, 2005) and was continued during the sedimentation of the red limestones of Adnet type (Gradziński *et al.*, 2004). One can presume that the trend continued towards the deposition of the overlying radiolarites which represent basinal and relatively deep-water deposits (Lefeld, 1974; Wieczorek, 1988). Such a trend, commonly recognized in the Tethyan deposits, is interpreted as an effect of deepening of the basin, which finally gave rise to the origin of radiolarites, deposited below the ACD or even the CCD (Winterer & Bosellini, 1981). However, the deposition of the discussed *Bositra* limestones, especially well-sorted *Bositra* grainstones/packstones, sandwiched between the red pelagic limestones and radiolarites, needs some additional comments.

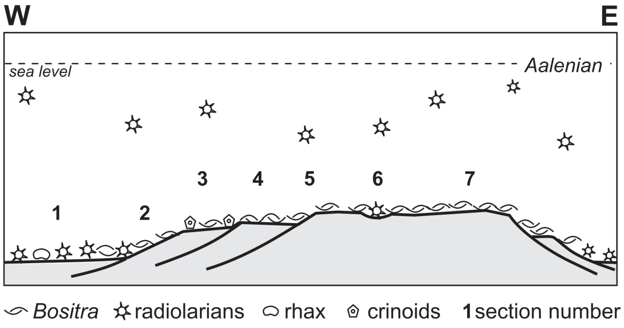

Fig. 4. Depositional model of *Bositra* limestones

The influence of taphonomic factor and dissolution processes of aragonite on the deposition of *Bositra* limestone must have been associated with the intensification of current activity. It enabled a winnowing and removal of fine carbonate fraction and led to the formation of *Bositra* packstones/grainstones on the platform edges. Such textural feature may indicate fall of the sea level (Martire, 1992). Deposition of the discussed limestones may be a response to Aalenian regressive episode recorded within a generally observed Middle Jurassic transgressive trend (Hallam, 2001). However, it is difficult to correlate the *Bositra* limestones with the global sea-level changes due to the lack of stratigraphical markers. Moreover, the Krížna Basin during the Early/Middle Jurassic was a tectonically mobile area, what could overprint the global sea-level changes.

Another explanation of intensification of current activity is related to remodelling of the basins, which caused palaeogeographic changes and which, in turn, were related to rifting in the Western Tethys during Middle Jurassic time. In this case current activity in deeper settings can be expected owing to an opening of new sea-ways. The currents could especially be effective in narrow basins. Nowadays, currents of velocity exceeding 30 cm/s are recorded at the depth down to several hundred metres in the basins separating the Ryukyu Islands (Tsuji, 1993). It is very probable that the Krížna Basin exhibited a narrow and elongated shape in the Middle Jurassic time. It was bordered from the north by the uplifted Tatricum domain, which was emerged until the Bajocian (Łuczyński, 2002), while from the south by the Veporicum, where shallow pelagic deposition took place (Kozur & Mock, 1996; Plašienka, 1999).

The origin of Jurassic radiolarites, the *Bositra* limestones are associated with, were traditionally linked with deep-sea condition. However, some papers stress that other factors led to their formation. According to the new models, the deposition of the radiolarites is ascribed to the lack of dilution by either terrigenous clastics or autochthonous carbonates along with the eutrophication of a water column, which in turn cut down an autochthonous carbonate factory (Baumgartner, 1987; Bartolini *et al.*, 1996; Cobianchi & Picotti, 2001). Nevertheless, the radiolarites are still regarded as relatively deep-water sediments formed in pelagic condition, as proved by Kiessling (1996) after quantitative analysis of siliceous microfauna from several Tethyan sections. Therefore, the bloom of *Bositra* leading to deposition of the studied *Bositra* limestones was probably facilitated or even caused by the changes in trophic conditions of the pelagic water-column. Further eutrophication and deepening of the basins led to deposition of overlying radiolarites. Hence, the deposition of both facies mirrored changes in trophic conditions of the sea-water during Middle Jurassic interval. The changes were in turn causally connected with increasing climate humidity affecting the vigorous run-off from the continents (Cobianchi & Picotti, 2001). Thus, the *Bositra* limestones of the Krížna unit represent the intermediate stage of basin evolution between red limestones deposited in oligotrophic conditions (Gradziński *et al.*, 2004) and radiolarites, which origin was related to increase of nutrients amount in the water column. It is noteworthy that similar temporal relationships were described also from other section of the Western Tethys, that is from the Umbria-Marche region in Italy (Conti & Monari, 1992; Bartolini & Cecca, 1999), the Subbetic area in Spain (Kuhry, 1975; Rey, 1998), and the Lučatín Unit in Slovakia (Soták & Plašienka, 1996). Thus, the above postulated genetic relationship between *Bositra* limestones and radiolarites can have universal significance.

CONCLUSIONS

Sedimentation of *Bositra* limestones began in the Late Toarcian or more probably in Early Aalenian time and continued until the Early Bathonian. Three factors might have controlled the formation of these limestones: (i) taphonomic factors strongly connected with energy of the sedimentary environment, which led to winnowing of fine-grained carbonate material and concentration of *Bositra* shells, (ii) ecological factors which caused domination of *Bositra* bivalves in benthos assemblage and (iii) dissolution factors which eliminated non-calcitic bioclasts. The eutrophication of water column and remodelling of the Krížna Basin, which finally led to deposition of radiolarites, seem to be significant. Therefore, *Bositra* limestones can be regarded as an indicator of the intermediate stage in the evolution of the basins towards radiolarite formation. The Krížna Basin during the deposition of *Bositra* limestones was composed of a range of pelagic carbonate platforms and adjoining depressions. Well sorted *Bositra* packstones/grainstones were laid down near edges of platforms, while *Bositra*-radiolarian wackestones in depressions.

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Streszczenie

WAPIENIE BOSITROWE – KROK W STRONĘ RADIOLARYTÓW: PRZYKŁAD Z TATR

Renata Jach

Wapienie bositrowe wczesnego aalenu–wczesnego batonu, które odsłaniają się w jednostce kriżniańskiej w Polskich Tatrach Zachodnich znajdują się w profilach pomiędzy pelagicznymi czerwonymi wapieniami a radiolarytami (Fig. 1, 2; Lefeld *et al.*, 1985; Gradziński *et al.*, 2004). Wapienie te wykazują wyraźne facjalne zróżnicowanie. Wydzielone zostały następujące facje: (i) bositrowe pakstony/greinstony, (ii) krynoidowe pakstony/greinstony, (iii) bositrowo-krynoidowe pakstony i (iv) bositrowo-radiolariowe wakstony (Fig. 2, 3). Bositrowe pakstony/greinstony powstały w środowisku o stosunkowo wysokiej energii, a bositrowo-radiolariowe wakstony w warunkach niskiej energii. Krynoidowe pakstony/greinstony są interpretowane jako osady prądów gęstościowych, a bositrowo-krynoidowe pakstony jako osady prądów gęstościowych zbioturbowane i zmiksowane z osadami tła depozycyjnego. Zróżnicowana morfologia basenu wpłynęła na oboczną zmienność facjalną omawianych wapieni i przestrzenny rozkład facji (Fig. 4). Powstanie wapieni bositrowych było warunkowane przez czynniki natury tafonomicznej, związane z energią środowiska sedymentacji, natury ekologicznej decydujące o dominacji bositr w zespole bentosu i procesy rozpuszczania eliminujące nie kalcytowe bioklasty. Postępująca eutrofizacja wód (Bartolini & Cecca, 1999; Cobianchi & Picotti, 2001) i przemodelowanie basenu kriżniańskiego związane z procesami ryftingu Zachodniej Tetydy, które ostatecznie doprowadziły do depozycji radiolarytów, wydają się mieć zasadniczy wpływ na powstanie wapieni bositrowych. Tak więc, wapienie bositrowe reprezentują przejściową fację poprzedzającą w czasie powstanie tetydzkich jurajskich radiolarytów.